Saudi Culture and the Potential Introduction of Digital Design Techniques: Influences and Interactions

By

Wajdy Sadagh A Qattan

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

Faculty of Design, Architecture and Building

University of Technology, Sydney

Australia

2016
Certificate of Authorship and Originality

I certify that the work in this thesis has not previously been submitted for a degree, nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

__________________
Signature of Student
Dedication

This thesis is dedicated to my mother, Fizah, and my father, Sadagh, who taught me that working hard is part of life and will achieve dreams. Thank you for believing in me. Their love and prayers are what brought me where I am today. I also dedicate this thesis to my wonderful and loving wife, Rash. I would not have been able to accomplish this research without her support, deep understanding and profound encouragement through the happy and hard times. I also thank my father-in-law Hussain and mother-in-law Azizah for their prayers, love and support. Finally, I dedicate this thesis to my beloved sons, Abdulrahman and Abdulaziz, whose unconditional love and sweet spirits lifted and sustained me during the darkest hours.
Acknowledgements

All praise and thanks are due to Allah, the one with whose blessings and grace all good deeds can be accomplished. The long journey to finishing this thesis would not be possible without great support and inspiration from many people along the way.

First, I express my deepest gratitude to my principal supervisor Professor Stephen Harfield who was my mentor, inspirer and friend. Your patience, guidance, charisma and effort were essential to the birth of this thesis and my formation as a researcher.

I thank the heads of architecture schools at King Fahad University of Petroleum and Minerals, King Saud University and Umm Al-Qura University for being helpful and participating in my research. I thank all the interviewees who participated in Saudi Arabia and Australia.

I thank the Saudi Arabian government for sponsoring my research and helping me overcome the logistic obstacles. I also thank all my friends and colleagues at the Faculty of Design, Architecture and Building at the University of Technology, Sydney, Australia. In addition, I thank Rhonda Daniels for her editing and proofreading. Finally, I thank all my family and friends for their understanding and kindness during this long journey.
Abstract
This study investigates Saudi cultural constructs re the potential to use digital design techniques, and how these may relate to certain cultural and educational aspects, influence ways of thinking and processes of designing, and advance architecture in Saudi Arabia. The study analyses the characteristics of Saudi culture and architectural education as the direct source of contemporary Saudi architecture. It also questions the relationship between the cultural background and current Saudi architecture and architectural education, as well as cultural and educational aspects that could prevent or challenge the use of digital design techniques.

The main research question asks: What are the potential influences and interactions of introducing digital design techniques to Saudi culture, Saudi architecture and architectural education? What are the methods or tactics to make this introduction happen? Will digital design techniques be introduced to Saudi Arabia in the near future?

The research establishes Saudi culture, architecture, and architectural education; architectural digital design techniques and architecture as an outcome from other countries; and the limitations or challenges of using new digital design tools in Saudi Arabia. The study is guided by qualitative research techniques, using the following methods to collect and analysis data: interviews with academic staff and students in three Saudi universities, focus group interviews with Saudi architecture students completing their architecture degrees at Australian universities, interviews with Saudi computer science students also in Australian universities, and analysis of all the interviewees’ views and expectations in relation to Saudi culture, architecture and architectural education, and the potential interaction with digital design techniques.

The study assumed there is a lack of knowledge – and application – of digital design techniques in Saudi architecture. There are some cultural aspects that could prevent the use of digital design techniques. Moreover, there is a challenge to change the usual way of architectural design. Finally, the use of digital design techniques is hard to understand and use compared to the current ways of architectural thinking and designing in Saudi Arabia.
The study finds that the perception of digital design techniques among Saudi architecture staff and students is a mix of positive and negative, and accepting and rejecting. Nevertheless, digital design techniques seem to be accepted. However, this is tied to gaining extra knowledge such as English, mathematics, programming languages and software, which are the main pillars of digital design techniques. Introducing these techniques to Saudi culture requires raising awareness of digital design techniques; an easy and smooth introductory period; and convincing Saudi culture of digital design techniques. Introducing these techniques will be achieved through architecture educators, architectural education, architecture students and computer science specialists.

The study is contributing to understand the new digital design techniques revolution at the three Saudi Arabia cultural levels (Saudi culture, architecture, and architectural education). More specifically, the role of these techniques in improving Saudi architecture, and in enhancing its architectural education.
Table of Contents

Certificate of Authorship and Originality ........................................................................... i
Dedication .......................................................................................................................... ii
Acknowledgements ........................................................................................................... iii
Abstract ............................................................................................................................. iv
List of Tables ...................................................................................................................... x
List of Figures ................................................................................................................... xi
List of Publications .......................................................................................................... xii

Chapter 1: Introduction ........................................................................................................ 1
  1.1 Introduction .................................................................................................................. 1
  1.2 Research background .................................................................................................. 1
    1.2.1 Research context and development ..................................................................... 1
    1.2.2 Research conceptual diagram and research steps .............................................. 5
    1.2.3 Research problem ............................................................................................... 7
    1.2.4 Research questions ............................................................................................. 7
    1.2.5 Research objectives and scope ......................................................................... 8
    1.2.6 Limitations of the study .................................................................................... 9
    1.2.7 Research hypothesis ......................................................................................... 9
    1.2.8 Contribution to knowledge .............................................................................. 10
    1.2.9 Ethical considerations ....................................................................................... 11
  1.3 Thesis structure ......................................................................................................... 11

Chapter 2: Kingdom of Saudi Arabia: Culture, architecture and architectural education .... 15
  2.1 Introduction ................................................................................................................ 15
  2.2 Saudi culture ............................................................................................................. 18
    2.2.1 Saudi culture: past, present and future ............................................................... 19
    2.2.2 Culture layers .................................................................................................... 22
    2.2.3 Saudi culture and technology .......................................................................... 22
  2.3 Architecture in relation to culture ............................................................................. 23
    2.3.1 The role of cultural values in Saudi architecture .............................................. 25
  2.4 Saudi contemporary architecture ............................................................................. 27
    2.4.1 Saudi built environment and cultural changes .................................................. 31
  2.5 Saudi architectural education ..................................................................................... 32
    2.5.1 Influences on architectural education ............................................................... 33
    2.5.2 Architectural education in government universities ......................................... 34
    2.5.3 Architectural education in private universities and colleges ............................. 37
    2.5.4 Impact of Western curriculum in architecture schools ..................................... 42
  2.6 Conclusion ................................................................................................................ 44

Chapter 3: Architectural digital design techniques ............................................................. 47
  3.1 Introduction ................................................................................................................ 47
  3.2 Evolution of technology theory ................................................................................ 50
  3.3 A new way of thinking and designing ...................................................................... 53
  3.4 Complexity and never before .................................................................................. 58
  3.5 Architecture and mathematics ............................................................................... 61
  3.6 Architecture and computation ............................................................................... 65
  3.7 Drawing tool or generative system ......................................................................... 71
  3.8 Conclusion ................................................................................................................ 74

Chapter 4: Digital theories and approaches in architecture ............................................... 76
  4.1 Introduction ................................................................................................................ 76
Chapter 5: Digital design techniques ................................................................. 103

5.1 Introduction ........................................................................................................... 103
5.2 Architectural digital generative behaviours .......................................................... 104
  5.2.1 Variety of possibilities ....................................................................................... 105
  5.2.2 Evolutionary generative behaviours ................................................................. 105
  5.2.3 Generative mathematical concepts .................................................................... 107
  5.2.4 Self-organisation as a complex behaviour ....................................................... 109
5.3 Shifting the architectural design process ............................................................... 110
  5.3.1 Shifting design process and techniques: swarms, flocks, fractals and crowds .... 110
  5.3.2 Integration of design, fabrication and construction .......................................... 112
  5.3.3 From exploitation to exploration ....................................................................... 113
5.4 Architects and digital design techniques frontiers ............................................... 114
  5.4.1 Algorithms and geometric calculations ............................................................ 115
  5.4.2 Fabrication, its machines and materials ........................................................... 117
5.5 Coding and scripting ............................................................................................ 118
  5.5.1 Understanding coding language ....................................................................... 118
  5.5.2 The benefit of coding ....................................................................................... 120
  5.5.3 Access to coding ............................................................................................... 120
  5.5.4 Techniques of coding ....................................................................................... 122
  5.5.5 Algorithms in coding ........................................................................................ 123
  5.5.6 Relationship between architects and scripting – computation ....................... 124
  5.5.7 Using scripting ................................................................................................. 125
5.6 Contemporary advanced architecture: how architects conceive it and what it looks like 128
  5.6.1 How architects conceive contemporary advanced architecture ...................... 128
  5.6.2 What does contemporary advanced architecture look like ............................... 131
5.7 Outcome of digital design techniques in Saudi Arabia ......................................... 136
5.8 Conclusion ............................................................................................................ 143

Chapter 6: Perception of digital design techniques among Saudi architecture staff and students.. 145

6.1 Introduction ............................................................................................................ 145
6.2 Research methodology .......................................................................................... 145
  6.2.1 Research strategy ............................................................................................. 145
  6.2.2 System of inquiry ............................................................................................. 146
  6.2.3 Research strategy and method .......................................................................... 147
  6.2.4 Tactics and techniques ...................................................................................... 149
6.3 Analysis ................................................................................................................ 158
  6.3.1 Coding ............................................................................................................. 158
  6.3.2 Data analysis .................................................................................................... 160
  6.3.3 Validation and accuracy .................................................................................... 160
  6.3.4 Qualitative data presentation ............................................................................ 161
6.4 Interviews and the participants ............................................................................ 162
6.5 Perception of digital design techniques among Saudi architecture staff and students 165
6.6 Digital design techniques from the interviewees’ cultural and architectural perspective 179
  6.6.1 Saudi culture will accept digital design techniques ......................................... 179
  6.6.2 Digital design techniques may conflict with Saudi culture ............................ 180
  6.6.3 Saudi architecture will accept using digital design techniques ....................... 181
  6.6.4 Saudi architectural environment is not ready to embrace digital design techniques now.. 182
  6.6.5 Digital design techniques technical knowledge and architecture .................... 187
  6.7.1 Architects’ views on technical knowledge ....................................................... 187
Chapter 7: Saudi culture and architecture and relationship to digital design techniques .......... 194

7.1 Introduction ............................................................................................................... 194
7.2 Perception of current Saudi architecture ................................................................... 194
7.2.1 Changes in Saudi architecture ............................................................................. 194
7.2.2 Global style ........................................................................................................... 196
7.2.3 The expectation and reality of current Saudi architecture ...................................... 198
7.3 Saudi architecture and its relation to digital design techniques .............................. 199
7.3.1 Outcomes of digital design techniques are in Saudi Arabia but not by Saudi architects 199
7.3.2 Why Saudi architects cannot use digital design techniques .................................. 201
7.3.3 Saudi architecture and current designing techniques .............................................. 202
7.3.4 Call for conservatism and the clash with the future .............................................. 203
7.4 Response of Saudi culture to digital design techniques ............................................. 206
7.5 Aspects preventing introduction of digital design techniques in Saudi Arabia .......... 210
7.6 Methods for introducing digital design techniques .................................................. 216
7.6.1 Saudi cultural level ............................................................................................... 216
7.6.2 Saudi architectural level ........................................................................................ 221
7.7 Conclusion .................................................................................................................. 224

Chapter 8: Saudi architectural education and relationship to digital design techniques .......... 226

8.1 Introduction ............................................................................................................... 226
8.2 Current Saudi architectural education ...................................................................... 226
8.2.1 Current designing techniques .............................................................................. 226
8.2.2 Current technology ............................................................................................... 228
8.2.3 Infrastructure and software ................................................................................. 230
8.2.4 Saudi architectural education plans ...................................................................... 232
8.3 Saudi architectural education and relationship to digital design techniques .......... 233
8.3.1 Current staff knowledge of digital design techniques ........................................... 233
8.3.2 Gap between Saudi architectural education and digital design techniques .......... 235
8.3.3 Perception of digital design techniques among Saudi architectural education ....... 237
8.4 Saudi architectural education response to digital design techniques ...................... 240
8.4.1 Acceptance .......................................................................................................... 240
8.4.2 Easy or difficult...................................................................................................... 241
8.4.3 Necessity ............................................................................................................... 242
8.4.4 Proponent or opponent ........................................................................................ 244
8.5 Aspects preventing digital design techniques in Saudi architectural education ......... 245
8.6 Methods for introducing digital design techniques to Saudi architectural education .. 249
8.6.1 Saudi architectural educators ............................................................................... 250
8.6.2 Saudi architectural education .............................................................................. 250
8.6.3 Saudi architecture students ................................................................................ 251
8.6.4 Computer science specialists .............................................................................. 251
8.7 Conclusion .................................................................................................................. 252

Chapter 9: Conclusion ..................................................................................................... 254

9.1 Introduction ............................................................................................................... 254
9.2 Expected future of digital design techniques in Saudi Arabia ................................ 254
9.2.1 Saudi digital style ................................................................................................ 254
9.2.2 Saudi architects as users or developers ............................................................... 256
9.3 Digital design techniques influence at all levels ....................................................... 257
9.4 Opportunities to introduce digital design techniques ............................................... 260
9.5 Overview and summary of findings ......................................................................... 261
9.6 Current implementation actions .............................................................................. 273
9.7 Future research directions ....................................................................................... 274

Appendices ..................................................................................................................... 275

Appendix 1: Human Research Ethics Committee approval .......................................... 275
Appendix 2: Interview transcript (example – transcribed from Arabic to English) ............ 276
List of Tables

Table 1: Summary of government universities and schools of architecture in Saudi Arabia ......................... 40
Table 2: Summary of private universities and schools of architecture in Saudi Arabia ............................... 41
Table 3: Coding exercise 1: A good first program, from Shaw (2011, p. 13) .................................................. 127
Table 4: Coding exercise 32: Loops and lists, from Shaw (2011, pp. 95-96) ............................................... 127
Table 5: Examples of contemporary building forms ................................................................................. 133
Table 6: King Fahad University of Petroleum and Minerals interviewees (academics and students), College of Environmental Design, Architecture Department .................................................. 155
Table 7: King Saud University interviewees (academics and students), Architecture and Planning College, Architecture and Building Science Department .............................................................. 155
Table 8: Umm Al-Qura University interviewees (academics and students), Faculty of Engineering and Islamic Architecture, Department of Islamic Architecture ......................................................... 156
Table 9: Focus group interviewees: Saudi architecture students who are studying overseas in Australia 156
Table 10: Interviewees: Saudi computer science students who are studying overseas in Australia ........ 156
Table 11: Measurement of participants’ responses ...................................................................................... 178
Table 12: Aspects preventing digital design techniques in Saudi architectural education ......................... 246
List of Figures

Figure 1: A conceptual diagram of the research ................................................................. 5
Figure 2: Research steps ........................................................................................................ 6
Figure 3: Relationships in digital tectonic ........................................................................... 96
Figure 4: Paradigmatic shift in physics and related mathematical concepts in digital design, which architects need to understand (Kotnik 2010, p. 3) .................................................. 129
Figure 5: King Abdulaziz Centre for World Culture, Dhahran ........................................ 137
Figure 6: Qasr Al Hokm Downtown Metro Station, Riyadh ............................................... 137
Figure 7: The Museum of the Built Environment, Riyadh ................................................... 138
Figure 8: King Abdullah Financial District Men’s and Women’s Portal Spas, Riyadh ........ 139
Figure 9: King Abdullah Financial District Conference Centre, Riyadh ......................... 140
Figure 10: King Abdullah Petroleum Studies and Research Centre Community Mosque, Riyadh .... 140
Figure 11: King Abdullah Financial District Metro Station, Riyadh .................................. 141
Figure 12: King Abdullah Petroleum Studies and Research Centre, Riyadh ...................... 142
Figure 13: Research structure outline based on Groat and Wang (2002) ............................ 146
Figure 14: Six categories of perceptions of interviewees (Saudi staff and students) on digital design techniques ......................................................................................... 166
Figure 15: Typical Saudi house with (Roshan) traditional elements attached (Albarqawi 2013, p. 4.35) 197
Figure 16: The current Saudi architecture and its relation to new technologies .................. 204
List of Publications


Chapter 1: Introduction

1.1 Introduction

This research studies the relationship between digital design techniques, architectural education and culture in Saudi Arabia. It also examines the potential influences and interactions between them. This chapter presents the research background, which comprises the research context and development, problems, objectives and scope, limitations, hypotheses, contribution to knowledge, questions and ethical considerations. The chapter concludes with the thesis structure.

1.2 Research background

The research focuses on studying the possible gap between digital design techniques, Saudi architectural education and Saudi culture. It focuses on the causes of this gap, the role of architectural education and Saudi culture, and the possible solutions.

1.2.1 Research context and development

This section shows the initial research focus points of the potential relationships between the fields of digital architecture ‘worldwide’ from outside Saudi Arabia and the potential – or the refusal – to introduce digital techniques into Saudi culture. The research investigation is established by exploring the means and conceptions of digital architecture, based on both use in other countries, and use by overseas architects in Saudi Arabia; analysing the structure, traditions, conventions and restrictions of Saudi culture; and questioning both architectural education at Saudi universities and contemporary Saudi architecture. The study is based on the complex relationships between new technology and culture, that is influences, interactions and possible conflicts and, more specifically, the potential relationship between architectural digital design techniques and Saudi architectural education.
Due to the varieties of new digital technology, and the increasing complexity of environmental and cultural issues in the new millennium, architecture has to evolve as a multidisciplinary environment where a more divergent array of both “practical” and “theoretical” knowledge is necessary to control the design process (Richards 2010, p. 48). Architectural digital design techniques are the pillars of this study. They reflect the contemporary architectural design revolution and evolution taking place in developed and developing countries. In this approach, computers have been used as generative systems that have the ability to produce or create very advanced and complex outcomes. These systems are challenging human ability to think and to make as they produce what the human mind never thought of. Unlike conventional architecture practices which use computers as drawing instruments, using computers as generative systems is completely different. It requires studying and understanding these systems in terms of their theories, principles and the nature of the potential outcomes. This is manifested in upholding and motivating the way that architectural designers think and design, resulting in potentially different, novel and complex outcomes, which may represent creativity.

The initial research analysis considers the structure, traditions, conventions and restrictions of the Saudi culture. Given that the Saudi culture is heavily connected to Islamic tradition and Bedouin values, this suggests a slight separation between the secular life and a religious life, and it is very important to understand the religion in order to understand culture and traditions (Schuster & Copeland in Rice 2003, p. 466). Accordingly, this strong connection between religion, traditions and Bedouin tribes could be considered as the restrictive aspect of Saudi culture. Yet despite this influence, Saudi culture has been changing in the last 70 to 80 years because the rapid oil revolution affected cultural development, and resulted in advances in all technological aspects which connect Saudi culture to the outside world. This led to rapid modernisation which caused, and continues to cause, social and cultural changes, as a result of which Saudi culture is in an active and changing status (Long 2005, p. 1).

The study analyses Saudi contemporary architecture as one of the initial research considerations. Contemporary Saudi architecture is a reflection of the history of Saudi
culture. About 100 years ago Saudi architecture was modest and made out of available local materials according to the place where it was built. Since the oil revolution in the late 1940s and early 1950s, buildings started to change, with the traditional buildings being removed and replaced with modern buildings (Eben Saleh 1998b, p. 163; Long 2005, p. 106) and it is ongoing. As a result of this transformation, the interplay and exchange between Saudi contemporary architecture and a large number of international companies and experts has increased, maximising the internationalisation of architecture in Saudi Arabia (Abu-Ghazze 1997, p. 234). The question is why Saudis allowed international companies and foreign architects to use new architectural technology rather than their own architects and educators.

While introducing digital architecture into Saudi culture is – potentially – a key focus, the main aim of this study is to research how this will influence Saudi architectural education, both as a part of the culture and as the main source of contemporary architecture. It is necessary to explore the architectural education currently provided in Saudi Arabia, and to observe how computers are used in the architectural design process to explore the potential impact of this new technology.

The first architecture school in Saudi Arabia was established in 1968 at King Saud University, followed by schools at other universities such as King Abdul Aziz University and King Faisal University. The architectural curricula in Saudi universities are similar to those institutions from which they were derived. For example, at King Saud University the curriculum was developed by UNESCO; Harvard University developed the curriculum of King Abdul Aziz University; and at King Faisal University the curriculum was revised with the cooperation and advice of Rice University in Texas, United States (Abu-Ghazze 1997, p. 247). In addition to the local architecture education, a large number of Saudis were, and are, sent abroad for advanced education that emphasises both teaching modern architecture and technical competency. However, the use of computation in architectural education is limited to the adoption of computer-aided design (CAD) which became the main approach since 1990 (Reffat 2007, p. 1). Though Saudi universities use computers in the architectural design process, the goal in this study
is to explore the possibilities and consequences of using new digital design techniques in architecture, with considerations of cultural structure, traditions, conventions and restrictive aspects.

This study is an investigation into the influences and interactions between digital architecture as a new architectural designing technique and Saudi culture, including its contemporary architecture and architectural education. To explore the basis of this interplay the study is inspired by the relationship between digital technology and creativity which invokes innovation and development. Using digital design techniques provides more solutions to solve problems and potentially enhances creativity in architectural design. According to Dasgupta (2008, p. 130), computation in architecture provides a framework for understanding creative thought. Krish (2011, p. 89) similarly argues that architectural computation provides the ability to explore endless design iterations at the early stages of design, which potentially produce far more beneficial results, while Chu (2004, p. 77) states that the nature of computation is assigned to change the world, including architecture. This provides the basis to investigate the possibilities of employing and using architectural digital design techniques in the context of Saudi culture to advance Saudi architecture through tertiary education.
1.2.2 Research conceptual diagram and research steps

Figure 1 is a conceptual diagram of the research, while Figure 2 shows the research steps.

The Research Area

- The effect of digital design techniques on Saudi culture & architectural education, and vice versa.
- The potential acceptance or rejection of digital techniques within Saudi education, culture and architecture.
- The notions of architectural education and the 'additions' to Saudi.
- The use of education to 're-develop' Saudi contemporary architecture.

Figure 1: A conceptual diagram of the research
### Exploring Research Background

<table>
<thead>
<tr>
<th>Saudi Culture, Architecture &amp; Architectural Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital-Design Techniques</td>
</tr>
<tr>
<td>Digital Theories and Approaches</td>
</tr>
<tr>
<td>What Constitutes DDTs.</td>
</tr>
<tr>
<td>DDTs’ perception among Saudis</td>
</tr>
<tr>
<td>The Current Saudi Culture and Architecture, and their Relation to DDTs</td>
</tr>
</tbody>
</table>

### Methodology

- Interview (voice recorded) with academic staff and students in Saudi.
- Analysis of the interviewees’ responses.
- Seminar and Workshop (focus Group)

### Question

**What are the potential influences and interactions of introducing digital-design techniques to Saudi architectural education and Saudi culture? and what are the methods or tactics to make this introduction happen?**

### Research

<table>
<thead>
<tr>
<th>Technology</th>
<th>Digital Architecture</th>
<th>Architecture &amp; Culture</th>
<th>Saudi Culture</th>
<th>Current Saudi Architecture</th>
<th>Saudi Arch. Education</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1.2.3 Research problem
The research problem is that there is a gap between current architectural education in Saudi Arabia and the use of digital design techniques. There may be several causes of this gap:

- Saudi architectural education is out of date compared to many other countries using digital techniques, with perhaps few Saudis knowing about digital techniques and/or not having the skills to use the techniques.
- There may be difficulties in using or interacting with digital design programs, such as software languages.
- There may be some cultural aspects, such as conservatism and/or technophobia.
- There may be resistance to change, as outcomes from digital design techniques may conflict with Saudi architectural education and/or cultural aspects.
- Saudi architectural education institutions may use CAD, Rivet and 3D modelling software, but not digital design techniques.

The primary purpose of this study is to identify and suggest the use of digital design techniques in Saudi architecture and architectural education, and to investigate the positive and negative effects of Saudi culture, architecture and architectural education.

1.2.4 Research questions
The main research question is:

- What are the potential influences and interactions of introducing digital design techniques to Saudi architectural education and Saudi culture? What are the methods or tactics to make this introduction happen? Will digital design techniques be introduced to Saudi Arabia in the near future?

The secondary research questions are:

- What are the cultural and architectural consequences of the introduction of digital design techniques in Saudi Arabia? What is the role of Saudi architectural education?
• Why are digital design techniques needed to change architecture in Saudi Arabia? What is the essence of digital design techniques in Saudi culture, architecture and architectural education?

• What is the role of cultural difference in potentially affecting architectural digital design techniques and vice versa?

• Can new digital design techniques be used to advance architecture in Saudi Arabia, how and in what ways?

• What is the relationship between digital design techniques, and Saudi culture, contemporary architecture and architectural education?

• What reasons prevent digital design techniques being used in Saudi architectural education?

1.2.5 Research objectives and scope

The research objectives are to:

• suggest introducing and using digital design techniques to Saudi culture, architecture and architectural education as new ways of thinking and designing.

• propose advancing Saudi architecture, especially in universities, to catch up with other countries using these techniques.

• encourage Saudi studies in technology to develop greater interest among Saudi researchers.

• understand digital design techniques to find possible ways to introduce them to Saudi culture and architectural education.

The research scope includes:

• architectural digital design techniques, in particular computational generative systems where computers receive rules and perform to generate architectural design.

• Saudi architectural education and the important cultural factors that affect architectural development and the introduction of digital design techniques.
1.2.6 Limitations of the study

This study is conducted with special reference and focus on Saudi architectural education. While the problem addressed of the gap between architectural education and digital design techniques use is perhaps manifested in various Arab countries, the aim of the research is to explore the nature of the problem, the causes, and the possible solutions for Saudi culture and Saudi architectural education.

The study does not set an implementation framework for digital design techniques, and does not establish a plan to introduce these techniques as new curricula in Saudi universities. The study focuses on the possibilities to fill the gap between Saudi culture, Saudi architectural education and digital design techniques. It investigates the current perception and knowledge of digital design techniques among Saudi architecture academics and students at Saudi universities.

1.2.7 Research hypothesis

This study assumes that there is a lack of digital design techniques, and knowledge of such techniques, in Saudi architectural circles, and that such techniques may be used to shift or change Saudi architectural education and potentially Saudi contemporary architecture. It argues that the reason for this lack is the Saudi cultural constraints that potentially oppose – or at present do not use – these techniques due to some cultural aspects, such as conservatism, connected very strongly to architecture. This is also related to the challenge of changing the usual methods of architectural design and, significantly, architectural education, which is inconsistent with the current way of thinking and designing in Saudi such as programming languages and the ways of using them. As a result, it is hypothesised that digital design techniques can and will influence Saudi culture and architectural education – and vice versa. It is also hypothesised that applying digital design techniques in Saudi Arabia will potentially improve architectural design.

The argument is thus that digital design techniques might have impacts on Saudi culture and architectural domains or vice versa. These impacts are the result of an existing lack of knowledge and use of digital techniques, cultural conservatism and the challenge of
changing. The use of digital techniques may potentially improve architectural education and architectural design in Saudi Arabia.

1.2.8 Contribution to knowledge
This research is significant as it contributes to understanding the current architectural design revolution, particularly the role of new digital design techniques in improving architecture, but more specifically introducing these digital techniques as a new way of architectural design, and as a new tool to enhance Saudi architectural education.

For Saudi architecture the study contributes to fill the gap between the current architecture and education in Saudi Arabia, and the use of digital techniques. It provides information on digital design techniques, and supports significant educational development and change in architectural design abilities by providing information to use these techniques in Saudi architectural education, enhance architectural technological development and innovations, and help to implement or enhance digital techniques in Saudi architectural education.

In relation to the existing literature in this area, the study addresses the lack of technological research in Saudi culture. According to Elmusa (1997, p. 346), because of the lack of interest in the question of technology in the Arab world among scholars studying this region, the relationship of technology and culture in Saudi Arabia has received little attention. The literature review also provides substantial understanding of digital design techniques.

In relation to Saudi culture, the study provides information and understanding on the implementation of architectural digital design techniques in Saudi Arabia. The thesis elaborates on the role and significance of digital design techniques, and establishes its beneficial aspects for Saudi culture. Finally, the study is potentially relevant and beneficial to architecture schools in other countries and could be used as a precedent or example to guide case studies in other countries.
1.2.9 Ethical considerations
The University of Technology, Sydney Human Research Ethics Committee reviewed the ethics application for the research with architecture academics and students and agreed that the application met the requirements of the NHMRC National Statement on Ethical Conduct in Human Research (2007). Ethics approval was granted with approval number UTS HREC REF NO. (2013000500), valid for five years from 6 November 2013. See Appendix 1 for details.

1.3 Thesis structure
An overarching study based on theoretical verification is required to fulfil the research objectives and answer the research questions. This section summarises the chapters of this thesis.

Chapter 2 explores the Kingdom of Saudi Arabia including culture, architecture and architectural education. Section 2.2 explores the Saudi culture’s past, present and future and also explores layers within Saudi culture and the relationship between Saudi culture and technology. Section 2.3 highlights the relationship between Saudi architecture and culture, and the role of cultural values in shaping Saudi architecture. Section 2.4 investigates contemporary Saudi architecture and the mutual relationship between the built environment and culture changing. Section 2.5 discusses Saudi architectural education, Saudi architecture schools and computer use in Saudi architectural education.

Chapter 3 discusses architectural digital design techniques in other countries. Section 3.2 explains the theory of technology evolution. Section 3.3 explores using computers in architecture design as a new way of thinking and designing. Section 3.4 explains the role of computers in increasing complexity. Sections 3.5 and 3.6 explain the relationship between architecture, mathematics and computation. Section 3.7 shows the difference between the possibilities of using computers as a drawing tool and as a generative system.
Chapter 4 presents important information about digital theories and approaches in architecture which may be introduced into Saudi culture. Section 4.2 studies folding in architecture and the blobs theories. Section 4.3 shows performative architecture theory. Section 4.4 reveals the theory of parametric design and parametricism. Section 4.5 explores morphogenesis, emergence and self-organisation theories. Section 4.6 discusses the nonlinear organisation theory. Section 4.7 deals with the theory of digital tectonics. Section 4.8 describes topology in architecture. Section 4.9 previews digital poetics theory.

Chapter 5 discusses what constitutes digital design techniques. Section 5.2 discusses architectural digital generative behaviours and how they provide a variety of options through evolutionary generative behaviours, the generative mathematical concepts, and the complex behaviour of self-organisation systems. Section 5.3 shows the shift in the architectural design process including how architects moved to use some behaviours from nature such as swarms, flocks and crowds, how they shift to integrate design, fabrication and construction, and how they also moved from exploitation to exploration through technology. Section 5.4 highlights the frontiers between architects and digital design techniques. It shows what knowledge architects need to cross the boundary line of digital design techniques such as algorithms, geometric calculation and fabrication (its machines and materials). Section 5.5 provides important information about programming (coding and scripting) in architecture including understanding coding languages, the benefit of coding, access to coding, coding techniques, algorithms in coding, the relationship between architects and scripting, and why and how to do scripting. Section 5.6 studies contemporary advanced architecture and how architects conceive it and how it looks. Finally, Section 5.7 displays some outcomes of digital design techniques in Saudi Arabia.

Chapter 6 presents the research methodology, analysis, the field work and the collected data to explore the perception of digital design techniques among Saudis in Sections 6.2 and 6.3. Section 6.4 presents a breakdown of the interviews and the participants. Then Section 6.5 investigates the perception of digital design techniques among Saudis. Section 6.6 studies digital design techniques from the interviewees’ cultural and architectural perspective, including answering the question of whether Saudi culture and architecture
will accept the introduction of digital design techniques. Section 6.7 then explores the technical notion of digital design techniques from the perspectives of Saudi architects and computer scientists.

Chapter 7 studies the current relationship between Saudi architecture and digital design techniques. In Section 7.2 the current Saudi architecture is discussed, including changes in Saudi architecture, the turn to global style and the expectation and reality of the current Saudi architecture. Section 7.3 investigates the relationship between Saudi architecture and digital design techniques. It answers questions such as why the outcome of digital design techniques is visible in Saudi Arabia, but not by Saudi architects, and why Saudi architects cannot use digital design techniques. It also discusses the designing techniques in use now in Saudi architecture, and the call for conservatism and the clash of the future. Section 7.4 deals with how Saudi architecture will respond to the introduction of digital design techniques and Section 7.5 shows what could prevent the introduction of digital design techniques. Section 7.6 points out ways to introduce digital design techniques at Saudi cultural and architectural levels.

Chapter 8 studies current relations between Saudi architectural education and digital design techniques. Section 8.2 explores current Saudi architectural education, specifically, the design techniques used, the technology used, the available infrastructure and the current plans. Section 8.3 investigates the relation between Saudi architectural education and digital design techniques including what educators know about digital design techniques, the gap between Saudi architectural education and digital design techniques, and the perception of digital design techniques among the educators. Section 8.4 highlights how Saudi architectural education will respond to the introduction of digital design techniques including the potential acceptance or rejection, difficulties and resistance. Section 8.5 explores what could prevent the introduction of digital design techniques to Saudi architectural education. Section 8.6 points out ways to introduce digital design techniques to Saudi architectural education through Saudi architectural educators, education, students and computer science specialists.
Finally, Chapter 9 summarises the study and presents the broad research conclusion. Section 9.2 previews the expected future of digital design techniques in Saudi Arabia. Section 9.3 highlights the influence of digital design techniques at all Saudi cultural levels. Section 9.4 shows the opportunities for introduction of digital design techniques. Section 9.5 is an overall summary of the thesis and the findings. Section 9.6 provides current implementation actions for digital design techniques. The last section suggests some future research directions.
Chapter 2: Kingdom of Saudi Arabia: Culture, architecture and architectural education

2.1 Introduction

Architecture is linked very strongly to its culture, or in other words, culture is the context where architecture is shaped and developed. To achieve this link, we need to consider the necessity of ensuring harmony between intangible social, economic and cultural aspects, and the tangible forms of physical planning and architecture. Culture and traditional values always move with the architectural transformation, which forces culture to engage with such development. This chapter discusses Saudi culture, Saudi architecture in relation to culture, Saudi contemporary architecture and Saudi architectural education.

The Kingdom of Saudi Arabia has been in existence for about a century. It is a unified nation whose birth as a state was announced on 23 September 1932 (Long 2005, p. 1). It occupies about 80% of the Arabian Peninsula and is divided into four major regions: the Central Region, the Western Region, the Southern Region and the Eastern Region. Its climate has had considerable impact on its traditional architecture, but not its contemporary architecture. Saudi Arabia has a desert climate with extreme heat during the day and a significant drop in temperature at night, and a very low annual rainfall. There is climatic variation between the coastal and central areas. The average summer temperature is about 45°C, but can sometimes reach up to 54°C. In winter, the temperature drops below 0°C, but the absence of humidity and windchill aspects makes for a colder temperature. In the spring and autumn, the temperature reaches an average of 29°C (Weatheronline 2015).

The total population of Saudi Arabia is 30.8 million in 2014 and Saudis make up 20.7 million while the rest are employees and workers from overseas (General Authority for Statistics Kingdom of Saudi Arabia 2016). The population includes Muslims from around the world. Arab and non-Arab Muslims from all over the world have migrated to Saudi Arabia throughout history, especially to the major cities of Makkah and Madinah. Family is the most important component in Saudi society. Saudi families can trace their roots and
individuals feel responsible not only for the family unit, but for the entire tribe (Long 2005, p. 35). The Saudi government system is a monarchy where the king is the centre and the Quran (The Holy Book) is the constitution (Long 2005, p. 21). There are no political parties, professional associations or trade unions. The Crown Prince usually takes up the Deputy Prime Minister’s position while other members of the Royal Family are heads of other important ministries and agencies.

The Saudi economy has changed rapidly since the discovery of oil resources in 1930. Architecture and urban development have flourished, as well as architectural education. As a result of the oil extraction, the economic development of Saudi Arabia can be divided into two periods: the period before discovery of oil and the period after discovery of oil. Prior to the discovery of oil, the Saudi economy was primitive depending on the revenues of pilgrimage to Makkah, trade, fishing and agriculture. After the discovery of oil, the Saudi economy changed significantly due to commercial oil exploitation.

Understanding Saudi culture, the relation between Saudi culture and architecture, Saudi contemporary architecture, and Saudi architectural education is important in introducing digital design techniques to Saudi culture, architecture and architectural education. Saudi culture is conservative and complex with very strict restrictions, traditions and conventions. In the early 1930s, everything started to change, and rapid modernisation and technology allowed for an unprecedented connection to the outside world, which imposed an interaction between Saudi culture, religion and modernisation. Saudis decided to seek modernisation, but at the same time maintain their cultural values. Over time, new cultural elements have been added, modified and adopted to be part of this culture. Due to the oil wealth, the desire to progress has increased, which make Saudis familiar with imported sophisticated technologies.

Consequently, culture starts to lose some of its aspects in the modern context. Cultural values play a significant role in Saudi architecture. This is manifested in local master-builders who are the most qualified to consider local culture, traditions, and natural and human resources. Those values are best seen in the internal and external arrangement of
Saudi traditional houses, as they show the role of socio-cultural values and lifestyle of its inhabitants in shaping local preferences. Nevertheless, modernisation requires moving forward in terms of culture and technology.

Because of the rapid development in Saudi society, almost everything has changed or started to change, especially its contemporary architecture. Mostly the changes have been caused by a huge growth in the Saudi economy and population. As a result of the population growth, the demand for housing in the country has increased which has accelerated the development process, resulting in modern architecture being imported to meet the need for buildings. *The current architecture is inconsistent with the Saudi culture and environment.* Thus, some architects have called for preservation of traditional architecture. Even though the preservation campaigns are widely recognised, the trend is continuing in the *opposite direction towards modernisation.* The Saudi built environment has changed, and in response, culture should change as well, but culture is often sensitive to architectural changes. Saudi culture has developed its own traits to meet the challenges in lifestyles and the built environment.

Saudi architectural education started with the foundation of the first architecture school in 1968 and has been influenced by Western and Arab architecture approaches and schools. This influence has led to huge debates in Saudi Arabia on whether it is appropriate to add new technologies (such as computers) to the traditions and conventions of Saudi architectural education, as Saudi architectural education is distant from technology use.
2.2 Saudi culture

Elaraby (1996, p. 138) explains culture:

Every culture builds in its own way, borrowing from the past, developing a distinctive style, then passing on to a new age those achievements which are proven most worthy. Each culture, then, is unique by itself and in itself, having distinguishing characteristics based on major aspects of human life such as religion, philosophy, ethics, habits, traditions and manners. In a few words, culture is ‘a way of life’, having a vocabulary of design elements and an identity interpreted and manifested in a specific architectural language that gives it its own style, distinction, character and personality.

The cultural aspect is considered one of the most important elements of this study, especially when culture can influence architecture. The majority of the cultural and architectural studies show that the relation between cultural factors and architecture is extremely complex. This complexity could be exaggerated when relating it to a very conservative culture like the Saudi culture, which has its own special architectural characteristics. Saudi culture could be considered as a conservative one with very strict restrictions, traditions and conventions (Al-Hathloul 2004).

The Saudi culture developed through the interplay between the hot desert environment and Arabian people in the context of the Islamic religion. According to Long (2005, pp. 1, 10), Saudi culture is distinctive as it emerged from a desert environment. It is known as an Islamic culture and it remains intact. This was the case until the exploration of crude oil in Saudi Arabia, which began in the early 1930s. Since the 1930s, everything has started to change. Americans arrived in Saudi Arabia to extract oil and export it in large quantities. After World War II, the influence of Western culture began to be felt to an extraordinary degree as the oil wealth began to affect local cultural patterns (Long 2005, pp. 3, 26). Saudi people were exposed to a wide range of foreign (mostly American) lifestyles, yet at the same time, they kept their religion and cultural practices. Kimball (1956, pp. 472, 474, 475) highlights that even though Americans built their own settlements in Saudi Arabia with all the services they needed, there were some restrictions placed on their behaviour by the Saudi government and they were not allowed to interfere in religious issues.
In the 1970s and 1980s, Saudi Arabia witnessed major social and cultural changes as a result of the rapid economic development. Long (2005, p. 1) explains that the rapid modernisation in transport and communications technology in Saudi Arabia made an unprecedented connection to the outside world, which imposed the interaction between its culture, religion and modernisation. Americans in Saudi Arabia were not the only source of imported Western culture and technology; Saudis themselves travel abroad, and as result import foreign goods and services, and even ideas.

As a result of the modernisation drive by the Saudi government, Saudi culture is encountering huge changes. Since the 1950s the Saudi government has spent billions on the development of social, physical and economic infrastructure for the benefit of its citizens (Long 2005, p. 43). Subsequently, Saudi cultural values and traditions are challenged by this modernisation movement. Saudis are now in a situation where they want to engage with modernisation, yet at the same time they want to keep their culture safe and strong. Long (2005, p. 32) illustrates that, for about 80 years, Saudis have been seeking to deal with the conflict between their Islamic culture and Western technological modernisation by “seeking modernization without secularization”. Elmusa (1997, p. 350) similarly states that Saudis are keen to get technology without endangering their culture. This is reflected in Saudi families and the structure of their traditions and customs. Saudi families are resilient as they strongly embrace Islamic social values, but these actual practices are mixed with modernisation (Long 2005, pp. 37,62).

The following three subsections discuss Saudi culture throughout its history, the idea of Saudi cultural layers, and the relationship between Saudi culture and technologies.

### 2.2.1 Saudi culture: past, present and future

It is important to highlight the significance of the Kingdom of Saudi Arabia as an Islamic society. It is unique among other Islamic countries as it hosts the holiest places in Islam: Makkah and Madinah. These are destinations for all Muslims around the world – the location of pilgrimage (Hajj). The country is governed by the Islamic law (Shari’a), which
is the implementation of the Quran and Sunnah (Holy Book and sayings attributed to the Islamic prophet, Muhammad).

Islam is the prevalent religion in the Arabian Peninsula, which means that the inhabitants share the same culture and language. According to Fadan (1983, pp. 32-39), Saudi society was divided into nomads and settlers. The nomads were a group of people whose life was in constant movement, chasing watering points and vegetation, whereas settlers were people (who could be nomads) who were born and lived their lives in cities, towns or villages and were never exposed to the desert life. The nomads’ and settlers’ communities consist of an extended family, a unit of social consolidation encouraged by Islam. Equally important is that the Arabian Peninsula does not have significant natural resources, such as fresh water and agriculture, necessary to live a comfortable life. Its climate is also very harsh. As a result, Saudis have learnt how to deal with these circumstances and limitations to the extent that they have become a self-sufficient society (Fadan 1983, p. 93). This was the situation before Saudi unification.

The unification of Saudi Arabia in 1932 was an important point in its history. It affected the major traditional living environment, accelerated the pace of changes, and dramatically transformed the Saudi nation from poverty to power and influence (Fadan 1983, pp. 66-68). In 1932, Saudis were mostly engaged in farming, fishing, pearl fishing, trading and other manual trades. Between 1933 and 1939, Americans discovered several oil fields in the country’s Eastern Region and exposure and contact with the outside world became inevitable. At the beginning, Saudis were employed by the American company as unskilled labourers (Fadan 1983, p. 70). People from the Western Region depend for the most part on trade with the outside world through pilgrims who visit the region regularly every year. Nevertheless, the oil wealth provided huge opportunities to many Saudis to work in commerce. Saudi workers, contractors and businessmen were the product of modernisation that came about through the interplay between Saudi culture and the Western world (Fadan 1983, p. 74). The influence on the Saudi lifestyle was obvious in the living environment and societal organisation.
It is obvious that Saudi culture has changed, and new cultural elements have been added, modified and adopted to be part of this culture. These changes show that: (a) all changes are new, as society does not accept elements if they are already met or satisfied within the culture, (b) changes result from observing how other societies solve the same problem – including government, religion, housing and dress, and (c) changes result from wealth and contact with the outside world. Wealth does not soften or reduce the impact of Western changes, but it boosts and speeds up the change process such that Saudis have become more attached to Western culture.

As a result, Saudi Arabia is witnessing technological advancements. It results in pressure to modernise its society within a short time, despite the lack of work force, material and infrastructure. Moreover, Saudi culture has become more consumerist, such that consumerism has become the main character of current Saudi society. Almost all new technologies, fashion, cars, brands and restaurants are imported from overseas. Unfortunately, Saudi culture is not a production culture: we do not make, but we consume. Furthermore, the structure of Saudi traditions has not changed, but the practices within the structure are changing to keep pace with modernisation. Saudi social customs and behaviour remain intact in the face of Western influence (Long 2005, p. 65). Islamic values and traditions are still kept, but the way events are performed is changing.

Throughout history, most cultures have changed according to the surrounding events, so culture re-evaluates its aims and then modifies itself to meet the new challenges and needs. It is expected that the new Saudi society will have a new ideology, and will look to change itself for the best, including Saudi architecture. Changes in Saudi culture will continue in evolutionary and revolutionary scales, but societal values and Islamic culture will remain cohesive. There is a growing call for cultural change to keep up with the technological revolution while maintaining the equilibrium between modernisation and Islamic values, which is the main challenge for Saudi Arabia’s future. While adopting technological changes, Saudi culture will continue to be conservative.
2.2.2 Culture layers

Saudi culture can be divided into three layers. The base layer is religion, the second is family, and the top layer is traditions and conventions. Usually, Western culture and technology can interplay with the ‘top’ layer, but when they get deeper, they cannot penetrate the last two layers, especially the religion layer. Long (2005, p. 10) stresses that two main factors in Saudi culture are extremely important and hard to change: religion and family. Similarly, Rice (2003, pp. 466-468) highlights the importance of family relationships. It influences the behaviour of all Arabs regardless of the education level, economic status, political philosophy or religion. Loyalty is always significant to tradition, religion and family, which means that imposing change into these layers is hard, even if change was made by Saudis who are educated overseas.

Notwithstanding the influence of Western culture on Saudi society, the extended families are not affected, especially the patrilineal organisation, because of the resilience of the extended family itself. It derives its strength from traditional Islamic social and political values (Long 2005, p. 37). The extended families’ patterns, however, have started to change due to the difficulty of maintaining close proximity to other family members in large cities. Family members used to live in the family compound, but now it is very hard to find or offer this kind of family environment. However, this strong family relationship has not disappeared, but it has been replaced with a high level of interpersonal telecommunication or by keeping a house in the hometown village and where they work (Long 2005, p. 39).

2.2.3 Saudi culture and technology

Oil wealth magnified the desire to progress and was also the starting point of intense cross-cultural relationships with other cultures (Fadan 1983, p. 91). Saudis became wealthier, which encouraged them to acquire new sophisticated technologies. Computer and internet user penetration varies across the Gulf countries. For example, computer and internet usage in Saudi Arabia increased from 41.0% in 1995-1999 to 47.5% in 2000-2004, 54.0% in 2005-2009 and 60.5% in 2010-2014 (World Bank 2015). The
considerable increase emphasises strong government support for computer education and information technology.

Technology is a necessity that promotes information generation and dissemination. The Saudi government places strong emphasis on education in general and on increasing the population of young educated people through reliance on digital technologies, but unfortunately progress is relatively slow and the education system continues to be criticised (Rice 2003, p. 467). Rice (2003, p. 468) argues that cultural values and conservatism may prevent people from using technologies, make people unwilling to shoulder responsibilities, and maintain the status quo. Rice implies that some Saudis do not use a computer for two reasons: because they do not like to expose themselves to technology as it could be against their values, and avoid assigning computer work tasks to them as they do not understand the technology so they have the excuse of ignorance. Low income and education could be another two reasons. For example, face-to-face is the preferable way of communication between workers, while email is a very efficient way to keep in touch. These reasons could prevent Saudis from using technology and achieving more than 60.5% of computer and internet use penetration.

2.3 Architecture in relation to culture

Architecture is everywhere, but culture is different. Each culture has its own notion of architecture, and each culture comprises a particular society, people, religion and background. As a result, architecture in a particular culture is expected to meet all these aspects. Thus, architecture is linked very strongly to its culture, or in other words, culture is the context wherein architecture is shaped and developed.

Eisenman (1992, p. 22) highlights that architecture is the physical expression of natural phenomena. He mentions the tangible aspect of architecture’s “physical existence” but misses the intangible aspects of “culture”. Unlike Eisenman, the Egyptian architect Hassan Fathy (Fathy, 1973 in Elaraby 1996, p. 140) states that:
It is necessary to achieve harmony between intangible social, economic and cultural aspects, and the tangible forms of physical planning and architecture. When we neglect any of our cultural elements, a vacuum takes place. This vacuum is then filled with foreign elements which are totally unsuitable.

By nature, architecture has always tried to embrace value, and such values definitely arise from its culture. Glassie and Rapoport, as cited in AlSayyad (2003, p. 9), add to the idea of architecture and tradition by saying that the built environment represents the physical realisation of culture. Similarly, Siddiqi (2002, p. 175) emphasises that the architectural designer should have the ability to extract ideas from the human culture which created the built environment. Parment (2000, p. 20) also affirms that architecture belongs to “moral laws or ethics, everything goes back to ethics” which means the architectural form can be changed, but we cannot change its background because it is something rooted in the culture. Ballantyne (2002, p. 49) admits that the building form is controllable, but the culture of the people who interact with the building is uncontrollable.

Culture and traditional values often move with the architectural transformation, interacting mutually. They move with people who use buildings, and as a result they are reflected by master-builders and/or architects in the architectural forms. Traditions move not only with generations, but also through space; they move with people from old to new homes (Jacobs 2004, p. 33). Eben Saleh (2000, p. 465) states that transformation of forms should deal with place and time, and with strong consideration of cultural values. However, this cultural movement is not always easy and smooth; it faces disturbances as well (Jacobs 2004, p. 34).

Modern architectural and technological development puts pressure on cultural movement. With the rapid changes in the built environment, changes are taking place in cities, culture, and therefore architectural practice, which require architects to design and think differently (Moussavi & López 2009, p. 7). According to Haseeb (2011, p. 269), it is necessary to produce the appropriate modern architectural environments for human activities. In both studies modern architecture is changing, which forces culture to change and to engage with it. As a consequence, culture starts to lose some of its aspects in the
modern environment, which leads to a weakening of the same culture (AlSayyad 2003, p. 8). Thus a fundamental shift is needed to change culture, otherwise culture will stay static and will not be able to make changes and possibilities for development (Moussavi & López 2009, p. 17). Eventually, architecture and culture remain in an interchangeable status.

2.3.1 The role of cultural values in Saudi architecture

Cultural values play a significant role in Saudi architecture to the extent that they control not only the building function, but also the form. Local master-builders are the best to consider local culture, traditions, and natural and human resources, which allow them to modify the new materials and techniques and adapt them to suit the local needs without neglecting the socio-cultural values (Fadan 1983, p. ii). Considering these values is fundamental to Saudi architecture; in other words, any failure to incorporate these values in modern architecture is counted as faulty modernisation. Eben Saleh (2000, p. 455) argues that any attempt to change without taking into account Saudi cultural values will be considered as a failure within modernist attitudes.

It is significant to look at the internal and external organisation of Saudi traditional houses as they portray the role of socio-cultural values and the lifestyle of occupants (Fadan 1983, p. 54). For example, internal courtyards are used to maximise privacy and to deal with the harsh weather by helping to cool down the hot air. The external windows and doors are also limited in number and oriented in certain ways to minimise the weather impact and increase privacy. Faden (1983, p. 56) highlights that the social internal concerns were expressed via various forms of barriers, such as a buffer wall located near the entrance hall, to prevent passers-by looking in and to secure and isolate access of the male guests to the reception room without being able to explore the rest of the house. The male reception room(s) is usually located adjacent to the entrance hall. Roof terraces also have social roles and requirements. They are usually surrounded by parapets of two metres or more to provide privacy. There is also an agreement between neighbours not to build their houses overlooking existing terraces (Fadan 1983, p. 57).
Based on that, most of the local architecture must be influenced by cultural values, local weather, local building materials and local building techniques to achieve harmony with the contextual environment. Fadan (1983, p. 58) points out that local architecture shows harmony between building techniques, adaptation of local materials, master-builders’ awareness of sensitive socio-cultural values and families’ needs, and the harsh natural constraints. Thus, master-builders are most likely to work out a balance between all these cultural and environmental aspects. Fadan (1983, p. 60) stresses that modern Saudi architects and homeowners must appreciate the value of builders from the past when constructing new homes.

The cultural characteristics of a society play a very important role in determining local architectural forms, techniques and materials. For example, Maghrabi (2000, p. 35) argues that cultural values are very important and play a significant role in housing design in Saudi Arabia. Principles such as hospitality, neighbour-to-neighbour relationships, extended families and women’s status in the family shape privacy concerns in Saudi traditional housing. According to Maghrabi (2000), there are two dimensions of privacy: vertical and horizontal. The vertical dimension of privacy is manifested in isolating the guests’ section from the rest of the house, with all guests’ facilities located in the ground floor (semi-private zone), whereas all the family spaces are located in the upper floor (very private zone). For horizontal privacy, within the upper floor there is, for example, segregation between sleeping and living rooms, and extended family privacy (a married son may live on the same floor or another floor). Additionally, windows (all kinds of openings) and terraces show another level of cultural traits. All windows must be covered with Rowshan, mashrabiah and shish to ensure privacy, while allowing the household to look outside. In the terraces which are outdoor spaces open to the sky, all the parapet sides are higher than the users’ height to block the view of nearby neighbours.

Change is necessary to move forward, but cultural restrictions sometimes may reject, limit or slow some aspects of this movement. Fadan (1983, pp. 10-11) argues that as a result of urgent built environment development, Saudi society does not understand the development process, does not maintain its customs and traditions which are being eroded.
to achieve newer environment and objectives, and is not able to reinterpret its traditional environment and customs under the new circumstances. An exotic architectural style has been established and the conventional building and its values have been weakened. In response, a preservation movement has started and has become widely recognised. Traditional Saudi houses have been modified after careful examination to maximise suitability, so features and functions are becoming more complex while maintaining Saudi cultural values. It is easy to say that cultural values are playing a crucial role in forming local architecture. According to Eben Saleh (2004, p. 625), to design a typical Saudi building all cultural, social, climatic, economic and religious aspects ought to be involved in the decision-making. The design process will necessitate the use of digital design techniques, but in harmony with those aspects.

2.4 Saudi contemporary architecture

Every culture usually has its own distinctive architecture that is an accumulation of principles and values from previous generations. Elaraby (1996, p. 138) notes that every culture is unique, and has its own distinguishing traits, which are manifested in its architectural style. As a consequence of the rapid development in Saudi society, almost everything has changed or started to change, especially architecture. Eben Saleh (1998b, p. 149) states that the political and economic changes in Saudi Arabia since its establishment were one of the main reasons for the change in its architecture and urban environment.

The contemporary architectural transformation in Saudi Arabia is a result of four issues: a huge growth in the Saudi economy as a result of oil revenue, the migration of people from rural to urban areas in large numbers seeking jobs and business, arrival of foreign companies and experts, and Saudi students educated overseas. Abu-Ghazze (1997, p. 230) confirms that since the oil boom in the mid-1970s, an accelerated development process has resulted in the import of modern architectural concepts to help meet building demands. The need for buildings is a natural result of the migration of large numbers of people to urban centres. Abu-Ghazze (1997, p. 234) points out that the migration of
people to urban centres chasing rapid economic growth has accelerated the transformation process of the physical environment. According to the General Authority for Statistics in the Kingdom of Saudi Arabia (2016) the population of major cities such as Riyadh and Jeddah will grow by almost one million people each by 2025. Riyadh’s population will grow from 6.1 million in 2010 to almost 7.4 million in 2025, with 3.6 million Saudis and 2.5 million non-Saudis in 2010. Jeddah’s population will grow from 4.1 million in 2010 to 4.9 million in 2025, with 2 million Saudis and 2.1 million non-Saudis in 2010. This migration could lead to the abandonment and neglect of traditional towns and villages. Al-Hathloul and Aslam Mughal (1999, p. 202) claim that, as a result of this movement, traditional towns and villages will shrink. At the same time, this will increase the demand for urgent growth in the built environment, which exposes the Saudi built environment to foreign companies and designers. Abu-Ghazzeh (1997, p. 234) points out that, with development, the contact and exchange between Saudi and foreign companies and experts will increase. But this is not the only source of Western modernisation; Saudis were and are being sent overseas to seek advanced education in large numbers (Abu-Ghazzeh 1997, p. 234).

As a consequence of the rapid migration to cities and foreign development, contemporary Saudi architecture has been changing. Saudi architecture is now suffering an inconsistency between Saudi culture and environment. The imported foreign design concepts are climatically inappropriate and contain spatial norms from Western culture that do not suit Saudi sensitivities. The foreign concepts are “culturally destructive” (Abu-Ghazzeh 1997, p. 234). Al-Hathloul and Aslam Mughal (1999, pp. 201-205) highlight that the implementation of the Western model disregards local culture and results in a lack of identity as well as styles that have no relationship to the local traditions. Another scholar argues that the substitution of traditional forms and dropping of local values are counted as an adopted failure from modernity. This is not always in harmony with the local culture, and could be considered as a conflict between modernity and tradition (Eben Saleh 2000, 2001).
As a result of this inconsistency some architects try to preserve traditional Saudi architecture by maintaining a balance between traditions and the demand for modern life. Eben Saleh (2004, pp. 629-633) believes in what he calls “New Vernacularism”: the concept of placing culture and religious aspects in the context of physical design. He claims that architectural preservation will benefit the development of cultural, economic, social and religious aspects of Saudi society. So, the New Vernacularism is an attempt to save the cultural values from the threat of modernisation. In another article, Eben Saleh (1998a, pp. 572, 573) states that to control the changes in the built environment, decision-makers and designers need to keep and save traditions’ continuity by seeking the links between tradition and modernity. Unlike Eben Saleh, Al-Kodmany (1999, p. 283) declares that even though the introduction of modern architecture is seductive, people still believe in their culture and tradition and would rather change or modify the modern design to match their way of life. Hence, it is enough to understand the core values of any culture in order to meet the needs of its people.

Foreign building development, which comprises exotic architectural style, reduces conventional buildings and weakens values. In 1970 Saudis were alarmed at the gradual extermination of their cultural values and architectural history and characteristics for the sake of development, and the tendency has shifted to preservation (Fadan 1983, p. 11). Despite the preservation movement, the prevalent trend is still heading in the opposite direction towards pure modernisation. Fences are erected high, and windows and balconies are blocked to prevent looking in to maintain privacy (Al-Marzoky 1999, p. 185). House design is modern, but with some modification to suit Saudi cultural and environmental requirements. The beauty of buildings – how they look – is not an important issue. Building structures take priority over external appearance because authorities do not pursue an architect if a building does not look good or the interior organisation is incorrect; rather, they will pursue an architect if a building collapses (Al-Marzoky 1999, p. 188).

All traditional old buildings in Saudi Arabia are very simple, using load-bearing walls and built using local techniques and building materials (Fadan 1983, p. 77). Building
techniques, style and materials were connected to the region where the construction takes place. Saudi traditional architecture is divided into four types according to the four Saudi regions: Najd (Central), Hijaz (Western), Asir (Southern) and Ahsa (Eastern). Each regional type has its special characteristics, but they are similar. Al-Marzoky (1999, p. 181) argues that discontinuity of traditional architecture took place at many levels with the introduction of contemporary architecture. This is due to rapid development and high demand for residential buildings, which are built through consultation with overseas architectural firms using steel, concrete and glass. As a result, traditional neighbourhoods have become modern districts with wide streets instead of narrow zigzagged streets. This poses a real issue for Saudi architectural educators. They need to produce architects who are aware of cultural and environmental needs. This was the case until recently, but with increasing price and demand for housing, the tendency has shifted to multi-story apartment buildings and/or small duplex villas. Each family owns a private apartment and/or duplex villa, or sometimes rents it. Reinforced concrete, aluminium and glass are the most commonly used materials for both residential and commercial buildings since the oil boom. Although they are popular, these materials are not the most appropriate for Saudi environmental conditions, and in some cases the use of glass does not achieve privacy, with a loss of cultural values.

An architecture teaching member at King Saud University, Ali Bahammam, interviewed by Al-Marzoky (1999, p. 192), claims that “most of the [new] dwelling houses lack aesthetic merit – in short they are ugly!” and not well organised in terms of internal functions. For instance, the kitchen is not close to the dining area, and living rooms are without windows – they do not have natural light. This is what is happening, but what should happen is very different. Rahim (2004, p. 201) argued that contemporary architecture practices and education must explore the relationship between contemporary techniques, culture and architecture. In the past, for example, the Saudi built environment was appropriate and responsive to all circumstances including climate, economy and culture, but now new building techniques, materials and climate control devices such as air conditioning have influenced local architecture.
2.4.1 Saudi built environment and cultural changes

Saudi architecture has history and traditions sourced from many years of communal life and a harsh environment. The harsh environment does not change, but the built environment has changed, and in response to that, culture needs to change as well. The culture could impose certain conditions for the new architecture to be accepted. It is inconceivable that the emerging Saudi society could accept such radical architectural changes without any psychological and cultural conditioning (Fadan 1983, p. 158). Culture is often sensitive to architectural changes, in other words, culture will pay the cost of change. Eben Saleh (2000, p. 456) argues that introducing new architectural forms often happens at the expense of those that already exist by demolishing traditional buildings, weakening the architectural and societal values, and changing culture to suit the new architecture. However, for many years, Saudi culture has developed its own traits, meeting the challenges in lifestyles and the introduction of new approaches to design and the use of new technologies (Elaraby 1996, p. 140).

In 1983, Fadan (1983, p. ii) stated that Saudi Arabia would be transformed into a modernised nation within ten years as housing projects are everywhere and entire new cities are built under an ambitious development plan. Fadan argues that to achieve the plan’s goal, assistance must be sought from the outside – experts and workers at all levels are needed. As a result, the socio-cultural values and the traditional built environment, unfortunately, have been overlooked. In 2015, the physical environment is still undergoing radical and rapid changes at all levels, including cultural, education, technology, transport, materials and relations with overseas experts. While the evolution of traditional architecture may be replaced with new foreign forms, culture is being impacted and changed at the same time which means the culture needs to respond to these changes.

Gated compounds in Saudi Arabia demonstrate how the built environment has changed dramatically, but Saudi society preferred not to have the full version of Western forms and have the choice of selecting what is appropriate for them. At the same time, Saudis segregate compounds to offer the residents total freedom – to practise their usual way of
life. After oil was discovered in the Arabian Peninsula in the 1930s by the Western oil company, ARAMCO, it built housing compounds for its workers in Dhahran in the 1940s. The Saudi government promoted these developments, and allowed the company to build housing compounds for its workforce to limit and control the cultural influences of Western foreigners in Saudi society (Glasze 2006, p. 85). Gated compounds offer residents a Western lifestyle, and at the same time, allow them to escape the strict cultural norms just outside the gate. More importantly, compounds ensure that the Western lifestyle inside the gates does not come into contact with and is not mixed up with Saudi culture (Glasze 2006, p. 86).

Every place has its own identity, so changing is always hard and could have certain consequences. The built environment and culture always interact and the current built environment is the outcome of the accumulated experience over time and history. Saudis now need to consider their built environment when adopting new modern socio-cultural values and meeting new cultural challenges. This is because culture and social relationships are very sensitive to architectural changes.

### 2.5 Saudi architectural education

Prior to the establishment of universities in Saudi Arabia, architectural education was very poor. Architects in Saudi Arabia were called master-builders or “Mualim”. Mualim must be qualified through many years of training before the chief of builders or “Shaykh al-Mualimin” could allow a master-builder to start an independent practice (Al-Marzoky 1999, p. 257). However, with the oil revolution, physical and cultural fundamental changes have taken place. As a result, there was an urgent need to establish a number of modern architecture schools. As literature on Saudi architectural education is limited and not up-to-date, the summary here is cited from the available literature. Due to this gap in the literature, architecture staff and students were interviewed with results presented in Chapters 6, 7 and 8.
2.5.1 Influences on architectural education

According to Al-Marzoky (1999, p. 106), Saudi architectural education has been influenced by the architectural education style of three countries: United Kingdom, United States of America and Egypt. When Saudi Arabia established its first architecture school in 1968 it looked at the architectural curricula in these three countries and used them as models. Firstly, the United States and United Kingdom have influenced architectural education in Egypt, and then they all indirectly impacted Saudi architectural education. Secondly, the Saudi architectural education programs were set up by American and British experts. Thirdly, many Saudi higher education students completed PhD and Masters degrees in these three countries, and then returned to teach in Saudi universities. Companies from these three countries have designed many of Saudi Arabia’s architectural projects. Finally, the majority of architects who work for Saudi architectural offices as consultants and experts come from these three countries.

Architectural education in Saudi Arabia began with the foundation of the first Saudi architecture school in 1968. It was based on the Egyptian architecture schools and run by one of the most famous Egyptian architects, Ahmad Fareed Mustafa (Al-Marzoky 1999, p. 257). Shortly after, a decision was then made to embrace the Western style of architecture school by importing its architectural curricula. Saudi architecture schools developed their curricula through consultations with foreign organisations and universities such as UNESCO, Harvard University and Rice University (Abu-Ghazzez 1997; Al-Marzoky 1999).

According to Al-Marzoky (1999, p. 257), in 1968 the first Saudi school of architecture was established within the College of Engineering – the first ever such school in the whole Arabian Peninsula. In 1969, it joined the University of Riyadh, “King Saud University”, and was based on the Egyptian schools of architecture. The Egyptian professor, Ahmad Fareed Mustafa, was the first head of the school and responsible for course structure and he followed the system of Egyptian schools which he knew well.
In 1975, major changes took place; Rice University in Texas, United States, was consulted to help develop the King Saud University school. The Department of Architecture was renamed as the College of Architecture and Planning. In the same year, King Faisal University in Dammam (now Dammam University) established its own architecture department. The curriculum was also developed by Ahmed Fareed Mustafa and was similar to that at King Saud University. Later, Rice University was also consulted to design King Faisal University’s program that was also similar to the previous one. Dr Morris Cambridge from Harvard University was involved in the development of the architecture program at King Abdulaziz University in Jeddah in 1976 (Al-Marzoky 1999, pp. 258, 259). Egyptians and Americans have played a very significant role in the development of Saudi architectural education from the start.

2.5.2 Architectural education in government universities

Architecture schools in government universities are summarised in Table 1. The first generation of Saudi architects graduated in 1971 from King Saud University, which was before the foundation of the College of Architecture and Planning. At that time, and as a result of the oil revolution, there was a real demand for more architects. Thus, the decision was made to set up more government universities such as the King Fahad University of Petroleum and Minerals (Dhahran) in 1976 and Umm Al-Qura University (Makkah) in 1983. The program in all architecture schools lasts five years – and remains so even today. Graduates are allowed to start practice with no registration or real practice experience (Al-Marzoky 1999, pp. 196-197).

King Saud University, located in the capital city of Riyadh, is the first university ever set up in Saudi Arabia. Founded in 1957, it represents the country’s earliest commitment to developing higher education (Al-Marzoky 1999, p. 249). King Saud University was a pioneering institution in establishing architectural education in the country. In 1984, it set up the College of Architecture and Planning with two departments: the Architecture and Building Science Department, and the Urban Planning Department. The college provides Bachelor, Masters and PhD degrees. Students are enrolled for two years in general studies aimed at developing their basic design skills and drawing abilities, while consolidating
theoretical knowledge related to the built environment. In the third year, students start their professional studies either in architecture or in building science (King Saud University 2015).

King Faisal University, now known as Dammam University, is located in Dammam City in the Eastern Region of Saudi Arabia. In 1975, it founded its own College of Architecture and Planning with five departments: Architecture, Urban and Regional Planning, Building Engineering, Landscape Architecture, and Interior Architecture (Dammam University 2015; Al-Marzoky 1999, p. 250). The aim is to develop the students’ design skills with special focus on the technical aspects as well as improving the students’ communication methods while striving for clarity, eloquence and professionalism. The program lasts five years, exposing students to a wide range of subjects such as design, construction, theories of architecture and engineering science, in addition to focusing on the local environment, economic aspects and social characteristics of the region. The department offers Bachelor, Masters and PhD degrees in architecture (Dammam University 2015).

King Abdulaziz University is located in Jeddah in the Western Region. It was founded in 1967 by a group of Saudi merchants who realised the importance of education. In 1971, it came under the jurisdiction of the Ministry of Education (Al-Marzoky 1999, p. 250). In 1998, the Faculty of Environmental Design was established with three departments: Architecture, Urban and Regional Planning, and Landscape Architecture. The faculty also provides Bachelor, Masters and PhD degrees. The architecture department curriculum focuses on the university requirements in the first year. The architecture program has recently implemented a vertical studio system where students of different years and levels are enrolled in the same studio with a team of instructors who continue with them from the first studio up to the senior level studio.

King Fahad University of Petroleum and Minerals, established in 1975, is located in Dhahran near the oil areas (Al-Marzoky 1999, p. 249). In 1980, the College of Environmental Design was established with three departments: Architecture Engineering,
Architecture, and City and Regional Planning. More recently, a Construction Engineering and Management Department has been established. The college provides Bachelor, Masters and PhD degrees. The architecture curriculum is based on American models with one orientation year before students are enrolled in the architecture program. Design studios and IT-based design applications are the focal points. The program is assessed by USA National Architectural Accrediting Board terms. Instruction is in English (King Fahad University of Petroleum and Minerals 2015).

Umm Al-Qura University is located in the holy city of Makkah and was established in 1981. The College of Engineering and Islamic Architecture has five departments: Islamic Architecture, Electrical Engineering, Mechanical Engineering, Civil Engineering, and Computer Engineering. The Department of Islamic Architecture at Umm Al-Qura University does not follow other Saudi universities in adopting the Western program. Instead, it uses or consults with other Saudi and non-Saudi experts in Islamic architecture such as Faud Faramawi, an Egyptian professor who was teaching at Umm Al-Qura University at the time (Al-Marzoky 1999, p. 263). The curriculum is influenced by the structure of architecture programs in Egypt. Emphasis is placed on Islamic architecture, Islamic cities and conservation of Islamic architecture heritage and values (Umm Al-Qura University 2015).

Qassim University was established in 2004 by merging two Qassim branches of Imam Mohammad Ibn Saud Islamic University and King Saud University. Since then, there has been an expansion in enrolment numbers and a significant growth in its faculty and staff. The Architecture and Design College is one of the most modern colleges in Saudi Arabia. It was established in 2009 and received its first students in 2010. Enrolled students must pass a foundation year, and then they need to pass qualifying skill tests as well as undergo a personal interview. It follows the rules of the semester system, which is based on studio-based learning. The study language is English and the program lasts five years. It only offers an undergraduate degree (Qassim University 2015).
Al-Baha University was founded in 2005 with 12 faculties. The Architectural Engineering Department in the Faculty of Engineering was established in 2005 and had its first graduates in 2010. The department uses a credit-hour system through ten terms that amount to 156 units (credit hours). It offers three Bachelor degrees, specialising in architectural design, interior design, and building technologies. In the first year, students increase their main skills and general awareness, followed by two years where students follow common specialised courses. The students then complete their study journey with a graduation project, which must show the students’ ability to present efficient solutions and prove through it the students’ efficiency and awareness of the necessary knowledge and skills to exercise the profession of architecture (Al Baha University 2015).

2.5.3 Architectural education in private universities and colleges

Between 1999 and 2000, private universities and college regulations were approved which allowed private and charity sectors to establish this private form of education in Saudi Arabia. In 2001, private universities and colleges rules were approved, such as administrative procedures and technical regulations, and the Ministry of Education became the authority that grants licenses for private universities and colleges. In 1999, Effat University was established as the country’s first private non-profit university. The Saudi government decided to generously support the private sector to encourage a diversification of economic activities including private higher education (Ministry of Education 2015). Five private universities that provide architecture degrees to both male and female Saudis are summarised in Table 2.

Effat University in Jeddah is a private non-profit institution of higher education for women in Saudi Arabia, operating under King Faisal’s Charitable Foundation. In 1999, it started offering academic programs in English to raise Saudi women’s educational level. The Department of Architecture in the College of Architecture and Design provides Bachelor and Masters degrees. The program is designed to meet Saudi architectural education requirements and is taught in English. The program may include principles and applications of technology, art, humanities, engineering, physical and social sciences,
business and management. The program lasts five years; each year has two semesters, and each semester includes a design studio (Effat University 2015).

Prince Sultan University in Riyadh was founded in 1999 as Prince Sultan Private College but in 2003, the Ministry of Education upgraded it to the level of university. The Department of Interior Design offers one undergraduate program and the expected duration is four years. Students need to successfully complete the courses in the orientation year, which aim to improve the student’s oral and written skills in the English language, to strengthen the student’s mathematical skills, and to introduce the student to basic computer knowledge and skills. The contents and structure of the programs are adopted from the United States, Canada and the United Kingdom, following the recommendations of leading international bodies such as the International Association of Interior Design, American Society of Interior Design and the International Facility Management Association (Prince Sultan University 2015). The influence of Western architectural education is clear, but unfortunately does not include using digital design techniques in interior design – and in all the other universities.

Dar al Uloom University in Riyadh was initially founded as Dar al Uloom Private College in 2008 and awarded university status in 2009. It offers some programs for Saudi and international students. All programs have been designed in collaboration with King Fahad University of Petroleum and Minerals. The Department of Architectural Engineering and Digital Design in the College of Architectural Engineering and Digital Design offers three Bachelor degrees in Architectural Engineering, Interior Design and Graphic Design. The program consists of one foundation year to meet the university requirements including English language skills, followed by four years of specialisation subjects (Dar Al Uloom University 2015).

Al Yamamah University in Riyadh was established in 2001 as a single college and accepted male students in 2004 and female students in 2006. In 2013, the Ministry of Education approved the proposal for a new program of engineering and architecture, and started receiving students in 2014. The College of Engineering and Architecture was
established, offering a Bachelor’s degree in engineering and architecture. The graduates will be qualified in interior design, furniture design, lighting design, architecture, building science and technology, and environmental design. The Department of Architecture offers three specialisations (Bachelor) in the field of architectural engineering: Architecture, Building Science and Technology, and Environmental Design (Al Yamamah University 2015).

Dar Al Hekmah University in Jeddah is a private, non-profit institution of higher education for women. It started as a college in 1999, but was declared a university in 2014. Classes are taught in English. Throughout its foundation, it received private donations and advice from the Texas International Education Consortium. It offers Diplomas, Bachelor’s and Masters degrees from four schools: the Hekma School of Business, Law and International Relations, Design and Architecture, and Education and Applied Sciences. The Hekma School of Design and Architecture offers a Bachelor of Arts in Interior Design, Fashion Design, Motion Graphics or Graphic Design, as well as a Bachelor of Architecture (Dar Al Hekma University 2015).
<table>
<thead>
<tr>
<th>University</th>
<th>City</th>
<th>Foundation</th>
<th>Departments</th>
<th>Degrees</th>
<th>Education Language</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>King Saud University</td>
<td>Riyadh</td>
<td>1984 – foundation of the College of Architecture and Planning</td>
<td>Two departments: Architecture and Building Science, Urban Planning</td>
<td>Bachelor, Master and PhD</td>
<td>Arabic</td>
<td>Male</td>
</tr>
<tr>
<td>King Faisal University or Dammam University</td>
<td>Dammam</td>
<td>1975 – foundation of the College of Architecture and Planning</td>
<td>Five departments: Architecture, Urban and Regional Planning, Building Engineering, Landscape Architecture, and Interior Architecture</td>
<td>Bachelor, Master and PhD</td>
<td>Arabic</td>
<td>Male</td>
</tr>
<tr>
<td>King Abdulaziz University</td>
<td>Jeddah</td>
<td>1998 – foundation of the Faculty of Environmental Design</td>
<td>Three departments: Architecture, Urban and Regional Planning, and Landscape Architecture</td>
<td>Bachelor, Master and PhD</td>
<td>Arabic</td>
<td>Male</td>
</tr>
<tr>
<td>King Fahad University of Petroleum and Minerals</td>
<td>Dhahran</td>
<td>1980 – foundation of the College of Environmental Design</td>
<td>Five departments: Architecture Engineering, Architecture, and the City and Regional Planning, and more recently, Construction Engineering and Management</td>
<td>Bachelor, Master and PhD</td>
<td>English</td>
<td>Male</td>
</tr>
<tr>
<td>Umm Al Qura University</td>
<td>Makkah</td>
<td>1981 – foundation of the College of Engineering and Islamic Architecture</td>
<td>Five departments: Islamic Architecture, Electrical Engineering, Mechanical Engineering, Civil Engineering, Computer Engineering</td>
<td>Bachelor, Master</td>
<td>Arabic</td>
<td>Male</td>
</tr>
<tr>
<td>Al-Baha University</td>
<td>Al-Baha</td>
<td>2005 – foundation of the Faculty of Engineering</td>
<td>Three departments: Architectural design, Interior design, and Building technologies</td>
<td>Bachelor</td>
<td>Arabic</td>
<td>Male</td>
</tr>
<tr>
<td>University</td>
<td>City</td>
<td>Foundation</td>
<td>Departments</td>
<td>Degrees</td>
<td>Education Language</td>
<td>Gender</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------</td>
<td>------------</td>
<td>------------------------------------------------------------------------------</td>
<td>------------------</td>
<td>--------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Effat University</td>
<td>Jeddah</td>
<td>1999 – foundation of the College of Architecture and Design</td>
<td>Three departments: Architecture, Visual and Digital Production, and Design</td>
<td>Bachelor and Master</td>
<td>English</td>
<td>Female</td>
</tr>
<tr>
<td>Prince Sultan University</td>
<td>Riyadh</td>
<td>2003 – foundation of the College of Interior Design and Architecture</td>
<td>Two departments: Interior Design and Architecture</td>
<td>Bachelor</td>
<td>English</td>
<td>Female</td>
</tr>
<tr>
<td>Al Yamamah University</td>
<td>Riyadh</td>
<td>2014 – foundation of the College of Engineering and Architecture</td>
<td>Two departments: Interior Architecture and Architecture</td>
<td>Bachelor</td>
<td>English</td>
<td>Male &amp; Female</td>
</tr>
</tbody>
</table>
2.5.4 Impact of Western curriculum in architecture schools

Based on the history of establishing architecture schools, the Saudi architectural curricula incorporated global standards, which are not oriented to deal with Saudi traditions, environment and architecture (Abu-Ghazzeeh 1997; Al-Marzoky 1999; Eben Saleh 2000). The general educational trends are oriented towards modern architecture and technology. As a result, several scholars argue that these imported curricula do not address local circumstances in Saudi Arabia and tend to ignore traditional Saudi architecture. Aba Al Khail (Al-Marzoky 1999, p. 260) states that the entire curriculum is not suitable for Saudis as it is not home-grown but imported from abroad.

The imported curricula have led to huge debates in Saudi Arabia as to whether they are appropriate or not to the traditions and conventions of Saudi culture. The generic view was antagonistic to these curricula as they are not from the local culture and are thus insensitive to local values. Abu-Ghazzech (1997, p. 242) argues that it is appropriate to teach traditional architecture and its history as they are very important for design, especially in Islamic society. Siddiqi (2002, p. 175) emphasises that architectural education and training are connected very strongly to social and cultural aspects that provide values that need to be preserved. In general, the curriculum must respect the socio-cultural, environmental and ecological settings in Saudi Arabia, which were clearly manifested in the principles of traditional buildings (Abu-Ghazzech 1997). Students need to learn and understand the historical and cultural aspects of their society and how those relate to modern architecture.

An architecture teaching member at the King Saud University, Ali Bahammam, interviewed by Al-Marzoky (1999, p. 192), claims that to compare Saudi architectural education with architectural education elsewhere we need to consider the nature of the surrounding built environment. For example, in Saudi Arabia traditional buildings are removed and replaced with new but poorly designed contemporary buildings. Thus, architecture students during their study develop a conflicting design mentality as they are asked to produce suitable designs in places where they only see unsuitable examples. It is important to understand that Saudi contemporary architecture tends to contradict
traditional architecture, and this is due to two factors: most of the contemporary buildings are designed by an overseas architect, and architectural education is derived from the Western system that has been imported by Saudi academics. According to Al-Marzoky (1999, p. 194), foreign and Saudi architects, architectural education, Saudi architectural practice, and building techniques, materials and rules are all reasons for the bias that the Saudi public have against contemporary architecture. Al-Marzoky (1999) blames only Saudi architects and architectural education for it. Architectural education used to be only for male students; with no Saudi female architects until recently. Now, some universities, especially private institutions, provide architectural education to Saudi women. The educators are both male and female, and Saudi and foreign.

2.5.5 Computers in Saudi Architectural Education

The use of computers in architectural design has increased in the last few decades, which has affected architectural design studio teaching and practice. Surprisingly, most architecture schools in Saudi Arabia still use manual techniques, the traditional way of doing architecture, carrying out the design process using manual techniques such as sketching, drawing and physical modelling. Saudi universities have provided only modest computer facilities to students to develop their skills and to keep current with the technological revolution. The use of such computer facilities is still very limited, focusing on drafting and montaging.

In 1999, the Saudi architecture schools confirmed that computer laboratories would help architecture students develop their skills in design, drafting and montaging. They started to introduce computer aided design software as part of their curricula (Al-Marzoky 1999, p. 294). Today, all architecture schools have such labs, but they are different in size and equipment, and most importantly is the way that computers are now being used in the design processes. Unfortunately, according to Al-Marzoky (1999, p. 294), most of the teaching staff and students in architecture departments at Saudi universities were not satisfied with the computer facilities provided. They complained about inadequate and poor quality computers to the extent that some students could graduate with no knowledge
of AutoCAD. The current situation is not significantly different from that in 1999, and is discussed further with interviewees in the following chapters.

In 2007, King Fahad University of Petroleum and Minerals used two unprecedented approaches to implement information and communication technology in architectural design studios as a new paradigm of thinking: paperless design studio and collaborative virtual computing. In this experiment, a fruitful dialogue was established between the designer and the tool. The experiment used the paperless design studio and collaborative virtual computing in the practical implementation and strategies of these two approaches in the design studio. The paperless design studio is characterised by excluding, as much as possible, hand-drawn designs, and replacing them with a strong dependency on the use of software. The virtual design studio is characterised by exploring the asynchronous and synchronous techniques in remote design collaboration using technologies such as video conferencing, internet publishing, email, Web3D and digital modelling (Reffat 2007, pp. 1-4). These were the only experiments ever carried out by Saudi universities using advanced digital design technology.

The historical development of computer use in Saudi architectural education is modest. The literature does not show much research in this area, especially in how Saudi architectural educators and students use computers in design processes. Saudi architectural education uses computers as an information processing tool, communication tool, and visualisation tool during the design process. Computers are used to process construction information and documentation, as well as drawing and montaging tools.

2.6 Conclusion

The oil boom has played a fundamental role in changing Saudi culture, architecture and architectural education. Although Saudi culture is conservative and complex, with very strict restrictions, traditions and conventions, it is still a dynamic one with the ability to select or reject changes. It is a culture that is “seeking modernization without secularization” (Long 2005, p. 32). Consequently, Saudi culture has changed by adding
new cultural elements, modifying and adopting them to become part of its cultural identity. Islamic values and traditions are still essential, but the way things are done is changing. Saudis will need to maintain the equilibrium between modernisation, technological development and Islamic values, which is the challenge facing Saudi Arabia’s future culture and architectural education.

Cultural and traditional values always move with architectural transformation in mutual interaction. However, this cultural movement is not always easy and smooth which makes the job harder for architects to produce suitable and/or appropriate architecture. The modern architectural movement is forcing culture to change and to engage with it. At the same time, culture is also able to change architecture. In the case of Saudi culture there are indeed many strong cultural restrictions and requirements. Thus, local architects are ideally placed to appreciate these restrictions and requirements to deal with them harmoniously using new digital design techniques.

As aforementioned, Saudi contemporary architecture is generally assumed to have failed to meet Saudi cultural and environmental requirements. One assumption argues that failure is inevitable, as contemporary Saudi architecture is produced by foreign architects who apply foreign ideas without understanding and studying the local culture and environmental needs. Another assumption is that Saudi architects have brought in Western theories and ways of thinking, designing and constructing when they return home after completing their architecture education overseas. The third assumption is that Saudi architects who are educated in Saudi Arabia fail to understand and consider local cultural requirements; because Saudi architectural education fails to deliver this type of knowledge. Saudi architects are responsible for the current architectural inconsistency because they have failed to understand and consider the environmental and socio-cultural context within which they design. Saudi contemporary architecture does not need to look spectacular or special; it just needs to ensure privacy and be aware of the surrounding environment, especially the neighbours.
Saudi architectural education follows the education patterns of three countries, the United Kingdom, the United States and Egypt, *but not in terms of using digital design techniques*. Some scholars argue that these imported programs do not address local Saudi circumstances and sensitivities – hence, they are irrelevant. They also argue it is appropriate to teach traditional architecture and its history, as they are very important for designing, in particular in Islamic Saudi society. Saudi architecture educators need to consider the cultural requirements, available materials, local climate and the nature of the surrounding built environment especially when digital design techniques are introduced.

In Saudi Arabia, there are 12 universities providing architecture programs, with seven government universities and five private universities. Although digital design techniques are a significant new trend, Saudi architecture schools *are still using manual techniques*. In 1999 research, staff and students in architecture departments at Saudi universities seemed dissatisfied with the existing computer facilities. In addition, using computers is still limited to the very basic tasks of drawing and montaging.

The following chapter discusses architectural digital design techniques – which, in general, are developed in overseas countries – including the theory of technology revolution, using computers as a new way of designing and thinking which increases design complexity, and the relationships between architecture and mathematics and computation, followed by the difference between using computers as a drawing tool and as a generative system.
Chapter 3: Architectural digital design techniques

3.1 Introduction

With recent technological developments, digital design techniques are constantly evolving and becoming more complex, which radically affects architectural design. Computer applications have become the contemporary designing systems, such that the design and fabrication processes in architecture have changed. As a result, buildings’ shapes, surfaces and overall outlook are also changing in unprecedented ways. From an architectural perspective, computers have become more available and affordable than ever before, which enables the production of cheap curvilinear and complex surfaces. So the architecture of the 21st century will be freed from almost all forms of restrictions, meaning that old, recent and future theories can be tested and visualised with no boundaries by the human imagination. In 1991, Eisenman claimed that “architecture was not only being confronted by electronic media, it had been swallowed up by it. With its emergence a reality shift took place and today there is no guarantee of what reality truly means” (Eisenman in Jakob 2011, p. 143). The architectural dream to computerise the design process to create more complex or organic geometries has started. These processes and their outcomes will be different due to the technology of the time and place where they are performed. Nicholas Mirzoeff states that “space can no longer be seen as simply an empty backdrop but as a dynamic entity with a history and characteristics that vary from period to period and place to place” (in Jakob 2011, p. 143).

Architecture has witnessed a transformation movement from the manual tool-based design to a global computer-based design. But, this transformation has not reached its full potential, which is due to a lack of architectural computational education or increased confusion on digital design (Terzidis 2006, p. 40). The use of this technology is still at an unstable phase. Some architects develop their designs in the traditional manual way and then use computers to increase the efficiency of the outcome, whereas others are using computers as a technique to explore new possibilities and expand beyond the limitations of the human mind. Using computer-aided design packages to manipulate architectural geometries is not ideal for this exploration. This exploration needs a new generation who
are willing to channel their efforts through computation, algorithms and architectural logics towards new digital architectural designs.

Like any type of technology, digital computation in architecture began in a time of crisis and then developed gradually to become an inseparable part of it. Spiller (2008, p. 9) claims that technological advancements happen in times of war, and this was also the case with digital architecture which was born in World War II when the Enigma Machine and Alan Turing used computation – coding – with evolution in cybernetics. Later in the 1990s, everything changed; electronic technologies quickly changed almost everything including culture, society, economy and aspects of daily life, and this changing wave pushed architects to believe that architecture should change as well (Carpo 2013, p. 8). In the 1990s, Peter Eisenman first initiated digital discourse in architecture with his two essays, “Vision Unfolding: Architecture in the Age of Electronic Media” and “The Effects of Singularity”. Eisenman highlights the progression from deconstructivism – which was the latest theory before digital – to the first age of digital design (Carpo 2013, p. 15). But up until 1992, digital was still not the tool or way of new design and building; it was seen as a digital culture which should inspire architects to experience unprecedented digital innovations and new ways of seeing the world (Carpo 2013, p. 15). The current digital age is more challenging and pervasive. Kolarevic (2004a, p. 3) points out that the current digital age is not only challenging the way buildings are designed, but also the way they are manufactured and constructed.

Originally, computers in architecture were introduced to replace humans in the design process and replicated human tasks. In the last few years this role has changed to become an intelligent system to help designers and to maximise the decision-making options. This role has evolved to cover almost all aspects of architectural design, from drafting to modelling and even form-based processing (Terzidis 2006, p. 60). Computers have become an intrinsic aspect of architectural teaching and practice to the extent that architects may not be able to design or build without them. For instance, Schumacher (2009a, p. 244) argues that digital design techniques such as scripting and parametric modelling have become prevalent phenomena to the extent that it is not possible to
compete with the contemporary architectural wave without mastering and domesticating them. Similarly, Carpo (2013, p. 8) states that a building in the digital age is not that one is being designed and built using digital technology, in fact it is one that could not be designed or built without it, and thus designers need to know about this new technology and what it can do, enabling them to find unprecedented solutions.

Digital technology has changed architectural practices in a way that no one had expected. It plays vital roles in many aspects of architectural design such as conceptual stage, form-finding, computation, geometrical configuration, genetic algorithms, kinetic and dynamic systems, and topology. Almost all these aspects are characterised by unpredictable and consistent transformation of the architectural geometry that opens up a new world of possibilities. Side by side with other disciplines like automotive manufacturing, aerospace, shipbuilding and computation, architecture has become a multidisciplinary practice. It moves from an autonomous process to a collective workflow (Marble 2012, pp. 7, 8). With these implications and advancements, architects now have the opportunity to experiment and investigate the possible geometries in terms of their material, tectonics, topology, generative system and kinematics. Moreover, computer-aided design and computer-aided manufacturing advancement have impacted the practices of building design and construction by allowing the production of very complex forms that were until recently both difficult and expensive (Kolarevic 2004a, p. 3). They have established a continuous link between design, fabrication and construction that provides incentives to explore more complex, curvilinear and organic forms.

Many contemporary architectural design approaches have abandoned the traditional determinism and have embraced the indeterminacy of new digital computation. Designers can now construct their own generative systems and control their behaviour to select a desirable form that emerges from a range of iterations in this digital operation. As such, there are no clues as to what the future of architecture will be or look like. All we can do is look at the contemporary free-form buildings and how they have succeeded by taking advantage of these technologies. The new digital technology, which is readily available
and affordable, contributes to generating free geometries and at the same time makes architectural processing easier.

This chapter discusses six main aspects of digital design techniques including their relation to architectural design, how they work and why they are important. Section 3.2 discusses the evolution of technological theories, showing how technology evolves and its relation to culture and needs, as well as its relation to the current technological involvement in architecture. Section 3.3 describes how these techniques became a new way of thinking and designing, focusing on the movement towards the new technology, thereby escaping from the old traditional way to produce what was once thought impossible. Section 3.4 discusses the role of digital technology in the increasing complexity of architectural design, exploring how complexity issues are raised as a result of digital technology to address architects’ concerns and interests. The relationship between architecture and mathematics is discussed in Section 3.5, including the increasing trend to exploit the ability of algorithmic logic in architectural design to produce complex forms, and how architects have linked algorithms, computation and design into one logic. Coupled with that is the relationship between architecture and computation. Section 3.6 highlights the scope or domain of the computer’s involvement in architectural design and the strong relations between computation, architecture and algorithms. Section 3.7 examines the debate on using computers as a drawing tool or as a generative system.

3.2 Evolution of technology theory

Tracing the evolutionary history of technology is significant to understand how and why technology is affecting our daily lives. Technology could be an accumulated knowledge developed to meet human needs. Based on that, some theories and definitions of technology have appeared. These theories pertain to the process of innovation and technology, and describe the technological development. This section shows how technology has evolved and its relation to cultures and human needs.
George Basalla (1988, p. 1), in his book *The Evolution of Technology*, proposes three characteristics of technological development: diversity, necessity and technological evolution. Basalla explained diversity as recognition of an enormous number of different kinds of artefacts that have been available for a long time and made by humans to cope with the surrounding environment. Second, necessity is the factor that pushes humans to invent artefacts to serve their needs, or as implied in the suggestion, “necessity is the mother of invention”. Third, technological evolution as an organic analogy concerns the appearance and selection of these novel artefacts, which often refer to larger and/or smaller changes made over a long time. In his theory of technological evolution, Basalla (1988, p. 25) highlights four concepts: diversity, continuity, novelty and selection, showing that:

- diversity is the result of technological evolution because artifactual continuity exists;
- novelty is an integral of the made world; and a selection process operates to choose novel artifacts for replication and addition to the stock of made things.

In this regard, diversity could be represented in greater artefacts in some cultures than others, whereas novelty could be represented in the role of knowledge and culture that promotes searching for novel solutions for technological problems (Basalla 1988, pp. 64-65). Similarly, Brooks (1980, p. 66) argues that different cultures produce or choose different technologies, thus technology does not consist of just artefacts, but also of the public knowledge that emphasises those artefacts and the way to use them in society. Technology and science cannot offer solutions by themselves; but they prepare conditions where cultures can develop solutions (Brooks 1980, p. 78). Brooks (1980, p. 67) also claims that it is possible for technologies to be diffused very quickly and widely as they are reproducible and transferable.

Fitzgerald (2002, p. 20) defines technology as “the application of knowledge and resources to meet human needs”. He states that technology had gone through several epochs: stone age, agriculture age, industrial age, space age and information age. Each of these ages has its special characteristics, but what is relevant is the information age where information can be stored and processed as never before. Carpo (2011, p. 11) also highlights the same point. After the introduction of digital technology, the sequence of
the technological ages began with the age of hand-making then mechanical-making and now digital-making. This digital age equips humankind with tools that allow calculation, communication and control of huge quantities of information. Now this technology will help make decisions based on stored information, which will advance problem-solving and critical thinking skills.

Arthur (2009, p. 23), in his book *The Nature of Technology: What it is and How it Evolves*, builds up his theory from three fundamental principles: “all technologies are combinations, each component of technology is itself in miniature a technology and all technologies harness and exploit some effect or phenomenon”. Arthur cites the *Oxford English Dictionary’s* definition of technology as “the collection of mechanical arts that are available for culture to make its economy and society function”, with the mechanical arts referring to methods, practices and devices a culture uses to make things work (2009, p. 27). At the same time, Arthur (2009, p. 28) puts forward three definitions for technology; the first is that “technology is a means to fulfil a human purpose”, the second is “technology as an assemblage of practices and component”, and the third is “technology as the entire collection of devices and engineering practice available to a culture”. Based on those definitions, technology evolution is connected to human and cultural purposes, and is made from combinations of previous technologies. This led to the relationship between technology and phenomena, so Arthur states that the source of all technologies is always a phenomena, and the spirit of technology is based on exploiting them to fulfil a purpose (2009, p. 56). Furthermore, Arthur claims that technology consists of a series of operations “software” which require physical equipment to render them “hardware”. The “software” embodies the process or method, and the “hardware” represents the physical device. This theory clarifies the strong link between technology evolution and cultures, and how the latter control this evolution based on the demands and purposes of human societies and their respective cultures.

The technological evolution has reached architecture. In the late 1990s, the design process was typical almost everywhere, using conventional methods such as freehand sketching, physical models, drafting boards and manual rendering. Even though technological
evolution occurs normally in every discipline, it comes across as a distinct phenomenon in the design culture. According to Dunn (2012, p. 14), two decades since computer technology was introduced into architecture in 1992, architects need to integrate design process with digital technology to understand architecture design. It allows for more effective controlling and perfecting of our built environment which changes its shape to adapt to our needs (Jakob 2011, p. 142). But technology does not stop here; it put more pressure on designers to improve their computational ability. Picon (2010, p. 9) states that the transformation we are witnessing is the result of a complex and recent adoption by designers of digital tools.

As is the case with many technologies in the past, the current digital architectural revolution is manifested in the exploration and advancement of the latest version of the available technologies. This provides new digital means of imagination and construction that produce complexity and curvilinearity. According to Kolarevic (2004a, p. 5), contemporary architecture, as an expression of a new information age with exchanges between societies, cultures and economics on a global scale, is seen as an inevitable product of the digital “zeitgeist”. This could also imply that every time architectural designing and construction techniques change, architecture itself changes as well. This is the influence of the technological revolution on architecture design and construction. Cook (2004, p. 43) claims that “there is no change without need, and certainly there will be no revolution in the way we build unless an urgent need for it is perceived”.

3.3 A new way of thinking and designing

Digital architecture or architectural computation has been introduced as a new way of thinking, designing or, in other words, as a new method of form-finding. It is a movement towards the new and to escape from the old traditional methods of architectural design (Terzidis 2006, p. 4). In digital architecture, new means a different designing process, structure, material, cost and form. These new techniques are the development and evolution of earlier architects’ wishes and imaginations, with a basis in the desire to compute the architectural design process. Does computation help produce a new and
unique architecture? The answer is manifested in the ability of new technology to go beyond the limitations of the human mind, which cannot perform such a sophisticated process and cannot run for a very long time as technology does. Technology has pushed the human mind’s capacity to produce what was once thought impossible. According to Jakob (2011, p. 142), the digital and technological revolution has expanded the limitation of imagination and possibilities.

Studying other technologies that were introduced in the past and the way people use them will help understand the role of digital design techniques in the design process and form-finding. According to Schroder (2008, p. 146), when photography was first introduced some artists used it as a new platform to do what they have always done, to “create painting” but better. As a result, there is a separation between the use of technology as a tool to optimise traditional designs and as a new way of form-finding. According to Igor Aleksander (in Frazer 1995, p. 19), who discussed the unique capabilities of the human brain,

the human mind is extraordinarily good at making guesses based on experience, at retrieving knowledge from memory without need for exhaustive searches, at perceiving analogies and forming associations between seemingly unrelated items. These aspects of intuition, perception and imagination are the traditional creative engines for architectural ideas. While the model of architectural creativity based on these digital technologies departs in many ways from the traditional model, it still relies on human skills for the essential first step of forming the concept.

This is the new way of thinking. So, testing, evaluation, modelling, prototyping and evolution all use the magical power of the computer, but the first spark comes from human ability (Frazer 1995, p. 19). Using computers in architectural design should be an extension of the human mind in order to make, generate and evaluate. Terzidis (2006, p. 22) claims that “architects have been using computers as a device to generate, discuss, and critique new forms in an attempt to introduce a new way of thinking about design”.

The generation of digital computational forms is contrasted with the traditional way of designing because it uses logical steps and/or calculations, whereas the latter depends on intuition and decisions of the human designer. Today, architects are using a collection of
digital techniques, such as algorithms, scripting and simulation, to generate complex forms that go beyond the traditional digital drafting and modelling (Tang 2014, p. 19). As such, the popularity of these technologies has increased, affecting architects and students of architecture as they can now conceive and construct geometries that were very difficult to achieve using traditional methods (Dunn 2012, p. 6). This is evidence that technology is a driving trigger that has opened up endless opportunities (Barkow & Leibinger 2012, p. 94).

Digital techniques provide more options and iterations to solve any given problem. It is a new way of designing that goes beyond the world of human making which it represents. Carpo (2011, p. 3) believes that since the world of the digital is rapidly embracing the mechanical process, being identical is becoming irrelevant. What Carpo implies here is the visual similarity between what humans can produce. This is because the ability of the human mind – human designs still cannot proceed with their production capacity – is unlike the computer’s ability, which can access this limitation and produce endless iterations to the same given design problem. But, at the same time, it could be identical in terms of replicated parts or tasks, as computers can repeat exactly the same tasks with the same outcomes whereas humans cannot. Handmade parts and/or objects are more expensive and time consuming and at the same time are not completely identical. In contrast with mass production techniques, being physically identical became easier as machines have the ability to produce 100% identical objects, and they can also produce a range of non-identical objects in a fraction of time. Carpo (2011, p. 7) explains the identical issue in his example of the individual copyists before the invention of printers. Copyists could make mistakes and changes at all copying stages, and this was inevitable in all cognitive fields until printing technology became available.

From an architectural perspective the exploitation of digital technologies is the ideal way to explore the new and/or future architecture. Le Corbusier and others claimed that the mechanisation of the 1920s has changed the world, so architects need to develop new forms by using the new tools (Carpo 2011, p. 13). These tools actually provide an important possibility, namely the exploration of very complex shapes and forms, as well
as freeing them from the physical constraints in the modelling process (Schroder 2008, p. 146). By introducing digital technologies to architectural design, the designer can achieve a coherent integration of concept and final design, investigate form-finding and generative approaches, and add intelligence and performative aspects to the outcome (Tang 2014, p. 8). Tang (2014, p. 12) also claims that computer software made the introduction of parametric design, digital fabrication, simulation, scripting, performance-driven design and nonlinear thinking possible. By using this technology in architectural design, architects can merge these new directions to explore and produce unprecedented forms, or simulate and evaluate buildings’ performance.

The interest among architects to borrow or reuse technologies from other industries is not something new. They are always looking beyond their limits and boundaries to integrate new materials, techniques, methods and processes. Mixing architecture and engineering as one is a common approach to architectural design. According to Oxman and Oxman (2014, p. 4), digital technologies have established a rich environment of digital generation and performance simulation as a collaborative paradigm between architects and engineers. Architects and engineers take advantage of each other to improve the quality of what they are designing, hence the design is no longer made by the architect alone. With increasing need for cooperation and integration, architects need to add some engineering skills to their knowledge. Preisinger (2013, p. 113) highlights that with the advancement in digital tools, the combination of architecture and engineering is required and the demand for experts with knowledge in both areas has grown.

Meanwhile, some architects are still questioning construction technologies, while others are involved in constructing architectural technology in an attempt to change the building and design process. When there is a change in the basic thinking framework – from manual to digital – then the shift in architecture is unavoidable and this is the nature of the human mind, just like any changes in cultural expressions (Jencks in Carpo 2013, p. 83). It resembles a mathematical equation, for when variables are changed the result will change as well. The question is: is the use of computers to design curved buildings a fashion or a change in the way contemporary architecture is conceived? It appears to be
a change in the way that architectural design is done. In the 1950s, Frei Otto used a soap film to generate minimal shapes for tension structures, but now computer generation has taken up this role and displaced the soap film (Cook 2004, p. 45). This example is clear evidence that shows how Frei Otto used a new technique to generate different outcomes, and now computers make use of the new technique.

Implementing the use of the digital in contemporary architectural design suggests a strong connection between designers and computers. Digital design relies on the collaborative partnership between the designer and computer to generate ideas and solutions in response to the design’s rules and conditions (Shea in Leach, Turnbull & Williams 2004, p. 89), or to generate new “funky forms” as Testa et al. (2001) has described it. This relation can generate more effective results. According to Piker (2013, p. 137),

> just like a craftsman develops a sophisticated feel for a material through time spent working with it, if we can interact and play with virtual materials in our CAD programs then we can extend our intuition and develop a more sophisticated feel for their constraints and possibilities.

Digital tools also maximise the designer’s limitation and imagination by allowing them to go beyond the normal boundaries. Computers can extend the capacity of our imagination and allow us to communicate as never before (Cook 2004, p. 41). It is a relationship where both designer and computer take advantage of each other. Computers provide an enormous calculation power but with no intelligence, meanwhile humans have a limited calculation power but with an enormous intelligence (Williams 2004, p. 79). In addition, digital tools not only connect the designer with the computer, but also with each other. For example, Burger (2012, p. 139) highlights that digital design techniques are a contemporary quest to integrate workflows between designer and consultant, digital model and fabrication elements, as the design should be approached from two directions: top-down, through form and program, and bottom-up, through component and fabrication.

Computers are tools to link architectural designers with the designed objects, as they allow feedback and offer solutions to their users. Carpo (2011, p. 119) highlights that
there is no need to separate the “thinker” – or in this context the designer – and the “making” – or in this context the fabrication and construction – from the use of digital tools. Architects now have the potential to see and monitor the whole designing process. Their role has also changed, as they are no longer the form-maker but the controller of the design process “formation”.

3.4 Complexity and never before

Recently, complexity issues have been raised which relate to the architects’ concerns and interests. As a result, architecture researchers and practitioners have attempted to digitise traditional design methods and techniques using computer-aided design tools. Terzidis (2006, p. 52) notes that complexity is “a term used to denote the length of a description of a system or the amount of time required to create a system. From network and computers to machines and buildings there is a great deal of effort spent on how to understand, explain, model, or design a system whose scope, scale, and complexity often challenge the ability of designers to fully comprehend them”. Based on that, design complexity studies support the idea of synthetic, artificial and human-made systems. On the other hand, Greg Lynn (2004b, p. 9) defines complexity – or, as he implies, “intricacy” – as a new model of connection that consists of extremely small-scale and extraordinarily diverse elements. It is the fusion of the disparate into continuity or components that sustain their status as pieces in a large composition that is not reducible. For Lynn, complexity is a matter of nature and its complex behaviour. The available technological techniques, such as computer systems, algorithms and advanced computation, can maximise architects’ exploration of the unknown world of complexity.

Before the intervention of computation in architectural design, forms which are difficult to draw and measure used to be difficult or impossible to build which means that most of the architectural outcomes were simple and able to be drawn and built, or, in other words, there was no complexity. Carpo (2011, p. 32) states that you cannot build what is in your mind if you cannot draw it in order to have others make it for you. But when you cannot make what you cannot draw, what then? In this case, the role of computers is emphasised,
as architects need technology to help them draw and make what is in their minds, even if it is extremely complex. Complexity may reach a certain level which can go beyond the human mind’s capacity. Thus, without computers some complex forms could not have been designed or built.

One of the key ideas behind complexity is manifested in the replication, combination and changing of small simple parts that follow simple rules to generate a series of unpredictable iterations and new information from those simple inputs (Burry & Burry 2010, p. 53). Often these ideas are discerned from some process in nature such as self-organisation. They also motivate architects to investigate the natural phenomenon to find answers to complex forms and behaviours. Frazer (1995, pp. 19, 20, 102) claims that in nature the developmental processes led inevitably to complexity, for in these processes every simple local rule can generate emergent attributes and behaviour in a way that is apparently not predicted by the rules. Similarly, Allen (1997, p. 72) argues that sometimes complexity could be the result of unexpected effects or irregular behaviour that are the outcome of a combination of elements or parts that are repetitive or regular. This complexity could be the result of mimicking the natural behaviour of flocks, swarms, crowds and schools. It is the outcome of a collective interaction of many parts or elements that follow the same rules that have been set by the designer.

Curved surfaces and nonlinear shapes represent the complexity aspects of computer design. Because of the intervention of computers in the architectural design process, architects can now think, design and make what they could not do before. According to Carpo (2013, p. 9), with the use of CAD boxes, “blobs” can be produced, but blobs are not like boxes, and they cannot be produced without digital technology. Carpo also claims that the presence of digital technology shows the link between digital design and curved surfaces, or, as he implies, “we make blobs because we can” (2013, p. 9). Likewise, Jencks (1997, pp. 80, 81) claims that the complexity of nonlinear architecture is manifested in the intention to show unpredictability or indeterminism, where the cause and effect relationship between the system’s variables is not stable. Jencks also claims that computers are vital for making complex buildings as their complex construction and
geometries could not be fulfilled without the aid of digital tools. In other words, digital design techniques can improve the structural techniques and materials in very advanced ways because they help to explore and exploit a new range of structural techniques or a new range of building materials that have never been used before due to their unpredictable nature, which often resembles complexity.

The processes of generating complex patterns of behaviour in nature is one of the goals that the complexity theory strives for, but in reality complexity itself is not so complex to be achieved, for it is simply achievable through clear and easy principles (Leach in Leach, Turnbull & Williams 2004, p. 70). For example, a flock of birds usually flies in a uniform movement, and each bird commits to the overall pattern of the group by following the bird in front and keeping enough distance from the others. From an architectural point of view, these flocks are complex in their overall outlook, but in reality they are created from very simple rules of a collective, natural and uncontrolled behaviour. This supports the idea of the complexity and uniqueness of digitally-produced designs. They are made of multiple components, each component being completely different from the others, and at the same time each component follows the same rules.

Using technology in architectural design offers a rich platform of new possibilities. Kolarevic (2004a, p. 7) is certain that using digital technology opens up new possibilities to generate and construct complex forms in novel ways, meaning that design processes are now more direct and complex, and because of the flexibility of the information that can be extracted, exchanged and utilised quickly, the design information is the information of construction. This strengthens the connection between complexity and computation in architecture. With the aid of computers, designers have the ability to handle greater complexity that could not be handled in the conventional way “by hand” (Schroder 2008, p. 154). Computation and complexity are now extended to influence even architecture practices and the profession. Bernard Cache (cited in (Dollens 2005, p. 74) states that new architectural forms cannot emerge out of effects achieved by more fluid, complex, pliant and heterogeneous shapes or architectural forms, but with the evolution of more complex, pliant and heterogeneous forms of architectural practices. In fact, it
implies changing to a new digital way of architectural thinking and designing. For instance, in his practice Karl Chu, as one of the digital design techniques pioneers, used computational generative systems as “an architecture that can produce itself through its genetic code of zero and ones”, and show both aesthetics and intelligence (Dollens 2005, p. 90).

3.5 Architecture and mathematics

In recent years there has been an increasing trend to exploit the ability of algorithmic logic in architectural design to produce complex forms using relatively easy and simple formulas. Architects have been able to link algorithms, computation and design in one logic to derive “algorithmic design”. The term “algorithmic design” brings together computational complexity and the creative way of using computers to allow architects to move towards programming architecture (Terzidis 2006, p. xii). This is not just a stand-alone algorithmic logic, it also relies on rules. According to Sakamoto and Ferré (2008, p. 3), algorithmic design is “a method of generation, producing complex forms and structures based on simple component rules”. Equally important is its connection to other cultural and design aspects. Terzidis (2006, p. xiii) admits that algorithms are not mere computer applications or computer languages, they are a theoretical model with deep connections to other issues like culture, design and art. Digital algorithms are mathematical models that tie together all contemporary architectural intentions.

The *Oxford English Dictionary* (1989) defines algorithm as “a process, or set of rules, usually one expressed in algebraic notion, now used especially in computing, machine translation and linguistics”. However, Terzidis (2006, p. 15) notes:

algorithm is a linguistic expression of the problem and as such it is composed of linguistic elements and operations arranged into spelling, and grammatically and syntactically correct statements. It can be seen as a mediator between the human mind and the computer’s processing power.

Usually, architects use algorithms as a mathematical way to solve an architectural problem. But after computers were introduced algorithms became a computational
platform for problem solving. An algorithm is actually a set of information and instructions given by users and performed by either humans or computers, and is based on the way that the problem is addressed and understood. Whether the instructions were performed by humans or computers, the difference is in the way of doing the process. Where it is performed by humans, it will be direct, precise, definite and logical (even though it could be problematic for some architects), but where it is performed by computers, it is a linguistic expression – code or script – written by humans to be run by computers to produce the same quality as the human outcome but in a shorter time and with huge iterations.

Peters (2013, p. 10) also defines algorithm as a “particular set of instructions, and for these instructions to be understood by the computer they must be written in a language the computer can understand, a code”. Algorithms can provide inspiration and go beyond the designer’s capability through the generation of unexpected results. When architects code an algorithm to help solve a design problem, they can explore more options by modifying the program or sketching it by algorithms. It is crucial to know that using algorithms is conditioned upon fully understanding the rules from the very beginning to the end. Williams (2004, p. 79) argues that an algorithm is only complete when every rule it contains is fully described.

The relationship between architectural design and mathematics is contradictory; that is, architecture needs mathematics in the design process to achieve its targeted geometries, but in contrast mathematics can run its rules and processes without any clear targets, so the targets are the contradictory points. According to Burry and Burry (2010, p. 6), architecture is a game with clear objectives but with no guiding set of rules; in contrast mathematics is a game with lots of rules but no clear objectives. Based on that, it can be said that mathematics is fundamental to architecture, or, as Burry and Burry imply, “mathematics being integral to architecture is like saying numbers are helpful when trying to count”. It is important for architects to fully grasp the relationship between algorithms, computation and design in the architectural digital world. Peters (2013, p. 12) states that:
when architects have a sufficient understanding of algorithmic concepts, when we no longer need to discuss the digital as something different, then computation can become a true method of design for architecture.

Algorithm is the current exploration vehicle of new architectural possibilities and an extension of human capability. According to Terzidis (2006, pp. 27, 38, 40, 65), in architectural design, algorithms are used to investigate and solve problems with increasing visual and organisational complexity. He also believes that algorithms are about the expansion, exploration and codification of the human mind, not about interpretation or perception. When sketching algorithms, architects deal with language and meanings using digital computers that link designers to computers and provide more possibilities. In Terzidis’ book Algorithmic Architecture (2006, p. 37), the term “algotecture” denotes the use of algorithms in design processes. Terzidis states that some complex problems require a synergetic link between the human mind and computer system, and this relation is only possible through the use of algorithms.

Algorithms could not be assigned to address one particular design problem; in other words, they could be used to solve other problems they were never designed to address. For example, if an algorithm is being designed to help find the ultimate curvature of a building cladding, the same algorithm can be developed to address completely different problems. Terzidis (2006, p. 23) indicates that the same algorithms can be used with different parameters from the original one to offer a completely unexpected behaviour. That does not mean the designer is not in control of the process, as designers can keep changing and tweaking the algorithmic variables until they are satisfied.

Algorithms are one of the key aspects in architectural design, and adding algorithms to the power of computer technology will break the boundaries set by human limitations. They are systems of processes which allow one to leap and explore the unknown world. Algorithm outcomes are completely different from the traditional problem-solving method as behaviour is often non-predictable and outcomes amaze even their own creators (Terzidis 2006, p. 57).
Recently, the relationship between algorithms and computers has become very intimate, but that does not mean it is fully computerised, as the human aspect still plays a vital role in the process. Some scholars such as Terzidis, Carpo and Burry and Burry agree that the relationship between algorithms and computers is not necessarily associated with computer science. Most of the algorithmic preparatory steps are pre-determined by the designer according to the design problem the designer is dealing with. Then the designer interprets these steps to allow the computer to understand them and calculate them in an algorithmic format. But overall, the designer has the responsibility of creating and understanding these algorithms before handing them over to the computer system to run them.

Computers are not fully automated machines which have the ability to run, process and produce without human intervention. Some architects think that they are great users or fans of digital design, but what they are doing is manual transaction “computerisation”; they engage in a so-called “mouse manipulation” which allows them to move, drag, bend and stretch what they see on their screens. Digital design is a process not a tool or a product; it is about using algorithms to make patterns to be run by computers. It is being able to explore the imaginary and unpredictable concepts which are impossible to be explored by the human mind to develop a new design strategy in the digital world.

Given that computers can calculate an algorithmic function and visualise it in an infinite number of curves that share the same algorithm, Carpo (2011, p. 90) argues that architectural smoothness is identified as a visual category and mathematical – calculus – function, so computers can manipulate its mathematical continuity to be involved in the process of conception and production of an architectural element. Carpo (2011, p. 91) also claims that without computers, the cultural need for form-making and mathematical continuity in architecture will dissolve.

One way of using algorithms in architectural design is imitating some natural behaviour such as genetics in an attempt to explore the unknown. Dunn (2012, p. 62) declares that
algorithms can be used to explore unknown possible solutions by simulating natural behaviours like genetics to investigate its evolutionary properties over time.

Genetic algorithms are an example of computational methods. Computation in architecture provides a design environment that is able to develop algorithmic procedures to mimic biological evolution and to accelerate the architectural design revolution (Weinstock 2014, p. 114). Frazer (1995, p. 58), for example, explains that genetic algorithms were developed for problem-solving and optimisation, but their ability to produce non-imagined solutions makes them popular. They are characterised by a string-like structure, very similar to the chromosomes of nature. Since optimum solutions are achieved, a selection from the population occurs according to the fitness criteria – survival of the fittest.

3.6 Architecture and computation

The question of what should be the exact domain of the computer’s involvement in architectural design has been worrying architects since the beginning of computer-aided design. Terzidis (2006, pp. vii,viii) points out that usually the computer’s involvement in architectural design takes two trends. First, some designers consider computers as an advanced drawing tool operating a set of programs that allow them to control their perception and produce complex forms. Second, other designers decided to enter the world of scripting and programming to take advantage of what computers can do in architectural design. Terzidis (2006) also states that architects should consider computers as partners or as another human mind, rather than an extension or mirror of the mind. Indeed, computers are not the human mind or designer, they are a complementary tool to humans that helps them to investigate their imagination and ideas, and even to think outside the box.

Architecture has moved from hand drawings to computerisation and, more recently, to computation. The terms “computation” and “computerisation” carry completely contrary meanings. According to Terzidis (2006, p. xi), computation is different from
computerisation, and is often in conflict. Computation means calculating, or using a mathematical or logical method to determine something, whereas computerisation is manifested in conversion, digitisation, mechanisation and automation of the well-defined, predetermined and preconceived processes or entities. While computerisation is a pre-defined process, computation explores vagueness, uncleanness and indetermination. It is about logic, algorithm, exploration and estimation; it extends human intelligence which involves cognition, simulation, problem solving and mental structure (Peters 2013; Terzidis 2006, pp. 10, xi). Typically, computerisation is the most prevalent method in contemporary architecture as it depends on converting what is already determined to be stored in the computer system, and is “the easy way”. In contrast, computation is less popular as it requires extra knowledge in programming and scripting fields, and is “the hard way”. As a privilege, the latter can exceed the limitations of the usual computer-aided design software. Usually most computer-aided design applications provide the technical ability to convert design ideas to digital tools, but others can be used for designing. The problem with computerisation is that the user cannot benefit from the computation power. Instead, the user can just manipulate or control the 3D computer model by using the computer mouse.

In architecture, computers could be exploited to push the limitation and boundaries of the human mind to overcome the current challenges and use the available resources. Thus, Terzidis (2006, p. 16) describes computers as “tireless vehicles” which help architects to overcome, realise and go beyond the mental and physical limitations. Compared to the conventional tool set, architectural computation has a notion of the exceptional and unprecedented. Indeed, architectural design is heavily affected by its tool set. Traditionally, designers choose what tool to use according to the tools that are available. As a result, the outcome will be something predictable and doable, and usual. Unlike the traditional way, the digital way depends on the available techniques or sometimes requires developing new techniques, and the resultant outcome is most likely something unexpected, hence the need to study the appropriate way to construct it. Terzidis (2006, p. 55) stresses that “concepts such as randomness, infinity, limit, infinitesimal, or even more elaborate concepts such as complexity, emergence, or recession are incomprehensible by the human mind not because they are metaphysical, magical or
mysterious but rather because they depend on intellectual means that are external and foreign to the human mind”.

Some architects think that computers are designing tools and have the ability to do everything in the design process, but in reality computers are just an electrical box. Mostly, design is a mental process that cannot be undertaken without mental thinking. According to Terzidis (2006, p. 21), architects believe that the design processes take place in the human mind, and computers are just a production and presentation tool. The history of human thinking shows successful achievements, but the question is: why do architects have an innate desire to use computers? Terzidis (2006, p. 29) suggests that computation is attractive as it is incomparable, different, foreign and alien, but not because it is restrictive, divisive and exclusive. Although most architectural design tasks like calculations and drawings can be done manually, they also require the use of computers to facilitate these tasks.

Even though computers are devices built and designed by humans, the information and processes in their systems could not be a new human invention (Terzidis 2006, p. 24). In other words, these may be human-invented computers, but the processes run by computers already exist, they are not something new. According to Terzidis, human existence is not necessary for the occurrence of the calculation process by computers. At the same time, these devices have the ability to calculate and perform more complex or complicated tasks than the human brain. Architects categorise computer use into tool makers and tool users. Tool makers refer to computation aspects that provide design exploration tools by using computers and they are usually software developers, computer scientists and mathematicians. In contrast, tool users seek to connect their designing ideas with the digital phenomena (Terzidis 2006, p. 56).

Overall, there is a strong correlation between computation, architecture and algorithms. Terzidis (2006, p. 22) states that computation is connected strongly to algorithms, as programmers write the process to exploit the algorithmic capability of the computer to achieve a particular result. Architectural programmers could be architects who want to
describe the design process using algorithms that use the computer’s capacity to produce a desirable outcome. Further, these relationships require a cooperative of other disciplines such as engineers, mathematicians, material specialists, and computer scientists. Computers and algorithm use in architecture are closely linked, thus architects need to understand the way they work individually and collectively. Understanding algorithms is not enough; architects need to grasp computation as an operator who can run algorithms faster and with more accuracy. According to Dunn (2012, p. 60), algorithms and their use in architecture may generate and develop design ideas, but architects need to understand that this requires a shift in the way they use computers. Indeed, they need some knowledge in computer programming to further exploit the capabilities of computers and algorithms. Algorithms in architecture use coding and/or scripting languages to access the computational power of computers. Dunn (2012, p. 62) suggests that “algorithmic architecture uses the processing power of the computers to directly address a design problem by searching strategically through possible solutions”.

Computer-aided design applications offer a collection of algorithmic commands which deal with a specific graphical design issue. The user of these applications may not understand the algorithmic logic running behind them or does not have enough knowledge of how they work, and therefore the user is not able to grasp the application’s ultimate power. When computers were used for the first time in architectural design, everything was different, there was no existing software that met all the demands of a certain project.

Frazer (1995, p. 23) explains how his practice was experiencing some difficulties throughout his projects:

It has been necessary to design and develop our own tools: our own computer software, our own computer languages and, in some cases, our own prototype computer hardware. When we started there was a shortage of software, computer power, and even books on computer graphic techniques.

In about a decade, this situation started to change. Lynn (2004b, p. 16) highlights that computer-aided design software allows for the exploration of calculus-based forms for
the first time in architecture. But not all computer-aided design programs allow for this flexibility. According to Terzidis (2006, p. 41), despite the huge range of commands that computer-aided design applications offered to facilitate the architectural design process, only a few applications allow for the combination of these commands algorithmically, breaking them down to explore “out of the box” possibilities.

The strength of mathematics and the speed of digital computation have provided architecture with a new power of complexity. Both provide a considerable contribution to the contemporary architectural design. The power of algorithms lies in a combination of the human mind and computers. It is not simply another tool, it is a way of thinking that allows humans to expand their cognitive limitations (Terzidis 2006, p. 38). They are together able to generate complex geometries out of the algorithmic calculations. Marcus (2012, p. 46) argues that the current output of digital architecture needs to be categorised under two domains: first, generating complex geometries using algorithmic rules, and second, using computational and numerical processing to generate responding architecture to address specific performance criteria.

Algorithms, computers, manufacturing machines and software are the components of the new digital architecture trend. They can produce identical and nonidentical elements, and may be generated randomly by the computer or by a designer. Carpo (2011, p. 99) expresses that digital technology is unlike a mechanical imprint; the algorithmic imprint allows forms to change and morph. Although the use of computation is the pervasive new trend of this era, architecture will still deal with gravity and have four walls, but it will be different. Eisenman (1992, p. 16) notes that computation “values appearance over existence and what can be seen over what is”, imposes ambiguity in how and what architects see, and allows architects to simulate reality.

The new digital techniques in the design process pose considerable difficulties for architects as they challenge the traditional way of design and construction that architects are used to – hence, they need training to be able to use digital techniques. Today most architectural products from the simplest to the most sophisticated ones are dependent on
digital technology. Kolarevic (2004a, pp. 6, 8) states that when applying digital technology to architecture it is important to know what is the tectonic form and ideology of the form, at the same time considering the significance of the information and who controls it. These requirements are challenging the traditional ways of designing and construction. Normally architects are familiar working with Euclidean geometry, but the emergence of new curved surfaces poses major difficulties.

The use of computer technology and algorithms in architectural design is recent, and is still in a developing and experimental mode. Kolarevic (2004a, p. 6) expresses that curves were ignored by architects until a few years ago and the reason behind it is ignorance of the technological three-dimensional digital modelling software which made curves easy and smooth. It appears that this interest in digital curvilinear geometry emerges from the ‘need to fulfil desire’ – where some surfaces and forms were impossible or very difficult to be drawn and constructed, then computer software made them doable. Architects need to borrow technologies from other disciplines (Lynn 2000, p. 125) to allow them to construct their targeted geometry or design using computers. Kolarevic (2004a, p. 8) declares that shipbuilding is an example to teach architects how to integrate other disciplines such as engineers, fabricators and contractors, with the help of digital technologies to develop design, analysis, fabrication and assembly processes. For example, some important projects would not be possible without the help of the shipbuilding industry like the roof of the Basilica at the Piazza di Signori in Vicenza and Frank Gehry’s Guggenheim Museum in Bilbao (Kolarevic 2004a, p. 8). Despite the significant difference between the design and construction of buildings and the design and construction of airplanes and ships, there are some important similarities with lessons for architecture (Franken 2004, p. 123).

In the early 1990s, most architects knew how to use computers to join dots with lines, but with the development of computer-aided design applications the process became faster and the price of this technology dropped to become available to almost anyone. Berkel (2013, p. 86) states that:
it is clear now that computation is ubiquitous, and form-making and form-controlling are no longer its most expedient uses, whether it is through proprietary and customised software or single piece of code, computation’s primary potential lies in its flexibility to communicate design across multiple disciplines via associative data.

3.7 Drawing tool or generative system

Throughout history, architects’ work has been linked to drawing as representational and designing tools, but today’s computerisation and computation still do the same job but in a more advanced manner. Unlike the past, computers have increased their formation and fabrication capacity to let architects imagine, model and generate more accurate and sophisticated architecture, as well as producing an enormous number of iterations that are often unexpected. Peters (2013, p. 15) argues that as pen and pencil are used to draw conceptual sketches and building details, computation tools can be used to provide better communication, increased efficiency and conceptual sketching of algorithmic concepts. Architecture is now experiencing a shift from drawing to generative algorithms where controlling formation parameters is attainable to achieve complexity (Peters 2013, p. 15).

In architecture, the term ‘tool’ refers to the cooperation between designers and computers, but digital technology may be viewed as a drawing tool or as a generative system. Some scholars look at it as just a drawing tool, some as a generative system, some as a collaborative partner, and others see it as both drawing and generative at the same time.

Ramona Albert, in a conversation with Terzidis (2006, p. 149), argues that computers are just tools that fulfil the designers’ needs because they do not have a mind of their own. Albert states that computers’ ability to perform very complicated tasks do not emphasise their intellectual characteristics, but rather their mechanical ability. Albert says that we even use algorithms because we need to be in control, “imagine if computers have their own mind and control, we will be living in a nightmare”. Junfeng Ding (Terzidis 2006, p. 149) believes that humans are more random than computers and agrees with Albert’s view by adding that,
it does not matter which tools the designers choose: pen, watercolour, or computer, the accidence and randomness somehow will happen and can be part of the creativity in the design process.

On the other hand, Christopher Shusta (Terzidis 2006, p. 150) emphasises the role of computers in decision-making drawing. He states that computer-aided design tools are modes of representation, but scripting’s logic, constraints and cause-effect relationships are modes of generation, and the difference is between converting the ideas into drawings – top-down – and converting them into forms – bottom-up. He argues that “computers are not the equivalent of pencil”, as a pencil never acts to generate forms, it only represents the designers’ ideas while computers can help in the decision-making. Unlike other scholars, Leach, Turnbull and Williams (2004, p. 8) argue that, by using these technological approaches, the designer is using computers as a collaborative partner within the design process, not merely as a representational tool. To the contrary, Marble (2012, p. 9) claims that the use of computers in architectural design is varied, for they could be used as representational and visualisation tools, and they could also be used as generative systems that receive coded algorithms to produce architectural outputs, hence can be used to increase the designer’s imagination capability. Frazer (1995, p. 10), like Marble, argues that computers are tools which could be used not only as an aid to design in the usual sense, but as an evolutionary accelerator and generative force.

The design process has changed from drawing surfaces to setting up rules through programming. The traditional computer-aided design software creates lines, circles and many other geometric objects in order to make drawings accurate, but the new generative and parametric design systems use a collection of constrained rules and relationships between objects (Vanucci 2008, p. 118). It is an exploratory shift towards programming in architecture in order to get the most benefit from computation. Terzidis (2006, p. 153) stresses that programming is a way of understanding and exploring the unknown and the pathway to map our way of thinking. It is a method where we can experiment using rules and principles, for it questions the way people think and the way the mental process develops through the use of computers, which is the only way to benefit from the full capacity of computers, and is also the vehicle for obtaining knowledge and seeing hidden things. Scheurer (2014, p. 289) argues that designing work does not just vanish, it shifts
to a higher abstraction level, from drawing to programming. For example, instead of changing a whole set of drawing using the computer mouse by clicking and dragging, it is easier to use algorithms by changing some of their variables. Scheurer (2014, p. 289) highlights that this translation is not free, for it needs some brain effort and actions to find a clever algorithm.

The generative processes in architecture could be discerned from the natural evolutionary biological concept of growth. The generative process follows the rules that govern the genesis of living organisms through exchanging the information that controls the natural morphogenesis (Kolarevic 2004a, p. 23). According to Frazer (1995), “architectural concepts are expressed as a set of generative rules, and their evolution and development can be digitally encoded”. Frazer used Chu’s approach as an example. In Karl Chu’s digital approach, architecture is a system based on the generative logic of the L-System – L-system – and its use in digital modelling software to simulate plant growth. It is derived from a recursive and rule-based branching system where the use of simple rewriting rules could construct complex objects. A simple set of defined rules can produce very complex forms in a recursive process that consists of a few levels. This is one way of using computers as a generative system, but there are also other ways. For example, Kolarevic (2004a, p. 19) claims that Greg Lynn was one of the first architects to use animation software as a medium of generation. According to Lynn (1997, p. 1), “motion implies movement and action, animation implies evolution of a form and its shaping forces”.

Krauel, Noden and George (2010, p. 11) claim that with the development of digital architecture most architects used computers as a tool to draw which does not impact the form or construction – optimising the drawing process. This is the traditional way of architectural design where architects draw what they can build and build what they can draw. But this was the case until the introduction of computation in architecture. After the advent of computers as a drawing tool, they have been used as a testing and analysing medium, but with continuous development, computers are used now as generative systems as well. Leach (2004, p. 75) confirms that architects and engineers have used
computer programs to test their design structure’s stability for some time, but now programs have been developed to generate novel structural forms using sophisticated genetic algorithms. Equally important is the generative process itself and its rules. According to Shea (2004, pp. 89, 90), a generative design is based on two factors: natural analogy and logical basis. He explains that natural analogy influences computer representation and the generative process, while the logical basis studies the logic and system of a given element to create the generation rules.

### 3.8 Conclusion

This chapter discussed how technologies had evolved and their importance to architectural design, highlighting five aspects:

- the evolution of technological theories
- using digital techniques as a new way of thinking and designing
- increasing complexity and novelty in architectural design
- the relationship between architecture, mathematics and computation
- the difference between using computers as drawing instruments and as generative systems.

It is important to highlight the mutual relationship between culture and technology. Culture plays a significant role in increasing or decreasing technological evolution. At the same time, technology cannot be diffused quickly if it is not reproducible and transferable. Technology is about using knowledge and resources to meet human needs. In the early 1990s, technology became a fundamental tool in architectural design to the extent that architects were unable to make progress without it. This supports the idea that changing the architectural production technology will also change the design processes and architecture in general.

With digital design techniques, architects need to (re)think and design differently, including all stages of the design: process, structure, materials, cost and forms.
Technology in architecture expands human imagination, limitations and possibilities. Technology has been used to generate, discuss and critique new architecture in an attempt to introduce a new way of thinking and designing. Architects are now able to understand and produce geometries that were previously very difficult to achieve using traditional methods, at least in terms of form diversity and quantity. This will also allow architects to explore far more complex shapes, in addition to breaking the barriers of physical constraints.

Before the computational intervention in architecture, complex forms were difficult to draw, measure or construct. Without computation, some complex forms could not be designed or even built. The use of technologies in architectural design will promote complexity, novelty and better opportunities, more than ever. Through clear and easy computational intervention, complexity itself is not complex to achieve.

The relation between architecture and mathematics, and between architecture and computation, is worth examining to prove their intimate connection. As a result of these relationships, architects are now able to link mathematics, computation and design as ‘one logic’ aimed at a single algorithmic design and/or programming architecture. They are both used to examine and solve problems with increasing complexity. But despite the intimate relation between architecture, algorithms and computation, the human aspect still plays a vital role in such a relationship. Often the algorithmic properties and computational programming are pre-determined by the designer in conjunction with a given design problem which will render computers designing partners rather than an extension or mirror of the designer’s mind. It will also strengthen computers as a generative system rather than just a drawing tool.

Architects need to understand that digital design techniques allow new ways of thinking and designing, maximise complexity and novelty, and enhance the intimate relationship between architectural design, mathematics and computation. Finally, digital design techniques also enable architects to use computers as generative systems rather than mere drawing tools.
Chapter 4: Digital theories and approaches in architecture

4.1 Introduction

This chapter explores progress made since 1990 in architecture theories, and how computers influence the way architects think, leading to the introduction of new theories and approaches. Computers offer new possibilities to create and manipulate complex geometries. Geometries such as folding in architecture and the blobs, performative architecture, parametricism, morphogenesis, nonlinear organisation, digital tectonics, topology in architecture and digital poetics all convey that architecture is entering a new era. This is an era where the material, function, form, structure, construction and performance are integrated to move beyond the traditional way of designing. Perhaps these architectural theories would flourish and develop by the use of computational programming and algorithms to get the most out of the computer’s capacity rather than merely using the commercial software packages. This chapter offers an understanding of computational design through its theoretical vocabulary and relevant histories.

Since 1990, the tendency in the world of digital architecture theories is to develop a unified theory to explain the holistic view of current and future architecture (Spiller 2008, p. 11) through the inclusion of elements from old and recent digital theories such as folding in architecture and the blobs, performative architecture, parametricism, morphogenesis, nonlinear organisation, digital tectonics, topology in architecture and digital poetics. Some of these theories were derived from the principles of science, nature, culture and information. For example, Frazer (1995, pp. 20, 21) argues that the new unified theory should firstly adopt everything under the evolutionary umbrella: evolution of chemical elements, physical contents, information and culture, all made to explain phenomena; and secondly, to benefit from the other developments in science like self-organisation, complexity, chaos and catastrophe to develop a new meta-theory. Theories are commonly understood as tools to understand, make and explain a given subject – the subject here is digital design techniques in architecture.
According to Oxman (2006, p. 233), in the 1990s there was increasing importance given to the growing role of digital design and it became a vital issue, which has been reflected in the theoretical discourse with two streams of influence. The first stream distinguishes digital design as a methodology to produce unique forms of design with significant results. The second stream defines the unique content of digital design. Oxman (2006) claims that most architectural activities in the 1990s were aimed at formulating the theoretical discourse of digital design to identify and characterise the relations between theories and the age of the first digital design. Two years later, Lynn (2008a, p. 280) states that in the late 1990s, the adoption of digital design tools was interwoven with architectural theories, which made an enormous transformation in the architectural fields with seduction of what is so-called “happy accidents”. Happy accidents could refer to getting the outcome – architectural geometry or form – from a computational behaviour, where the architect cannot control the form, but the process or behaviour that led to the form.

The natural or scientific theories of self-organisation, emergence and nonlinearity assume that nature sometimes behaves in unpredictable ways that even modern science cannot account for or anticipate. This could be called the accidental or chance notion of nature. The phenomenon fascinates architects and has become an inspirational motive to change the way architects design. With the introduction of computation in architecture, these behaviours became possible and can be mimicked and applied to produce new families of forms, shapes and geometries.

Architectural digital theories do not arise in a vacuum, but in conjunction with recent practical work coupled with a desire to change the prevailing trend. The question here is from where do digital theories arise, and how. Introducing digital tools to the theoretical narratives of architectural design is the reason behind the rise in digital theories. According to Oxman and Oxman (2014, pp. 12, 13), imposing the digital in theoretical circles occurred in stages. The first stage occurred in the first decade after folding in 1993, and was characterised by a rational interrelationship with mathematics and philosophy. The second stage was post-folding, which was an attempt to theorise concepts relating to
emerging technological possibilities and their influence on the design processes. The third stage moved to the scientific, computational and technological discourse, and this included parametric design, digital tectonics and material design. Finally, folding was replaced by other secondary theories such as performative architecture, new technology of materialisation and fabrication, and computational models of natural design.

The recent theoretical debate is developed around these digital phenomena to understand, clarify and address its nature. To explain this phenomenon, some aspects are evoked such as materiality, tectonics, structure and behaviour. For example, Allen (1997, p. 62) declares that the traditional understanding of space was linked to the fixed and frozen geometries, but now technology and culture can better conceive the complexity of spatial systems like self-organisation, fluid and drifting as they exist in nature such as swarms, herds and flocks; or as crowds and mobs as known in social science. Thus, the behaviours that architects use in their designs could be borrowed from nature, culture and site variables such as traffic flow and land topography and mimicked by using computers.

According to Oxman and Oxman (2014, pp. 58, 59), six models of digital design theory and computational methods have emerged as form generation methods. First, mathematical form generation exploits mathematical formula as the basis of generative procedure. Second, tectonic form generation employs tectonic patterns as the basis of form generation, and is closely related to mathematical generation. Third, material form generation is based on three-dimensional models of material structures and types of tectonic generation. Fourth, natural or neo-biological form generation exploits the natural phenomenon, process, procedure or biological principles as the basis of form generation in architecture. Fifth, fabrication design logic and techniques are used to develop a procedural model of design. Sixth, the physical data as input to design processes is used to balance performance with other desired objectives.
In the late 1980s and early 1990s, architecture theories were preoccupied with deconstructivism and its attributes and principles, until Deleuze published his book *The Fold: Leibniz and the Baroque* in 1988, while in 1991 Eisenman elaborated an architectural version of *The Fold* in his publication about his project Rebstock. In *The Fold*, Deleuze suggests a unified figure that joins different planes and segments to merge in continuous volumes and lines (Carpo 2011, p. 86). Then Eisenman interpreted Deleuze’s fold as an emphasis on the concept that forms are able to move, change and morph, and of the emergence of a new object category defined by the way they change and by the laws which control their continuous variations, but not by the way they are (Carpo 2011, p. 87). Later in 1993, a special issue of *Architectural Design* entitled *Folding in Architecture* was edited by Greg Lynn. Lynn argues that folding might be streamed from a pliant and smooth mixture, as they are able to achieve complexity through flexibility, which in reality are forms of bending, twisting and folding (2004a, pp. 24, 28). Then Lynn changed the term folding to “the blobs” when the process of folding developed towards a fully digital curvilinear and smooth architecture (Carpo 2013, p. 28). Since the early 1990s the dominant style was characterised by continuous lines and smooth curving surfaces (Rahim, Jamelle & Gage 2007, p. 209). The folding theory imposes a cultural demand for digital design to the extent that once computers became available, architects have adopted and/or embraced them immediately.

In 1993, Lynn, in *Folding in Architecture*, argued for continuity of symbolic, socio-political, environmental, technical, formal, programmatic and visual; yet, at the same time, folding is different from topology, morphology and morphogenesis (Carpo 2011, p. 89). That means folding will continue to consider all aspects which used to be employed in architectural design, even though it differs from any of the previous and future theories. It will also take into account the role of cultural and environmental requirements in the formation processes, as well as the use of mathematics. Lynn (1993, p. 39) states that forms of folding, bending and twisting are a result of dense curvilinear logic that sought to embed contextual forces and culture within forms to produce flexible forms deformed by their environment. Lynn then included the calculus path, working in folding that
pointed to several directions such as searching into continuity, subdivision and generalised mathematics of curvature (Lynn 2004b, p. 11). These aspects are attainable through the use of computers that allow far more flexibility and addition. Menassa and Kulby (2012, p. 70) argue that Lynn investigates new ways and techniques to manipulate geometries using animation software in order to be able to combine time with architecture. They also claim that Lynn is interested in smooth continued surfaces – “blobs” – for he is one of the pioneers who promoted the transition from rigid triangular form to what may be called “digital architecture” today. Folding in architecture is the cutting-edge theory from 1993 that spearheaded the move towards computation in architecture. On the one hand, folding in architecture is an attempt to provide theoretical and operative alternatives to one of the future theories in practice. On the other hand, folding is also an attempt to set a theory of digital design as an important part of architectural design theories (Migayrou 2014, p. 12).

Folding in architecture is the shift theory that moves from corners to curvature and from product to process. According to Carpo (2004, p. 14), folding in architecture is published as a profile in *Architectural Design*, to be the “end of the millennium” architectural theory, which allowed the 1990s to start angular and finish curvilinear. This influenced the designers at the time and forced them to decide whether to go angular or curvilinear. For example, Rem Koolhaas decided to continue in angular mode, whereas Frank Gehry preferred the curvilinear approach and he designed his most famous building, the Bilbao museum (Carpo 2004, p. 14). In addition, folding is a process to create forms using generative tactics. Eisenman (1993, p. 28) mentions that folding is a process rather than a product; it is about building forms, “a strategy for dislocating vision”. This was the vision until Carpo (2011, p. 87) argued that the folding process is purely generative, a process not a product, and may not necessarily produce true folds.

Folding came about as a zeitgeist theory in 1993 that relied on computer technology, at a time when computers became a critical part of architectural design. Carpo (2004, p. 16) suggests that the story of folding started when folding turned digital. In this way, technology is used to go beyond its limitation to produce something different and unique.
The new technological algorithms can surpass the architectural deconstructivism, characterised by favouring the new logical dialectics of vectors and flows (Allen 1997, p. 62). As a result, the way that geometry is used in the design process has changed. Topological modelling tools, the animation tools and basic forms like cubes, cylinders and spheres are not used as a starting point as in the past, and forms are now fluid “thanks to the computers” (Lynn 2008b, p. 144). Forms became more flexible, so that they could be deformed, blended, morphed, transformed and animated, which is very different from the way they were used prior to computers. The reason behind developing the fold in this way is the commercial development necessity (Lynn 2004a, p. 29).

When digital tools become affordable and available, architects quickly adopt and test them to get the best out of them. In the 1990s, architects were obsessed with the fold, but with the development in computation the fold evolved to be fully digital and became the blobs (Carpo 2011, p. 92). With this digital engagement other designing tactics appeared to influence architectural forms. Blobs use the power of computer animation to propose the force of evolution, growth, animalism, virtuality, animism, vitality and actuation. Blobs also depend on two models: the first involves procession, and the second involves superimposition (Lynn 1997). Animation is an example of this integration, and forms can be modelled in a dynamic flow, in a space populated by different forces, attractions and movement. Animation methods are incorporated with nonlinear, dynamic and kinematic motion techniques, and they motivate and encourage perhaps all creative fields rather than the rigid linear sequence (Lynn 1997).

4.3 **Performative architecture**

Performative architecture is another digital architecture theory or approach, based on using building performance expectations as a medium to determine the form, or in other words, prioritise performance over form-making in the design process. According to Kolarevic (2004a, p. 24), this new kind of architecture “utilizes the digital technologies of qualitative and quantitative performance-based simulation to offer a comprehensive new approach to the design of the built environment”. It emphasises redefining
expectations of the building design and its construction processes. It relies on analytical computational techniques where the geometric digital model is partitioned into small elements to analyse their structural, energy, fluid dynamics and performance. For example, the digital analysis and evaluation of sunlight patterns throughout the year could affect or change the form dramatically to achieve higher building performance. The role of computation techniques is manifest in the analytical software and how it could preserve the overall form but at the same time how it could alter the geometry to achieve better optimisation of performance.

Performative architecture is a controlled design process with variability through computation to integrate form, structure and performance within a shorter time. Tang (2014, p. 18) argues that computation performative-based design, as a powerful parametric tool, offers geometric modelling and analysis within a controlled process. It is controlled and, as a result, becomes the guiding principles of the progression of the design process (Kolarevic 2014, p. 105). In terms of variability, Rahim (2002, p. 63) states that the organisational system of a performative model needs to achieve variability in all scales, such as space, structure and material through computational programming. Furthermore, the complexity aspect is enhanced by digital design techniques. Thus, the focus is aimed at improving buildings’ performance through computational design (Kaijima et al. 2013, p. 120), which has the ability to construct complex geometries and to get analytical performance feedback on their models (Peters 2013, p. 15). Computation is a design tool that impacts architectural design, and will become a new way of designing structure and form in parallel with architects, engineers and generative software cooperation to produce efficient and futuristic buildable forms (Shea 2004, p. 101). It will allow designers to speculate and modify, immediately and intelligently, to improve a very large number of designs within a short amount of time (Besserud, Katz and Beghini in Peters 2013, p. 50). It allows designers to test the design quality and performance quickly using different real-world environmental conditions to save on time and cost (Payne & Johnson 2013, p. 147).
Optimisation is the second important aspect of performative design. It is a form-finding process towards achieving the best result by using computational algorithms under a set of restrictions and instructions. Architects use optimisation as a form-finding tool. Because design started with a state that is the closest fit to the purpose, the geometry will then be assessed to determine if the overall performance is close enough to the goal, and if not to restart the optimisation process to find a better one. This was the idea behind using optimisation as a form-finding technique as discussed by Burry and Burry (2010, pp. 118-119), in addition to linking it to biology and structural economy. As Oxman and Oxman (2014, p. 97) implied, it is related to the concept of how the environmental context could inform the complex process of design configuration, which is closely linked to digital simulation, evaluation and optimisation. It is a technique for finding the best result with the help of computers. Optimisation means finding the best, but in architecture it refers to finding the best fit for a particular purpose, which is in a special state of performance and/or best-achievable economy of means (Burry & Burry 2010, p. 117). Seeking out the best is accompanied by the use of computational algorithms, following some restrictions and instructions. According to Besserud, Katz and Beghini (2013, p. 51), using automated search algorithms helps identify some optimal solutions with greater efficiency, which are valuable means to help designers identify the best performance designs and to understand why the best solutions perform well. The optimisation process is often employed in models such as biological systems, architecture or structural systems under a set of restrictions to find the best design solution (Burry & Burry 2010, p. 117).

The restrictions and/or conditions control the optimisation process, whereas the nature of the models control the outcomes. Then the computer instructions and interactions lead the designer to change constructional and/or geometric information to improve performance, and then to repeat the human/machine interactions to achieve the optimal design solution (Kolarevic 2014, p. 106).

4.4 Parametric design and parametricism

Parametric design is a computational conception of architectural forms, providing a range of possibilities depending on variables and multiplicity (Kolarevic 2004a, p. 17). It can create different objects and configurations by assigning different values to the parameters.
Parametric design is also defined as a “mathematical formula that requires values to be substituted for a few parameters in order to generate variations from within a family of entities” (Yessios 2004, p. 263). This generated entity can easily be changed and this is where parametric design became important in architecture. Kolarevic (2004a, p. 18) shows that architects for the first time in history are:

designing not the specific shape of the building but a set of principles encoded as a sequence of parametric equations by which specific instances of the design can be generated and varied in time as needed. Parametric design calls for the rejection of fixed solutions and for an exploration of infinitely variable potentialities.

Other scholars have defined parametric design from different points of view. For instance, parametric design could refer to system, relationships, process and logic. According to Tang (2014, p. 16), parameter is a term:

used to identify a characteristic, a feature, or a measurable factor that can help in defining a particular system. But in mathematics a parametric equation defines the relation of parameters and variables.

Unlike Tang, Dunn (2012, p. 54) argues that “parametric design enables the designer to define relationships between elements or group of elements, and to assign values or expressions to organize and control those definitions”. As a process, Sakamoto and Ferré (2008, p. 3) claim that parametric design is a “process based on fixed metric quantities but not on consistent relationship between objects, allowing changes in a single element to propagate corresponding changes throughout the system”. Then as logic, Migayrou (2014, p. 3) explains it as a way of digital design thinking, as it focuses on “a logic of associative and dependency relationship between objects and their parts-and-whole relationships”. In contrast, Picon (2014, p. 52) asserts that parametric design allows for the coordination of different project aspects in a way that they could be stored and modified in an easy way even with extreme intricate geometries.

There are other characteristics and required knowledge of parametric design. Dunn (2012, p. 55) highlights the key features of parametric design as the ability to iterate further versions by describing the design as a series of relationships. It allows for generating
multiple options by using values denoted by the designer. The designer dedicates time and effort to making a system that will iterate the design. According to Mark Burry (Dunn 2012, p. 55), this is known as “designing the design”. To master this approach to design, designers need to understand the algorithms for architecture and use them professionally. Janssen (2006, p. 50) claims that:

the parametric approach tends to be used to generate and evolve designs that are diverse but not disparate: the character of the design is altered by varying the dimensions, shapes and materials of elements and parts. But the overall configuration of these elements and parts of the design – which in nature is referred to as the ‘body plan’ – remains the same.

Later, Woodbury (2014, pp. 155-168) points out that in parametric design, defining relationships is a complex thinking task, so some skills and strategies are needed. These skills include conceiving data flow, dividing to conquer, naming, thinking with abstraction, thinking mathematically and thinking algorithmically, whereas strategies include sketch, copy and modify, search for form, use mathematics and computation, defer decisions, make modules, help others and develop your own toolbox. These steps and process must be applied using computer software which allow architects to deal with a large database of information where the design process and decision are made, and this has the advantage of making change and/or rework easy (Burry 2004, p. 149). Thus, parametric forms are characterised by variability, continuity and potential for local differentiation (Oxman & Oxman 2014, p. 57).

Parametricism originally arose from digital animation techniques in 2009 by Patrik Schumacher, and it relies on parametric design systems and scripting methods. Schumacher (2009b, p. 243) states that parametricism is a new style instead of just a new set of techniques. He highlights “taboos and dogmas”; in taboos the designer needs to “avoid rigid geometric primitives such as squares, triangles and circles, avoid repetition of elements, avoid juxtaposition of unrelated elements or systems”, whereas in dogmas the designer needs to “consider all forms to be parametrically malleable; differentiate gradually – at varying rates – inflect and correlate systematically” (Schumacher 2009b, p. 244).
Schumacher (2009b) claims that the existence of parametricism depends on the continuous evolution of sophisticated computational geometries. Thus, he suggests five agendas to be injected into the parametric paradigm to further this style (Schumacher 2009b, p. 247). First, the parametric interarticulation of subsystems moves from single differentiation to a scripted association of multiple subsystems. The single differentiation, for example, is swarms, whereas the multiple subsystems, for example, are navigation voids, internal subdivisions, structures and envelopes. Second, the parametric accentuation is the enhancement of the overall integration and composition of an organic form. Third, parametric figuration is “complex configurations in which mutable readings are latent and can be constructed as a parametric model with extremely figuration-sensitive variables”. Fourth, parametric responsiveness in the urban and architectural environment is through integrating dynamic capacity that allows adapting and reconfiguring according to the architectural environment occupants’ behaviours. Fifth, parametric urbanism or deep relationality aims towards the integration of the evolving built environment, tectonic articulation in detail and interior organisation, and it may also apply to the three previous agendas. He also states that, unlike modernism which relies on universal space [empty space], parametricism relies on the concept of field which is filled with moving components such as swarms or fluid (Schumacher 2009b, p. 250). In Picon’s view, parametricism allows designers to achieve full fluidity at all design stages as scales, from the initial sketches to construction, and from building to urban compositions (2014, p. 52).

The parametric approach tends to be used to generate and evolve designs that are diverse, but that are not disparate: the character of the designs is altered by varying the dimensions, shapes and materials of elements and parts, but the overall configuration of these elements and parts of the design remains the same (Janssen 2006, p. 50).

4.5 Morphogenesis, emergence and self-organisation

Morphogenesis has a connection to nature. Nature is a source of architectural inspiration for creating an artificial life, which helps decision-making and form-finding. It is also the source of biology and biomimetics as a logic and incentive to architectural design. Architecture has frequently drawn inspiration from nature’s forms and structures and, most recently, from the inner logic of its morphological process (Frazer 1995, p. 10).
Morphogenesis benefits from the natural system of decision-making in the architectural design process. In most natural systems, the decision-making and reactions are locally raised from the interrelationships between the component parts to produce global behaviour (Hensel, Menges & Weinstock 2013, p. 162). By adding technology to these inspirational aspects, architects will be able to mimic natural behaviour to benefit from its forms and structures. In other words, with the aid of computation, architects can use an unreal “artificial” environment to develop their design to produce forms like those in nature taking the principles of “morphogenesis, genetic coding, replication and selection”, and aiming at an evolutionary architecture (Frazer 1995, p. 9). According to Leach (2009, p. 34), architects use biology as a logic of form generation and pattern-making in an organism via growth and differentiation processes. It emphasises material performance over appearance, processes over representation, and formation over form. This has led to biomimetics as an important field of research, referring to learning from the replication of the mechanisms of nature (Leach 2009, p. 35).

Morphogenesis theory in architecture is strongly linked to the theory of evolution, which is a very important source of inspiration. It streams its rules and principles from theories like emergence, complexity, nonlinear behaviour and self-organisation. From 2004 until 2006, Michael Hensel, Achim Menges and Michael Weinstock highlighted its principle and rules, and then distinguished between the natural life and computation (Carpo 2013, p. 158). According to Menges (2013, p. 165),

natural morphogenesis, the process of evolutionary development and growth, generates polymorphic systems that obtain their complex organisation and shape from the interaction of system-intrinsic material capacities and external environmental influences and forces.

Unlike traditional architectural design, where form generation is prioritised over material selection or “materialisation”, in natural morphogenesis the formation and materialisation processes are deeply connected (Menges 2013, p. 165). Thus, architects need to understand the material system in morphogenesis not as an element to simplify construction, but as a generative aspect in the design process. Dunn (2012, p. 66) also defines it as “the evolutionary development of form in an organism, part thereof”. He argues that we need to grasp these living organisms as a system that often develops
complex forms and behaviour patterns as a consequence of the interactions between their components over time.

Morphogenesis in architecture is profoundly linked to computation, which requires the integration of mathematics and natural traits and principles in an artificial environment. This will result in evolutionary forms that copy the survival behaviour of natural life known as morphogenesis. It could be defined as digital architecture which is “computationally-based processes of form origination and transformation i.e. the processes of digital morphogenesis”, which put emphasis on the logics underlying computational concepts such as topological geometries, isomorphic polysurfaces, motion kinematics and dynamic, key-shape animation, parametric design, genetic algorithms and performance (Kolarevic 2004a, p. 13). The computational aspect puts forward the idea of mathematics integration to allow simulation of natural behaviour. It is a mathematically encoded process formalised through computation to be a homogeneous geometric domain (Migayrou 2014, p. 17). This permits investigating the qualities of growing plants, such as leaf overlapping, and applying them to shape and function of potential architectural structures and/or surfaces with consideration of the material properties (Dollens 2005, p. 16). This process deals with information used to create design and materials that represent the actual design model, which is known as “genome and phenome” according to Weinstock, Hensel and Menges (2004b, p. 9), or as “genotype and phenotype” as Carpo (2013, p. 10) and Janssen (2006, p. 49) described them.

Recently, morphogenesis has been appropriated within architectural design. Weinstock, Hensel and Menges (2004a) described it as a design approach that uses a bottom-up logic of form-finding, rather than the top-down processes of form-making. The bottom-up process relies heavily on the algorithms of form generation, which are responsive to the feedback loops received from the given environment or participants, resulting in evolutionary forms that mimic the self-selective behaviour of organic life known as morphogenesis. John Frazer is perhaps the first to explore the potential design of this approach which has become a very popular inspirational source of digital design (Carpo 2013, p. 48). But, these design strategies, as Weinstock, Hensel and Menges (2004b, p.
7) described them, are not really evolutionary unless they integrate iterations of physical modelling, and/or self-organisation material effects of industrial logic of production.

“Emergence”, an important aspect of morphogenesis, is a well-discussed term in many disciplines. It is strongly linked to complexity, evolution, biology, intelligence and systems. At the same time, it has become a common term in architecture. Its principles and dynamics of organisation and interaction are derived from the mathematical laws that natural systems obey and can be used in a computational model. Weinstock (2004, p. 11) asks what is emergence, from where does it emerge, and how does emergence come about. Form and behaviour emerge from a process, which produces, elaborates and maintains the form and structure of biological organisms, and consists of complex steps of exchange between the organism and its environment (Weinstock 2004, p. 13).

What is emergence and from where does it arise? In 2013, Hensel, Menges and Weinstock (2013, p. 160) reckoned that in science the term refers to “the emergence of forms and behaviours from the complex systems of the natural world”, and it requires enough knowledge in the fields of biology, physical chemistry and mathematics to properly understand it. Emergence as a technique or process is intensely mathematical and sometimes moves to other domains if fundamentally needed. Weinstock (2004, p. 10) investigates the mathematical basis of the process which could achieve emergent forms and behaviours in both nature and computational environments. Therefore, computation and mathematics can be used in a morphogenetic process to generate, evolve and construct forms and designs. How do these forms evolve and on what basis? The evolutionary technique relies on the development of the form population, even though only the fittest ones evolve (Hensel, Menges & Weinstock 2013, p. 161). Furthermore, Dunn (2012, pp. 66, 68) emphasises that the concept of emergence is a key theme of morphogenesis and he used Weinstock’s view, as shown above, as evidence to support his argument. He also adds that emergence is best understood as a type of self-organisation where the design component changes their arrangement which may transform the overall form in the process. Still, it is interesting to note that the emergent structures are usually the result of simple, repetitive rules that interact with each other.
Hensel, Menges and Weinstock (2013, p. 163) identify three main aspects which are important in architecture. First, morphogenesis and emergence are mathematical techniques to model the emergence form and behaviour of the complex natural system alongside form-finding techniques. Second, genes, date and speciation focus on patterns, geometry and behaviour, with computational and material evolution of population and species of architectural forms with complex behaviour. Third, environment, material and behaviour are concentrated on adapting the natural and architectural material systems’ behaviour and the potential smooth industrial integration of production and design. This is a property of the system that cannot be deduced from its parts; it explains how natural systems have evolved and maintained themselves. This is the processes of creating digital systems to produce forms, complex behaviours and intelligence. It is also a shift towards a new paradigm and its techniques of evolution and morphogenesis, which is more than the sum of its parts (Weinstock, Hensel & Menges 2004b, p. 6). They argued that the techniques and processes of emergence are intensely mathematical, and it requires knowledge in the overlapping domains such as mathematics, physical chemistry and biology (2004b, p. 7). It requires recognition of buildings as complex energy and material systems with a life span, and coexists with the built environment and as an iteration of evolutionary development to produce an intelligent ecosystem (Weinstock, Hensel & Menges 2004b, p. 7). Similarly, Castle (2004, p. 5) describes emergence as a “scientific mode in which natural systems can be explored and explained in a contemporary context”. It offers patterns and rules to create intelligent computational systems that can produce complex forms and behaviours. According to Johnson (2001, pp. 18, 19), emergence is a “movement from low-level rules to higher-level sophistication and a higher-level pattern arising out of parallel complex interactions between local agents”. Johnson (2001, p. 22) introduces four principles of emergence: local interactions of neighbours, pattern recognition, feedback, and indirect control. Weinstock (2004, p. 11) also has the same idea of producing complex forms and the behaviour of natural systems in a mathematical computational environment, where “every higher-level physical property can be described as a consequence of lower-level properties”.

At the same time, self-organisation is another crucial aspect of morphogenesis, as it is a form-finding technique closely linked to emergent behaviour. Form and behaviour
interact and influence each other within the contextual environment in this strategy. The form-finding technique in architecture was pioneered by Frei Otto who used material self-organisation systems under the influence of eternal forces (Menges in Carpo 2013, p. 166). It often displays emergent behaviours derived from the interactions between lower-level entities. According to Hensel (2006, p. 6), self-organisation could be described as a “dynamic and adaptive process through which systems achieve and maintain structure without external control”. But, the global form-finding process is not the only way to implement the self-organisation capacity of material; it could also be deployed in a local manner. Indeed, in the self-organisation strategy, form and behaviour play a vital role despite having a very complicated relationship. Weinstock (2004, p. 13) declares that the form of an organism influences its behaviour in the environment, and a specific behaviour will produce different outcomes in different environments, as if different forms were active in the same environment. Not only do form and behaviour interact, their contextual environment does so as well. Stewart (2003, pp. 1101-1102) argues that all self-organisation systems are organised by themselves and their context, such as the natural selection and intervention of other organisms like predators or parasites. He means the response to the context environment, so that the organisation will become the consequence of its dynamic rather than being forced directly by any external influence.

Morphogenesis is an approach that allows architects to explore geometric configuration through the logic of formation and materialisation. It allows the rethinking of architecture towards efficiency and functionalism. So, there is a strong connection and/or relationship between morphogenesis as the main framework, and emergence, complexity and self-organisation. In other words, self-organisation is a notion of complex nonlinear behaviours that lead to the emergence of new forms representing morphogenesis. Morphogenesis is interesting for architects because the search for unexpected and novel outcomes is the most significant factor that motivates architects. Dunn (2012, p. 120) argues that the development of morphogenesis is manifested in the willing acceptance by architects of unknown nature and its consequences such as being unforeseeable, novel and filled with excitement.
4.6 Nonlinear organisation

Nonlinearity in digital architecture relies on the relationship between information and formation models. Kolarevic (2004a, p. 26) argues that in this system the information needs to be defined first by setting up the rules, relations, constraints and influences, then the resulting generic structure formation is the outcome of processing this information. The designer becomes the editor of the designed digital system who sets the information and then becomes the operator of the system. In this generative system, the process is highly dependent on the designer’s perceptual and cognitive abilities (Kolarevic 2004a, p. 26). Moreover, information processing is highly sensitive to the extent that any addition or subtraction can dramatically affect the potential behaviour and eventually the outcome. Kolarevic (2004a, p. 26) supports this idea in claiming that a small quantitative information change can have large qualitative formation effect. It also requires knowledge of other disciplines and not only architecture, leading to further experimentation and innovation. The nonlinear process of working is a result of diverse practices of making, achieved by hybrid modes of experimentation and representation (Dunn 2012, p. 76). It is about being an explicit expression of the notion of unpredictability and unexpectedness. It is also about the ability towards form-finding through a dynamic in-deterministic digital organisational system to produce new and unexpected outcomes.

4.7 Digital tectonic

When computer use in architecture started to spread in the mid-1980s there was an expectation that computers would reinforce the structural and tectonic aspects, but in many cases the opposite was happening – many signature buildings were struggling to find a balance between architectural form and tectonic (Picon 2010, p. 127). It is paradoxical, but it did happen in the past. Now computers have the ability to connect architectural imagery, reality, building techniques and materials. Digital tectonic design is more about engaging designing ideas with construction and fabrication processes in all stages, from the initial concept to one-to-one building. It is about the relationship between material, structure, construction, form and fabrication. It is also about the relationship between conception and production, materialisation and fabrication. Digital tectonics is a
moderated step between digital design and digital fabrication which are interconnected by mutual influence to reach a harmonised result or solution (Meredith & Sasaki 2008, p. 161).

In 2004, Leach, Turnbull and Williams argue that digital tectonic is a new paradigm in architectural culture, when there was a campaign claiming that the production of seductive computer imagery does not succeed in grasping the essential nature of architectural production (2004, p. 4). They also highlight that with time, computers have penetrated almost every architectural production aspect and allowed architects to model the material properties of sophisticated architectural components. But, it has to achieve reality to be a true and acceptable architecture. Architecture, according to Kenneth Frampton (in Leach 2002, p. 9), “is a question of building, and form generation on the screen are just utopian fantasies if they do not conform to the tectonic requirements of the real world”. This view highlights the difference between designing a form based on the algorithmic potentials and the tectonic parameters of the real building materials. This will lead architects to experiment from the very beginning with the digital design process and the capacity of the new and available materials. Leach (2002, p. 9) believes that digital is not versus material, but digital is serving material.

In this architectural digital age, the relationship between conception and production has been reconfigured to link what can be conceived with what can be constructed. Kolarevic (2004a, p. 33) confirms that the constructability of buildings became a part of computability, offering valuable opportunities for tectonic exploration of new geometries. Thus, architects need to understand the digital techniques to be able to link formality with materiality and construction, which are the most important pillars of digital tectonics. Architectural geometry needs to be developed in conjunction with the construction and materiality techniques such as 2D laser cutting, subtractive computer numerical control, additive 3D printing, and formative fabrication force stretching to be able to build in real 1:1 scale. Thus, the digital design medium has been expanded which puts pressure on the invention of new methods of construction and materials to fulfil the designers’ visions. As a result, the construction and fabrication process has been automated, so there is no
longer a need for people to cut and prepare these materials on site (Lynn 2008c, p. 252). Architects simply need to set up the cutting paths, select material and machines, then send them to a cutting workshop or, as some scholars call them, ‘fabricators’. All two dimensional drawings and 3D models are used to simplify the installation and assembly steps for both study models and/or one-to-one construction. Architectural practice procedure has been revolutionised by the digital manufacturing technologies (Agkathidis et al. 2010, p. 121).

Computers are now helping to design and construct complex forms using data, regardless of whether it was a building or just part of it. Computers can be used not just to calculate the individual building’s components, but also as a helper to fabricate and experiment with them in stage one of the design process (Leach 2002, p. 10). This gives the advantage of investigating more sophisticated forms. Architects do not need to be limited to the use of usual forms like boxes and then assemble them with standard construction, but with the use of digital techniques. This will move architects from using rules and requirements to using information which maximises potential and opportunities. One of the most significant aspects of digital technology is that the design data is often the construction data or at least connected to it, which resulted in a vast configuration of special and material potential (Dunn 2012, p. 76).

As architectural tectonics is connected to digital technology, there is an important need to involve algorithms in this computational process. In digital tectonics, generative scripting, algorithms and computer-aided design tools are used as a design component, as well as a device that can help systematise and rationalise the construction process of complex geometries (Agkathidis et al. 2010, p. 4). The use of architectural algorithms has become fundamental. Carpo (2011, p. 93) states that digital technology can deal with a variety of forms that can be designed and built, but the algorithm is indispensable in this process as it is a key aspect in manufacturing and production. Various approaches have been proposed regarding digital tectonics; for instance, digital tectonics as virtual materiality, as physical materiality, as fabrication materiality, as structured materiality,
as digital form-finding and morphogenetic processes, and as adaptive materiality (Oxman 2014, pp. 232-234).

It is desirable that the outcomes of these approaches are buildable. Architects need to connect all relationships between material, structure, construction, form and formation (see Figure 3). Originally, tectonic relates to that overall theory of structuring, whereas architectonic relates to the overall conditions of tectonic contents of architecture, even though tectonic in architecture relates to the relationship between material structure and architectural form (Oxman & Oxman 2014, p. 221; Pigram, Larsen & Pedersen 2013, p. 162). Furthermore, the use of digitally generated information to make complex and precise forms is one of the digital tectonic attitudes, and this process often includes the construction and assembly details and techniques. It allows architects to generate and analyse information, then use it to manufacture to make the digital tectonic possible. Digital techniques have profoundly redefined the relationships between conception and production (Krauel, Noden & George 2010, p. 13). Whitehead (2004, p. 83) adds that it is important for architects to develop their skills to be able to work with different materials and a variety of media.
Cook (2004, p. 41) lists the fundamental and key factors of the architectural tectonic:

Material: our ability to use what is around us or to find ways of adopting it. Ability: our ability to assemble, our ability to come together as a work force and collaborate, and our ability to communicate an idea. Need: our reason for needing the building, from safe shelter to a symbol of power, something of utility or something of beauty.

Cook (2004) asks: how do we harness the new ability of digital creation to use materials and satisfy our needs? Digital tectonics has become an important part of the onsite building assembly. Bell and Simpkin (2013, p. 90) find that with computation it is possible to generate a machine code to produce the building component drawings, which draw a direct relationship between the design information and construction components. It also surpasses the traditional design approaches by facilitating a greater fluidity between design generation, development and fabrication (Dunn 2012, p. 20).

Knippers (2013, pp. 76-81) highlights the impact of computational design strategies on the composition and development of load bearing systems. Firstly, the technical means to develop new structural forms have been provided by computational design. Secondly, new approaches towards constructing structures have been provided by computational manufacturing. Third, the use of computational design and manufacturing breaks down the traditional hierarchical and linear design strategies. Computational design and manufacturing – digital tectonics – offer valuable opportunities for designing and constructing new structures that go beyond the existing ones.
4.8 Topology in architecture

Topology in architecture is seen as the embodiment of a new computer age between 1996 and 2001 (Carpo 2011, pp. 84, 85). Most commonly, it refers to continuous, smooth, not polygonal or ripped surfaces. Kolarevic (2004a, p. 6) claims that as topology is often expressed by mathematicians as curved forms, which gives expression to topology being the equivalent of curvilinearity, it is actually an architectural misunderstanding that links topological architecture to curved or vice versa. Kolarevic (2004a, pp. 6, 7) also adds that what makes topology attractive is its emphasis on structures of the relations as well as internal and external interconnections of the forms whether it be curvilinear ‘blobby’ or rectilinear ‘boxy’. The form should result from the performative circumstances surrounding the project, such as cultural, morphological, tectonic, material, economic and/or environmental.

Topology is strongly connected to mathematics, as it allows architects to know and study a shape’s properties, its ability to twist, stretch and fold. According to Kolarevic (2004a, p. 6), topology “is a branch of mathematics concerned with the properties of objects that are preserved through deformation”. But, in mathematics topology is defined as “a study of intrinsic, qualitative properties of geometric forms that are not normally affected by changes in size or shape, i.e. which remain invariant through continuous one-to-one transformation or elastic deformations, such as stretching and twisting” (Kolarevic 2004a, p. 13).

For instance, the circle and ellipse could be considered as a topological equivalent of the square and rectangle as they both could be stretched to become a circle or ellipse. Equally important is knowing that topology in mathematics is a relatively new way of looking at the world. Henri Poincare, “the father of topology” as cited in (Burry & Burry 2010, p. 158), defined it as “the science that lets us know the qualitative properties of geometric figures, both in ordinary space and in space with more than three dimensions”. Burry and Burry (2010, p. 159) admit that surfaces in topology can be described as a two-dimensional manifold embedded in three dimensions.
Topology in architecture is about spatial relations. Kolarevic (2004a, p. 6) states that topology is about relations, interconnections with spatial context, and specific forms – “a single topological construct”. It is about spatial relations, not spatial distinctions. The notion of topology in architecture emphasises the relations between and within a real site and proposed program. At the same time, these relations become the structuring and organising principles that help generate the form (Kolarevic 2004a, p. 13).

4.9 Digital poetics

Digital poetics is a recent theory introduced by Marjan Colletti in 2013. Colletti (2013, p. 9) declares that the theory of digital poetics must be dynamic and synthetic or what he implies as “volution and convolution”. Colletti (pp. 9-11) also claims that digital poetics is the theory of architectural technology being approached through poetics. It is also the theory of evolution and of how technology has helped architecture evolve, a theory of devolution which bridges theory with research, as well as being the theory of involution from outside technology looking to penetrate into it to reveal some of its capacities. Lastly, it is also a theory of revolution because it is a self-referential theory or theory of theory.

Digital poetics requires a higher level of computation and mathematical skills, as well as sufficient knowledge in theories and design. Colletti (p. 8) states that:

the theory of digital poetics presumes a dynamic architect; one who can scrutinize something from numerous perspectives, who can zoom in and out, and who is able to navigate through multiple theories and designs; one who could attribute spatial and atmospheric properties to drawings, appreciate the winding roads of design processes, find his or her own routes through the mathematical and geometric jungle of CAD software.

It also requires understanding human and computer interaction and its expected outcome. Colletti (p. 8) also claims that the theory of digital poetics is about “constructs of multiple viewpoints of speculation of spiralling at, around, inside, outside-inwards and back inside-out the human-computer feedback system that lays at the core of digital design”. In addition, it highlights the relationships between human-computers and architecture.
Colletti (p. 12) points out that the digital poetics theory is a first step to a hybrid and synthetic understanding of the interactions between technology, society and architecture.

Digital poetics adds terms to the digital architecture dictionary to understand digital capacity and expand cultural production. Digital poetics is an attempt to introduce a series of concepts that widen the digital vocabulary beyond processes (p. 17). It is a theory of cultural production by design and production, for as a post-digital theory it aims at interpretation, codification and translation of digital capacities into cultural production (p. 21). Regarding the new terms, for example, Colletti (p. 9) states that the notion of “volution” is an overarching systematic and conceptual model to explain the dynamic, open and speculative theory of digital poetics. But, the notion of “convolution” is used to define the voluted structure of digital poetics. It refers to blurring the boundaries of the discipline and of digitality, overlapping theory and practice, design and fabrication, interference, interdisciplinarity and multidisciplinarity, and multilinearity of the design processes (p. 11). Accordingly, the theory is rooted in and has emerged from a series of paradigm shifts, such as postcyber, postvirtual, postfluid and postdigital (p. 12).

The postcyber and postvirtual paradigms are used by Colletti (p. 14) to describe the pathway from matter to substance and from virtual imagery to machine fabrication. They are used to define the era of the new digital paradigm and real-world physical production based on the evolving processes. Postcyber and postvirtual are key words to picture digitality, actual applicability, and cultural production through design and machinic fabrication. Colletti (p. 14) used the term postfluid or postliquid to describe the smoothness, fluidity and liquidity of digitality which distinguishes the digital age. Postliquid is used to illustrate generating geometries of fluid and turbulent, and convergence of the solid and cristalline in architecture. Colletti (p. 16) states that Non-Uniform Rational Basis Spline geometries that are modelled or scripted could be described as smooth, fluid and liquid. Finally, the term postdigital has been used to describe the form-finding process from nature or from the so-called computational morphogenesis, biomorphic emergence, genetic and genomic algorithms (p. 18). It is
about understanding the interaction between architecture, society and technology, as it is a theoretical framework by architecture for architecture.

4.10 Conclusion

Carpo (2013, p. 12) states that with the dotcom crash of 2000 and 2001, all digital theories had already been developed since 1990, but technology continued to evolve, which pushed the development of digital design theories in architecture alongside implementation, and almost all occurred within or extrapolated from the base theoretical platform of the 1990s. The 1990s was the main source of digital architecture and the study of it. Since the integration of computation and architectural design, theories have started to evolve through a period of cultural transformation and technological revolution. Similarly, new digital theories in architecture are undergoing evolution and transformation. Therefore, all digital theories are seeking to integrate computational systems in the process of design, materialisation, production and construction. Almost all new theories of digital architecture are related to the fields of emerging technologies.

Introducing digital tools to the theoretical narratives of architectural design is the reason behind the rise of digital theories. In addition, architectural digital theories are evolving according to demand and in conjunction with technological development. If there is no new architectural technology, there is no need to set up a new theory. The current technological trend revolves around the relationship between computation, fabrication, formation, optimisation and structure. As a result, most common and recent theories from 1993 until now focus on this relationship. Architectural interest is directed towards generative, evolutionary and emergent behaviour in science and nature, such as self-organisation, fluid, drifting, biology, intelligence, systems and complexity, though all as a methodology to produce unique forms and designs. With the introduction of computation in architecture, these behaviours have become possible and can be mimicked and applied to produce new families of forms, shapes and geometries.
Mathematics is one of the most important concepts in digital architecture. It allows architects to know and study a shape’s properties, such as its twisting, stretching and folding ability. It is also a way to integrate natural traits, principles and behaviours in computer simulations. Nature follows or obeys mathematical laws. It can be used in a process to generate, evolve and construct forms and designs. Thus, designers need to understand the algorithms of architecture in order to produce sophisticated computational geometries. For example, the mathematics of curvature are equations to produce pliant and smooth lines or surfaces that are able to achieve complexity through flexibility, which is in reality forms of bending, twisting and folding. Sometimes mathematics is not enough, and knowledge in the fields of biology, physics and chemistry is also required.

Sometimes, the environmental context could inform the complex process of form-finding, which is intimately linked to digital performance and optimisation. That means performance is the determining factor of forms, and it could be related to the structural or environmental aspects to optimise design, which refers to the fittest form for a particular purpose. Thus, the optimisation process could be repeated to find a better form. Performative and optimisation approaches often conduct searches in biological, architectural or structural systems to produce the optimum forms.

With computation, architects can now design the design, by designing the design process instead of the product. They are not designing any specific shape of the building but a set of principles encoded in parametric equations to generate many iterations. Parametric design calls for the rejection of fixed solutions and for an exploration of the potentialities of infinite variables. Parametric design is system, relationships, process and logic. But, in morphogenesis, nature is the source of architectural inspiration towards creating a computational life that helps decision-making and form-finding. It emphasises material performance over appearance, processes over representation, and formation over form. In particular, the processes of formation and materialisation are deeply connected.

In a nonlinear organisation, relationships are between information and formation models. Information needs to be defined first by setting up the rules, relations, constraints and
influences, and then the resulting generic structure or formation. The designer becomes the editor of the designed digital system who sets up the information before becoming the operator of the system. It is about seeking unpredictability and unexpectedness to produce new and unexpected forms. Unlike a nonlinear organisation, digital tectonics reinforces the structural and tectonic aspects by engaging designing ideas with construction and fabrication. It looks to connect relationships between material, structure, construction, form and fabrication. It also involves connecting relationships between conception and production, materialisation and fabrication. It allows architects to generate and analyse information, then use it to manufacture and construct real buildings.

Topology in architecture refers to continuous and smooth, not polygonal or ripped, surfaces. It is the equivalent of curvilinearity, even though this is a misunderstanding. Curvilinear ‘bloppy’ or rectilinear ‘boxy’ forms should result from the performative circumstances of a project, such as cultural, morphological, tectonic, material, economic and/or environmental. Lastly, digital poetics requires a higher level of computation and mathematical skills, as well as enough knowledge in both digital theories and design. The designer needs to be dynamic and able to navigate through multiple theories and designs to find routes through the mathematical and geometric jungle of computer-aided design software, and to understand human and computer interaction and its expected outcome, in technology, society and architecture.

The current digital theories and approaches take their rules and principles from the same source of mathematics, natural behaviours, materials, tectonics, fabrication and physical data. It is important for architects to develop their skills to be able to work with different materials and a variety of media. The question of how technology has helped architecture evolve connects digital theories with architectural research, education and practice.
Chapter 5: Digital design techniques

5.1 Introduction

A quantum leap in computing power and availability, as well as the adaptability and flexibility of 3D software, has made computers indispensable to architecture in the last few decades. Computers provide easy access to calculation process and functions, through coding or programming languages. Architects and architecture students have the advantage of using this technology in addition to a variety of fabrication machines, materials and techniques. Human interactions with computers are mainly to experiment or test an idea based on input and output information to get important feedback based on the computer’s intelligence and speed which are both crucial elements of digital design techniques. Because computers are fast and intelligent they can easily perform what architects want, to produce architecture.

To produce architecture using computation, architects need to know and understand architectural digital generative behaviours. Most of these behaviours are derived from nature. Architects take advantage of nature and its evolutionary generative behaviours to fashion a variety of options and possibilities. But the virtue is not only to do with nature as generative mathematical concepts which are the core of these behaviours. There is no way to make evolutionary behaviour by computers in the absence of mathematics, which is the gate to nature – manifested in self-organisation and its complex behaviour. As a result, architectural design techniques have shifted in many aspects. Architects use computers to simulate behaviours digitally to generate geometries, and to integrate design with fabrication and construction. As a result, computers became exploration tools rather than exploitation. Frank Gehry, for example, is one of the leaders researching the use of computers as a design manager and as a guiding system to construct impossible sculptural forms (Lynn 1997).

Due to the shift in designing techniques, architects require knowledge in the field of algorithmic and geometric calculations. The conceptual understanding of geometries, their mathematical formulae, how it works, how it is generated, and how it is fabricated
and built, is absolutely fundamental. Architects also need to be up-to-date with the available fabrication machines and materials. New fabrication technologies have managed to widen the construction options, such as computer numerical control machines. The computational world of architecture is accessed through coding and scripting. Architects will become toolmakers rather than tool users if they use the benefits of computation. Architects need to understand coding languages, its techniques, how to access them, and the role of algorithms in this process. With that, a new relationship between architects and coding has become inevitable. Nevertheless, why and how should coding be joined with architecture? Maeda and Burns (2004, p. iv) ask, “How much do we need to know about the computer to survive?” Their answer is that it is strongly recommended to know the art of program ‘coding’, which is a popular term and a crucial skill for any designer.

Because of this shift, contemporary architecture has changed; the way architects conceive architecture has changed; and architecture itself looks different from the implementation of digital techniques in Saudi Arabia today. In the early 1990s, computer use in architecture design was limited. Then it became more common, but some architects still considered it as a whim. Eventually it became inevitable, but the way architects conceive architecture has changed. Architectural forms have become more complex – curvilinear (blobby) or rectilinear (boxy). Currently, there are some iconic buildings that have been designed by foreign architects, which have been built or under construction in Saudi Arabia.

5.2 Architectural digital generative behaviours

Architectural digital generative behaviours are one of the important components of digital design techniques which provide architects with fields of generative ideas and solutions. This section provides a general understanding of some crucial aspects. Most of these behaviours are sourced from nature to discover and produce a variety of possibilities and forms. At the same time, generative behaviours could be evolutionary behaviours, which allow design to evolve through computational evolutionary search algorithms. As
algorithms are important for generative behaviours, architects need to master them. Generative mathematical concepts such as chaos, fractals, flocks and crowds are discussed. Self-organisation is complex behaviour performed in nature to produce variations of unpredictable and indeterminate outcomes. Examples of self-organisation are slime mould and ants’ nests.

5.2.1 Variety of possibilities

Generative behaviours have the ability to produce a variety of possibilities and options. Kolarevic (2004b, p. 13) proves that instead of modelling the external shape, designers set forth an internal generative logic which produces a variety of possibilities that the designer can choose from for further development. Despite the complexity of generative behaviours, they are very powerful and generate a massive range of design alternatives. This could be used in the early stages of the design process, focusing on discovering design alternatives (Janssen 2006, p. 50). Generative behaviours use information “genotypes” and rule-based growth procedures to generate design alternatives that are different from each other. Janssen (2006, p. 50) argues that with generative behaviours, “design tends to be disparate but not diverse: the overall configuration of the elements and parts varies widely, but the character of these elements and parts remains similar”. This way of design requires the designer to grasp and encode a range of design ideas that the computer program can use to generate alternative forms within the range of these design ideas. It allows designers to generate concepts with formal, structural, constructional, aesthetic and other configurations, before the program allows the manipulation of this concept into a building form in response to a given problem (Frazer & Connor 1979, p. 1). Designers use computation techniques such as L-systems, cellular automata, genetic algorithms and multi-agent systems to generate new forms and at the same time to understand, test and evaluate these forms (Leach 2009, p. 35).

5.2.2 Evolutionary generative behaviours

Generative behaviours could also be evolutionary ones as they are challenging forms, that is they are more than just an instrument for inspiration. Usually, generative behaviours are characterised by variability and connected to evolutionary systems, which allow a
divergent range of alternatives to evolve. Natural generative behaviour is one source of architectural inspirations to generate forms. This behaviour shows a high level of evolution, function and integration through dynamic feedback loops and interaction with the surrounding circumstances. Bentley (1999, p. 2) argues that the main source of evolution behaviour is nature or biology, which produces intricate shapes or designs through slow, gradual and mindless processes, and this teaches architects that there is no design more complex than the one which has evolved in nature. According to Bentley (1999, p. 2), “evolutionary design is simply a process capable of generating designs”, but it can never be or called the designer. This supports the idea that designers should control the design evolution. Janssen (2006, pp. 50, 51) states that in order for forms to evolve, designers must carefully control the variability of the form to ensure that the design is complex, intelligible, unpredictable and desirable. Complexity refers to “the level of complexity within the designs [which] must be commensurate with the complexity of the entities being designed”; intelligibility refers to “the forms [which] must be directly intelligible as designs by both people and by other software systems”; unpredictability refers to “the forms [that] must be disparate”; and desirability refers to “the forms [which] must embody certain qualities that are seen to be desirable by the designers using the system” (Janssen 2006, pp. 50, 51). Furthermore, as evolution is best produced by natural life, computers are also able to make designs evolve. According to Bentley (1999, p. 3), the evolutionary design of nature is capable of producing perfect innovative designs, just as the evolutionary design by computers is capable of generating such innovation.

Evolutionary computation is a search using algorithms to define a problem in a space filled with possible solutions. Evolutionary search algorithms are techniques to develop solutions which are an emergent property of the algorithms themselves (Bentley 1999, p. 5). Bentley and Corne (2001, p. 8) highlight four main families of evolutionary algorithms: genetic algorithms created by John Holland in 1973 and 1975; evolutionary programming created by Lawrence Fogel in 1963; evolution strategies created by Ingo Rechenberg in 1973; and genetic programming created by John Koza in 1992. Even though these algorithms are old, they are still important especially in computation. Bentley (1999, p. 4) provides a number of reasons why the use of evolutionary algorithms remains important. First, evolution is a good, general purpose problem solver. Second,
uniquely, evolutionary algorithms have been used successfully in every type of evolutionary design. Third, evolution and the human design process share many similar characteristics. Fourth, the most successful and remarkable designs known to humankind were created by natural evolution, with the inspiration of evolutionary algorithms.

Given that evolution is a property of nature, it suggests that computational behaviour should use one of the evolutionary algorithms to follow the natural process in order to develop design. Genetic algorithms are a computer simulation of evolutionary processes – in a digital environment with virtual plants or animals – and in this process creatures mate and pass their virtual genetic materials to their offspring; the fittest genes determine the next generation’s forms. These tasks are operated automatically by computer programs that make them look easy. Architects need to search for rich evolutionary algorithms to get truly surprising results, otherwise these programs will be useless (Delanda 2002, p. 117). Similarly, Bentley and Corne (2001, p. 6) state that computers are instructed to breed fit solutions by allowing the better solution to “have children”. Then the bad solutions die and the fit ones are allowed to have children, and so on. All these steps happen in the environment of computational evolutionary search algorithms. The designer cannot easily force these programs to generate desirable forms by using the computer mouse for example.

5.2.3 Generative mathematical concepts

As genetic algorithms are fundamental for generative behaviour, architects need to master them. Some commonly used terms and/or generative mathematical concepts are discussed. Chaos is the behaviour of systems with certain characteristics such as nonlinear, deterministic rather than probabilistic, sensitive and sustained irregularity (Burry & Burry 2010, p. 55). Recursion is a “method of defining functions in which the function being defined is applied within its own definition. Thus within a procedure, one of the steps is to run the whole procedure again; … the output of applying the function becomes the input of the next iteration” (Burry & Burry 2010, p. 55). Fractal is a term to describe a highly fragmented and unorganised geometry in nature, an infinite number of distinct scales, chance and fragmentation (Burry & Burry 2010, p. 56).
Packing or tiling are two mathematical ideas that are connected together by the notion of space-filling and symmetry. Space-filling is about subdividing space into the smallest possible pieces, to infinity in some cases; whereas symmetry goes beyond its 2D meanings – mirroring – where scale and repetition are paired (Burry & Burry 2010, pp. 77, 80). For example, stacking oranges on a shelf or in pile produces a 3D tetrahedral structure which challenges the mathematical rules, which means finding the proper rules to subdivide the stacking space with no leftover gaps. This belongs to the mathematical subdivision theory of Voronoi which relate to dividing a plane into regions while keeping the same distance between the centre points. The common example of 3D packing is soap foam. It is similar to adjacent bubbles sharing surfaces and able to fill the whole space with no gaps. A famous built example is the Water Cube in Beijing, China.

Allen (1997, p. 73) argues that flocks, schools, swarms and crowds in architecture are artificial behaviour following local rules. For instance, in flock behaviour, each individual follows its local organisation’s rules such as maintaining minimum distance from others, matching velocity and moving towards the perceived centre of the group. None of the rules ask individuals to form a flock; the rules are totally local and rely on what the individual can do. Based on that, this collective behaviour is defined by simple local rules and conditions to deal with the surrounding environment, to create architectural forms or patterns. Allen (1997, p. 75) then describes crowds as dynamic behaviour motivated by complex desires, and interacting in less predictable patterns. Allen uses Canetti’s (1962) four primary traits of crowds: first, crowds always want to grow; second, there is quality within crowds; third, crowds loves density; and fourth, a crowd needs directions.

All these mathematical concepts aim to create generative behaviours that are useful for architects. Most of these behaviours are self-organisational, which means that they happen with no external force, influence or intervention.
5.2.4 Self-organisation as a complex behaviour

Self-organisation is a complex behaviour that carries many meanings such as unpredictability and unrepeatability. According to Jencks (1997, p. 80), self-organisation is a complex behaviour with continuous variations that can be unpredictable or indeterminate and which spring from natural behaviour, where patterns never repeat themselves. It comes in conjunction with the surrounding natural circumstances which means there are no pre-decisions; it happens as a response to and to survive. Hensel and Menges (2006, p. 28) argue that self-organisation is a dynamic and adaptive process through which the system achieves and maintains structure without external control. It often shows emergence behaviour of the interactions between lower-level entities – components and rules to achieve the required performance capacity and optimisation.

As an illustration of self-organisation behaviour, Johnson (2001) mentions two important examples: slime mould and ants’ nests. Slime mould and ants’ nests are intelligent organisations that can behave in a particular way to survive with no external intervention. Slime mould has the ability to build itself to have the shortest way to its food source. Ants can build their nests depending on the individual behaviour to protect and grow the colony. Both are bottom-up behaviours and consist of simple individual components that are able to build high-level intelligence. This is inspiring for architects to simulate such natural behaviour to generate new original ideas by using computation to take advantage of these self-organisation complex behaviours to produce designs or geometries. In 2000, Toshiyuki Nakagaki, a Japanese scientist, used the slime mould to find the shortest way through a maze, placing pieces of food at two of its exits. Despite the slime mould being a primitive organism, it has the ability to navigate efficiently through the maze to find its food (Johnson 2001, p. 11). On the other hand, the ants’ behaviour is collective intelligence, aiming to build colonies with no external intervention.
5.3 Shifting the architectural design process

Nicholas Negroponte, in his 1970 book *The Architecture Machine*, states that:

In the past when only humans were involved in the design process, the absence of resolute rules was not critical. Being an adaptable species, we have been able to treat each problem as a new situation, a new context. But machines at this point in time are not very adaptable and are prone to encourage repetition in process and repetition in product. The result is often embodied in a simple procedure that is computerized, used over and over, and then proves to be immaterial, irrelevant, and undesirable (Negroponte 1970, p. 3).

Then, at the end of the book, Negroponte prefers to “build machines that can learn, can group, can fumble, and can be architects’ partners, machines that are thought to be human” (1970, p. 121).

5.3.1 Shifting design process and techniques: swarms, flocks, fractals and crowds

Shifting architectural design processes and techniques happened with the introduction of computation in architecture. When architects add the possibilities of scripting, parametric modelling and performance-based generative techniques – multi-agent systems or genetic algorithms – a broad shift is defined, and appeared in some progressive schools of architecture, and even in mainstream architectural culture (Leach 2009, p. 37). Computers were developed to take the place of humans in the design process in the 1960s. In the 1970s, the role of computers changed towards creating an intelligent assistance system. But in the 1990s, computers are significantly involved in the design process, from drafting and modelling to intelligent systems and processing architectural information (Terzidis & Vakalo 1992, p. 5). The design process has changed towards bottom-up and behavioural form generation. For Allen (1997, p. 77), crowds and swarms are two examples that could shift the architectural design process from its traditional top-down forms of control to more fluid possibilities of a bottom-up approach.

As a result of digital design techniques, architecture designers now have new roles that are dependent on their computational skills. According to Oxman (2006, p. 242), architects now interact with generative, performative processes and mechanisms, using
information as a new material. The designer becomes a tool builder which means designers need to improve their computational skill sets to deal with this new architectural trend. Oxman (2006, pp. 242, 243) puts forward four components of digital design: representation, generation, evaluation and performance. Representation is related to the representational media; generation includes generative processes; evaluation refers to analytical and judgmental processes; and performance relies on performative processes related to programmatic and contextual considerations. This puts restrictions on the architect’s role as a designer. The historical architecture designer’s role has shifted; the designer is no longer the solo author of the design. According to Marble (2012, p. 8), the author or creator role of architects is replaced with semi-autonomous, algorithmically-driven, design workflows within a collective digital communication infrastructure.

The interaction between designer and digital media is totally different from the traditional design. According to Oxman (2006, p. 243), in paper-based interaction the designer can interact directly with the shape that the designer draws on paper, whereas the interaction with computers relies on the implementation of computational constructs. The designer describes it as external and internal interactions. In the external interaction, the designer can interact directly with shapes and forms in a traditional way. On the contrary, internal interaction refers to the interaction with digital form via the digital environment, computational processes or mechanisms. Oxman (2006, p. 244) suggests four classes of interactions. The first is interaction with a free form, paper-based, non-digital representation. In this case, the designer interacts directly with forms through sketching, drawing and physical modelling to create designs. The second is interaction with digital constructs, known as computer-aided design where designers interact with digital sketches, digital drawing or modelling. The third is interaction with digital representation generated by a mechanism, where designers interact with a digital structure generated by a mechanism according to a group of predefined rules and relations. The fourth is interaction with the digital environment that generates a digital representation. This type deals with interaction with the operative part of generative design mechanisms, where designers interact with the computational mechanism that generates the digital representation.
As a result of this shift, most of the digitally designed architectural projects belong to one of the following domains. First, projects with complex geometries are generated by algorithmic rules, digital sculpting processes or other computational tools. Second, architecture relies on computation and numerical processing to create significant buildings to achieve particular performance criteria (Marcus 2012, p. 46), which supports Barkow and Leibinger (2012, p. 99) who argue that the digital has been directing design and its processes in a way that architects’ imagination alone cannot handle.

5.3.2 Integration of design, fabrication and construction

The architectural design process has also shifted toward the integration of design, fabrication and construction. With the use of computation, designers have a range of intricate surfaces available, but the challenge is how to determine fabrication techniques to construct these surfaces (Burry & Burry 2010, p. 16). Computation provides the connection between design and fabrication. Designers need to rethink their design process by developing new methodologies to address digital design fabrication requirements, which can happen by allowing the generation, integration and strategies of manufacturing to inform each other (Dunn 2012, p. 185). First, as a result of this shift, a new innovative, motivated, highly skilled generation of programmers and designers will engage in a discourse of material and fabrication processes with unprecedented results. Second, the benefits of integration of digital design and fabrication are growing fast and that makes simultaneous feedback mechanisms apparent (Dunn 2012, p. 186). The shift in architectural design is characterised by extensive knowledge sharing and collaborative production, as well as a noticeable increase in digitally fabricated buildings.

Unlike Dunn, Marble (2012, p. 8) finds that there are three themes that shift the architectural design processes, and they are deeply dependent on each other: designing design, designing assembly and designing industry. Designing design is a procedural issue. It is a step to redefine the design process as integrated design systems. It poses design itself as a design problem where architects engage with broad cultural and technological discussions between scripting (open world) and application (closed world). Designing assembly is a material issue to address the influence of digital production and
material properties on the design concepts (Marble 2012, p. 9). It is a further step of digital fabrication dealing with the logic of assembling building parts as important criteria during design to thread through design concepts, material properties, methods of production and assembly sequences. Finally, designing industry is an organisational issue towards multidisciplinary practice; the range of information in a given architectural project is expanding faster than the architects’ ability, thus there is a demand to incorporate a range of expertise to link information with design, fabrication and construction (Marble 2012, p. 10).

Architectural practice has shifted since the integration of digital, fabrication and construction throughout all the design phases. As a result, Barkow and Leibinger (2012, p. 95) state that designing assembly has become a critical aspect of this shift, and requires understanding of the way tools shape materials which comprise surfaces, forms and space. They also claim that the architect’s competency in using computers has evolved from simply a drawing tool to a new guiding system for designing and tooling materials. The integration of design, fabrication and construction is a shift away from merely representational models. According to Hensel and Menges (2006, p. 34), instead of the representational models, the integration has become:

a) scaled functional models that serve form-finding and performance capacity analysis functions; (b) scaled rapid prototype models for checking geometric and topological coherency of larger assemblies of elements while also serving form-finding purposes; and (c) full-scale prototypes that serve to investigate manufacturing and assembly methods as well as performance capacities.

5.3.3 From exploitation to exploration

The shift has also expanded to challenge the exploitation of computation. But the exploitation phase has already passed, so architects are now focusing on using computation as an exploratory medium to reveal more possibilities and expand limitations. The processes of architectural design have shifted from exploitation of computers to exploration through computers. Benjamin (2012, p. 23) argues that computation is a way to explore rather than to exploit, to creatively search within wide-ranging possibilities rather than being stuck in narrow possibilities. Computation has enabled new conceptual, formal and tectonic explorations, focusing on the emergent and
adaptive properties of forms. Shifting the process from “making of form” to “finding of form” has replaced stable by variable, and singularity by multiplicity (Kolarevic 2004b, p. 13).

To make the exploration happen, architects should know how they will think and how design is developed. Computers are exploratory machines to uncover hidden ideas and solutions. Terzidis and Vakalo (1992, p. 4) state that all computer operations are very similar to human thinking, which suggests that design could be explored as a mental process. To do that, it is better to perform all operations through computers independently without human intervention, starting from running the scripts until results are obtained. As a result, designers can negotiate the decision-making process via computers. The designer must be an active participant in the process of software creation – not necessarily a programmer, though working in collaboration with programmers – they must define the design ideas encoded as generative rules, which would result in positive creative feedback between the system and designers (Janssen 2006, p. 52). This will allow architectural exploration which deepens the investigations rather than merely relying on computers as a convenient tool.

This indicates that computer techniques in architectural design range from representation and visualisation to coding or scripting, where custom algorithms are used as a design system to generate geometrical output from numerical input. This way of using computers accounts for the shift and expands the architect’s ability and imagination.

5.4 Architects and digital design techniques frontiers

In digital design techniques, designers need to be aware of and increase their competency in digital aspects, including but not limited to algorithms and geometric calculations, fabrication of the machines and materials. Despite the significant role of the digital media, architectural designers remain the central operators and thinkers in design processes. Based on that, the frontiers between architects and digital design techniques are twofold. First, architects need to be qualified and skilled to access the computational capacity to
get the most out of it. Second, they are still the “decision-makers” who design the design process – designing design.

5.4.1 Algorithms and geometric calculations

In terms of algorithms and geometric characteristics, architects now need to understand the relationship between architectural design, computation and algorithms, and to be able to use them to serve their design goals and objectives. In computing, algorithms are procedures to transform inputs into outputs. In architecture algorithms are used to formalise the design process as procedures and instructions to produce geometries (Burry & Burry 2010, p. 252). Algorithms are important to create functions and instructions; they are also a crucial part of the geometric traits. When architects want to create a computational geometry it is better for them to know its algorithms, even if it is ready to use as a function in the software. As a result, sufficient knowledge is desirable in fields such as catenary models, cellular automation, curvature, developable surfaces, dynamic relaxation, elliptical geometry, emergence, fluid dynamic, fractals, hyperbolic geometry, immersion, inversion, Lindenmayer systems, minimal surfaces, non-Euclidean geometry, nonlinearity, non-uniform rational B-splines, recursion, system dynamics, topological transformation, topology models, and Voronoi diagrams. To understand the algorithms and geometry architects need to look at their mathematical and logical composition before using them.

Burry and Burry (2010, p. 7) argue that the mathematical processing of the algorithms is usually overlooked or deliberately concealed in commercial design software. For example, while using the software is a series of mouse clicks and keyboard strokes, behind that are very fast complex mathematical operations. Using algorithms and computation in architecture produces more options (forms) resulting from a range of constraints. Within this process the algorithms are driven to meet the designer’s intentions to eventually find the final form. At the same time, it follows the geometric constraints that require strong understandings of the relationship between design, computation and algorithms. The examples presented by Burry and Burry (2010), such as mathematical surfaces and seriality, chaos, complexity, emergence, packing, tiling and topology, show
how to understand and use these mathematical and geometric concepts through computation to help find new and unique solutions.

Architects need to know that using these techniques are more than simply a set of formal software with ready to use commands and icons. They also need to know that there are a new range of emerging terms of algorithms and geometry. They need to know that the design processes and techniques have shifted towards generative, self-organisation and optimisation, which are different from the traditional concepts and techniques. This shift is defined when the architects add the possibilities of scripting (generative techniques such as multi-agent systems or genetic algorithms). This imposes a significant shift from the traditional top-down forms of control to more fluid possibilities of a bottom-up approach. However, this shift is usually permeated with hardship, mistakes, errors and frustration especially at the beginning.

Using algorithms and geometric properties in scripting is a new knowledge that architects need to obtain. They need to be skilled in using algorithms, geometric calculations, and scripting languages and logic. According to Saud Nassir, a PhD candidate in computer science (interviewed 2015) learning programming skills requires different knowledge. This will move architects from an architectural design environment to a programming environment, which will be very hard. Architects need to learn to master using the commercial software plus using programming languages. For example, they need to learn how to use Rhino and Python or Maya and Maya Script.

One of the challenges of using algorithms and geometries is combining designing and scripting abilities. The other challenge may be the algorithmic activities, based on parameters and rules that allow design strategies which are different from the conventional design strategies (Lee, Gu & Williams 2014).
5.4.2 Fabrication, its machines and materials

Fabrication plays an important role in digital design with deep connection to industries, technologies and materials. Fabrication machines are devices that can automatically transfer digital objects from the design world into material realisation (Mitchell 2004, p. 78). With fabrication technologies, architects can shift the design process to be material, structure and form-finding, which is what Oxman and Oxman (2014, p. 302) are arguing for.

Hensel and Menges (2006, pp. 37, 38) declare that in the 1950s the United States military introduced numerical control as a machine of metalwork to break the limitation of mass production. In the following decades computer numerical control was introduced to produce a wider range of material and scales. This happened with the increase use of computer-aided design applications. Hensel and Menges (2006, p. 38) uphold that once the potential of computer numerical control is understood as a key aspect, the integration of materialisation and form-generation becomes clear and essential. This suggests embedding the making of constraints in the material systems to allow for the exploration of material self-organisation and assembly logics.

A three dimensional digital model of building can easily be cut by the computer numerical control machine which requires less control and can create millions of copies of identical and non-identical elements. The functionalities of computer numerical control machines can be grouped into three categories: cutting, subtractive and additive (Kolarevic 2004c, pp. 34-37; Krauel, Noden & George 2010, pp. 12, 13). Usually, cutting happens with two dimensional elements. A flat sheet of almost any material can be cut, and the common cutting technologies are laser, water-jet and plasma. Subtraction is the removal of layers of the volume of the material to create a form; the removal could be mechanical or chemical, but it also depends on the freedom of the milling tool. For example, four or five axis tools make forms that are more complex. Additive, or as it is known by different names like 3D printing, is a way of adding modelling material layer-by-layer, and the only limitation of this technology is scale as it cannot create big objects. But now 3D printing is used to create large objects such as cars and houses.
Most of the recent studies have focused on the translation and/or realisation of digital models to one physical prototype. As a result of considering function and materiality in relation to manufacturing and production, some fabrication and designing techniques appeared as a response to these technologies. These, for example, include but are not limited to the following: cross segmentation, accumulation, frameworks, loops, folding, twisting, lofting, triangulation, drilling, knotting and framing (Agkathidis 2012; Agkathidis et al. 2010).

These techniques and others became available and affordable; they are no longer expensive and are more efficient than traditional techniques. Each time a new fabrication technology is invented and becomes available, a new architecture style or approach will appear and make its impact. The new designing and production technologies are making an irreversible impact on the development of architectural practice today and will continue to do so (Agkathidis 2012, p. 6).

5.5 Coding and scripting

Rocker (2006, p. 18) notes that “today, when architects calculate and exercise their thoughts, everything turns into algorithms! Computation, the writing and rewriting of code through simple rules, plays an ever-increasing role in architecture”.

5.5.1 Understanding coding language

It is important for architects to understand coding and scripting languages and techniques, especially when commercial software does not fulfil the designer’s desires and the design requirements. Architects are able to lay down working procedures that seem natural; they may also have a basic understanding of computer processes and languages. Thus, the development of scripting languages and machine codes required a careful understanding of the structure of language and the coding of information (Frazer 1995, p. 23). The evolution in architects’ computational skills is a result of the technological development and the way of using technologies in architectural design. According to Shea (2004, p.
100), it is not expected that architects become experts in programming, but to take advantage of the full capacity of computers, they need to understand and use coding languages. For Krauel, Noden and George (2010, p. 1), scripting involves the use of computer programming in architectural design. In doing so architects do not limit themselves to the use of ready-to-use commercial software, but they explore the possibilities of creating forms through algorithmic processes.

According to Reas (2004, p. 44), programming is:

…an exact set of instructions that tell the computer precisely what to do. It is a sequence of formatted words and symbols that encodes ideas into a structure that can be interpreted by a machine. Every programming language is a collection of words and symbols ‘syntax’ with a set of rules defining their use ‘semantics’. Each language allows people to convert their ideas into code in different ways.

This is a technical explanation of coding, but for Burry (2011, p. 9), scripting language is often the equivalent of programming language and it means supplying the computer with highly specific instructions to interact with. Oxman and Oxman (2014, p. 363) state that scripting is the writing of short programs within the framework of existing modelling packages like Python in Rhino and MEL in Maya. All of these scripting descriptions are a programming language to describe a set of instructions for the computer.

Architects need to use computers as a problem-solving tool. They need to use the generative capacity of computers, which means that design will be described with the use of algorithms. These algorithms will be translated to computers using coding languages, which make using such behaviours possible.

These scripted behaviours are not universal, so any designer can use them to generate an output. Sometimes coding is characterised by selectivity; it is written to produce a specific result at a particular time in the design of projects (Doscher 2012, p. 207). But that does not mean that the computer will do the complete job. Architects cannot just set up the rules and let computers do the job for them. In a few cases, designing rules can be set up
perfectly to run on their own. Indeed the process needs to be explored, played and mastered with care and cleverness (McCullough 2006, p. 184).

5.5.2 The benefit of coding

With coding and scripting it is possible to produce endless forms, geometries and materials in less time. Coding is an investment of intellectual effort, time and money; it is an insight to expand a few parameters into many details. A small pace of coding can save a large amount of model construction time, and it is better if it can be repeated to generate a variety of solutions in different contexts (Mitchell 2004, p. 75). Kwinter and Payne (2008, p. 225) argue that scripting is the simple and efficient way to produce differentiated repetition in digital modelling which requires great time and effort. Thus, scripting is an effective tool and important technique to process digital design. Payne (2008, p. 225) believes that scripting should be backgrounded as playing a supporting role in recent works.

Although learning coding is not easy, it is a vital aspect to achieve creativity. Restrictions on forms’ construction and characters through scripting does not limit creativity. According to McCullough (2006, p. 12), every medium has its language, types and genres which allows for the richest expressions and widens the chances of achieving more unique and creative results. Programming is creative because, according to Simon (2004, p. 46), what motivates the designer to program is breaking the boundaries of commercial software and activating the designer’s model of inventing a new kind of software. Programming is creative thinking because, as Simon (2004, p. 46) asserts, writing code is also writing something to create, the code becomes a reality-making machine, and it is interesting to watch what it will create.

5.5.3 Access to coding

Coding maximises the possibilities of creativity. In most computer-aided design software, there are some modelling commands ready to use by clicking an icon. These commands are for designers with conceptual understanding of geometry, and they require some skills
to use, but they provide exploration that allows for geometric freedom (Aish 2004, p. 246). In the same computer-aided design software, there are other functions that are not accessible for architects through the interface. These functions are for designers with programming skills, and are extremely powerful (Aish 2004, p. 246). The question of what will happen if the software providers do not offer architects the right tools they need was asked by Ulrich Flemming in an interview (Kolarevic 2004a, p. 296). Flemming argues that programming is a crafted artefact, so the only software worth using is software with programming and customising flexibility. That gives a hint to the importance of mastering this skill to conquer the current design phenomenon. But Payne (2008, p. 234) claims that mastering scripting requires a higher level of technical expertise which takes years to achieve. It is not something quick and easy, it needs certain knowledge in mathematics, coding language and software skills.

According to McCullough (2006, pp. 184-187), in 1986 computer use in architecture was limited to the specialists in computing and architecture in the age of shape grammar; they were using coding language like Lisp in AutoCAD. In the 1990s, the focus was to develop a graphical interface which makes computing accessible to all architects. As a result, the majority of designers were non-coders. By 1996, architectural intentions were directed towards rediscovering programming, albeit in different form from 1986. Included but not limited to the following, parametric design and other coding languages (such as Java processing) were introduced, in conjunction with some educational courses (as at MIT in the United States).

As a result of rediscovering programming in architecture, most architecture circles (universities and practices) set up digital research units to benefit from these technological techniques. In addition, domains with form-making interest such as architecture, engineering and fabrication have already begun to use, adapt and expand the generic software tools. This is reflected in most design firms having their own coding employees, because it adds an extra level to the design thinking (McCullough 2006, p. 183). Research by design then emerged as a multidisciplinary cooperation medium. Oxman and Oxman (2014, p. 4) claim that in the age of scripting, research by design has emerged from many
of the leading practices – in the United Kingdom, Germany and Japan – by establishing their own multidisciplinary research units to exploit computational geometry. Because it is hard and multidisciplinary, architects need help to enter this era. Now scripters work at a deeper level than a decade ago, but for designers to work with scripting they need assistance in code writing and this may take time (Burry 2011, p. 31).

Even though architects can master coding, that does not mean handing over all designing activities and processes to computers. Computers are powerful tools especially in storing and calculation, but they need human thinking to find solutions and describe them precisely. In architectural design, computers need a team of knowledgeable experts in all the design stages who are able to define a solution even if it is very complex (Scheurer 2012, p. 116). Coding provides wider options in design generation and manufacturing. As a result, computational designers can now write codes to generate results and to generate different codes for other systems to interpret (Doscher 2012, p. 208), which means having access to wider design circles including physical models, engineering analysis, building information modelling, virtual building models, and any type of digital information influencing design. At the same time, it offers an open source through the internet to all interested architects. The power of scripting is enhanced by the internet which provides a platform to share knowledge in a “dynamic reference hive”, where the accumulation of information is far greater than the sum of individuals (Burry 2011, p. 10).

5.5.4 Techniques of coding

As coding is an open source and shared knowledge, it consists of a wide range of techniques, languages and interfaces in which each code is used to deal with a particular problem. These techniques are developed systematically. There was a gradual progression from machine code to high-level coding language like Python and Lisp (Reas 2004, p. 44). As an example of these techniques, the L-system is one of the common techniques of coding that often deal with biological forms. Technically, it is an algorithmic code to mimic or simulate branching in a way known as rewriting systems (Dollens 2005, p. 78). This is when the code system writes and rewrites itself based on the information that has
been given by the designer and then re-given by the system itself. Usually architects start by planning the information to be fed to computers, but they can always change it during the generation process. McCullough (2006, p. 183) argues that architects start by setting up some rules to generate forms, then they run themes to see the outcome, then they tweak them again and again to get the desired form. Sometimes they add a simple interface, just a few buttons and sliders, to change the input variables fairly quickly.

Along with scripting, plug-ins are developed as part of the current computer-aided design software. The development of plug-ins is very similar to scripting, but they are packaged as small pieces of software and became part of the design environment (Davis & Peters 2013, p. 126). Nevertheless, the power of scripting and its techniques also suffers from limitation as each script is written to solve a particular problem and does not suit other projects unless it is modified dramatically. In that case, a custom code is written to solve the design problem of a particular project, and it is not expected to be applicable to other projects unless it is modified significantly; this code is known as disposable (Marble 2012, p. 226). Accordingly, a disposable code is designed to deal with specific design development, not the code itself. In addition, Burry (2011, p. 32) describes scripting as a “scripting culture”, and he defines three scripting cultures: scripting for productivity, scripting for experimentation in coding as research, and scripting for creative discovery. In this case, scripting techniques could be directed toward one of these three scripting cultures.

5.5.5 Algorithms in coding

Scripting techniques are linked strongly to the use of algorithms in scripting language to allow architects to access the calculations capacity of computers. According to Dunn (2012, p. 61), algorithms are a very empowering method that work as a mediator between designer and computer. Dunn suggests two factors to consider. First, the process of algorithm must be specified gradually in order to build its logic effectively. Second, the accuracy of the algorithms, for if there is just one simple error such as a character, the script will not run properly or not at all. Scheurer (2012, p. 111) argues that a missing semicolon will prevent the whole program from running or lead to unexpected wrong
results. This highlights the significance of the architects’ mindset and practice, as they work usually with flexibility, not precision. Moreover, it is crucial to know how a set of rules and instructions create something that the designer does not expect. Simon (2004, p. 46) states that this could be possible through genetic algorithms where the interactions of random, unusual emergence and independent objects occur.

5.5.6 Relationship between architects and scripting – computation

Scripting is a computing program that changes the designer’s role from tool user to toolmaker. The software which is modified by designers through scripting provides more possibilities of creative speculation than using software in the way manufacturers intended it to be used (Burry 2011, p. 9). Instead of drawing a line by clicking and dragging, architects can now write custom program “script” to generate lines based on a set of rules. This will extend the computer-aided design functionality by developing custom tools that allow for innovation (Scheurer 2012, p. 114). Instead of producing digital models, designers need to write a program, which generates a complex geometry. That means architects need to interpret algorithmic thinking to understand the results of the generating code and to know how to modify it in order to explore new possibilities (Peters 2013, p. 10).

Architects can explore and generate architectural spaces and concepts via writing and modifying algorithmic codes, which relate to element placement, configuration and relationship. This places making these tools within the design itself (Peters 2013, p. 11). Where some software may lack some important features, it points to the need for scripting. For example, in the De L’Orme Pavilion in Barcelona, Bernard Cache (2003) states that because of the lack of projective geometry in the current computer-aided design software, the team need to implement this procedure using scripting (Cache 2003, p. 154). As a result, architects need to know enough about coding as they can gain information about it from others. According to Davis and Peters (2013, p. 131), architects need to understand and know enough in the scripting world, but not to know everything; their role will be diversified by adopting coding and design coordination.
The idea of knowing enough had increased the number of architects using scripting. Davis and Peters (2013, p. 126) believe that the number of architects using scripting is increasing, and those architects are able to create geometries and find forms through sketching with codes. The recommended way to start is by writing small and simple scripts, as there are some challenges ahead. According to Scheurer (2010, p. 289), scripting has three challenges. First, architects need to know how to program and designers need to deal with unambiguity rather than the usual ambiguity. Second, abstracting a given problem by finding a common definition for all different details is difficult. Third, knowledge about geometry is needed, as all mathematical equations are hidden behind computer-aided design interfaces, and architects need to be able to play with them.

The current generation of architects is able to digitally experiment with most – if not all – of the architectural design aspects, and many of the current leading circles have become digitally oriented. Although scripting offers interactions between the designer and computer by automating routine aspects and repetitive activities to facilitate an endless range of potential solutions for the same amount of time, scripting still remains challenging. Many designers believe and are aware of the power and potential of scripting, but they still see scripting as difficult (Burry 2011, pp. 10, 27).

5.5.7 Using scripting

(Burry 2011, p. 17) notes that “scripting is a driving force for 21st century architectural thinking”. For Burry (2011, p. 27), scripting is a road without clear signposts. He asks why architects want to join scripting. Are they joining mainstream alternative practice, a club, a movement, or counterculture? Burry (2011, pp. 34, 35) states that the difference between scripting oneself and using others to script is not clear at all. He suggests that when a designer works with others who are scripters, there are three models to follow. First, in the most prevalent model, through studio teaching, the project designer shares knowledge – sometimes pieces of code – with the scripter, who is working with more complex projects. The studio and the project benefit from the experience of the project leader. Second, the designer works closely with the programming expert whose
background is not design but code writing. The third model is a variation of the second, where a collaborator works between designer and scripter.

To use coding, architects must know how to use computers in this way. Coding is the process of describing all of the steps that a computer must perform to complete a task. Computers are not like people: they can do only one task at a time, and they cannot guess or interpret meanings if they are not described exactly (Reas, McWilliams & Barendse 2010, p. 15). In other words, describing to a computer the steps it must perform requires much more detail than describing it to another person. It is commonly known that computers are stupid. That means there is only one interpretation for every piece of code, and before computers run a code they need to convert it from the human format to the computer format or machine code (Reas, McWilliams & Barendse 2010, p. 15).

To take steps into coding, architects need to know some terms and what they mean, such as statements, sequences, conditions and loops. Statements are a combination of instructions that perform an action. Sequences are a list of statements to be performed in order. Conditions are the way to choose between alternative sequences. Loops are a sequence of instructions that is repeated.

Shaw (2011), in his book *Learn Python The Hard Way*, presents 52 exercises to get architects to start coding, and describes coding in this phrase: “the hard way is easier”. Tables 3 and 4 show some basic coding examples that architects usually use to start coding with Python. Then, the exercises become more advanced and sophisticated to end up with reasonable knowledge and skills.
**Table 3: Coding exercise 1: A good first program, from Shaw (2011, p. 13)**

<table>
<thead>
<tr>
<th>Code</th>
<th>What you should see</th>
</tr>
</thead>
<tbody>
<tr>
<td>print &quot;Hello World!&quot;</td>
<td>$ python ex1.py</td>
</tr>
<tr>
<td>print &quot;Hello Again&quot;</td>
<td>Hello World!</td>
</tr>
<tr>
<td>print &quot;I like typing this.&quot;</td>
<td>Hello Again</td>
</tr>
<tr>
<td>print &quot;This is fun.&quot;</td>
<td>I like typing this.</td>
</tr>
<tr>
<td>print 'Yay! Printing.'</td>
<td>This is fun.</td>
</tr>
<tr>
<td>print &quot;I'd much rather you 'not'.&quot;</td>
<td>Yay! Printing.</td>
</tr>
<tr>
<td>print 'I &quot;said&quot; do not touch this.'</td>
<td>I'd much rather you 'not'.</td>
</tr>
<tr>
<td></td>
<td>I &quot;said&quot; do not touch this.</td>
</tr>
</tbody>
</table>

$ python ex1.py

**Table 4: Coding exercise 32: Loops and lists, from Shaw (2011, pp. 95-96)**

<table>
<thead>
<tr>
<th>Code</th>
<th>What you should see</th>
</tr>
</thead>
<tbody>
<tr>
<td>the_count = [1, 2, 3, 4, 5]</td>
<td>$ python ex32.py</td>
</tr>
<tr>
<td>fruits = ['apples', 'oranges', 'pears', 'apricots']</td>
<td>This is count 1</td>
</tr>
<tr>
<td>change = [1, 'pennies', 2, 'dimes', 3, 'quarters']</td>
<td>This is count 2</td>
</tr>
<tr>
<td></td>
<td>This is count 3</td>
</tr>
<tr>
<td></td>
<td>This is count 4</td>
</tr>
<tr>
<td></td>
<td>This is count 5</td>
</tr>
<tr>
<td># this first kind of for-loop goes through a list</td>
<td>A fruit of type: apples</td>
</tr>
<tr>
<td>for number in the_count:</td>
<td>A fruit of type: oranges</td>
</tr>
<tr>
<td>print &quot;This is count %d&quot; % number</td>
<td>A fruit of type: pears</td>
</tr>
<tr>
<td></td>
<td>A fruit of type: apricots</td>
</tr>
<tr>
<td># same as above</td>
<td>I got 1</td>
</tr>
<tr>
<td>for fruit in fruits:</td>
<td>I got 'pennies'</td>
</tr>
<tr>
<td>print &quot;A fruit of type: %s&quot; % fruit</td>
<td>I got 2</td>
</tr>
<tr>
<td></td>
<td>I got 'dimes'</td>
</tr>
<tr>
<td></td>
<td>I got 3</td>
</tr>
<tr>
<td></td>
<td>I got 'quarters'</td>
</tr>
<tr>
<td></td>
<td>Adding 0 to the list.</td>
</tr>
<tr>
<td></td>
<td>Adding 1 to the list.</td>
</tr>
<tr>
<td></td>
<td>Adding 3 to the list.</td>
</tr>
<tr>
<td></td>
<td>Adding 4 to the list.</td>
</tr>
<tr>
<td></td>
<td>Adding 5 to the list.</td>
</tr>
<tr>
<td></td>
<td>Element was: 0</td>
</tr>
<tr>
<td></td>
<td>Element was: 1</td>
</tr>
<tr>
<td></td>
<td>Element was: 2</td>
</tr>
<tr>
<td></td>
<td>Element was: 3</td>
</tr>
<tr>
<td></td>
<td>Element was: 4</td>
</tr>
<tr>
<td></td>
<td>Element was: 5</td>
</tr>
</tbody>
</table>

$ python ex32.py

$ python ex1.py

$
5.6 Contemporary advanced architecture: how architects conceive it and what it looks like

The question is no longer whether digital technology is good or bad for design; it is rather about how people conceive it, what its outcome looks like, and the direction architecture is taking under the computer’s influence.

5.6.1 How architects conceive contemporary advanced architecture

There are two ways of considering the use of computers in architectural design: computer-aided design and computational design. According to Menges (2012, pp. 1, 2), computer-aided design uses computers as a helpful tool based on geometric information that represents architecture as a metric construct of lines, points, surfaces and solids. All this information was drawn manually, but now it is transformed into digital. It is a method of accumulating information and encapsulating it as explicit and symbolic representation, so the amount of information never surpasses the supplied drawing or modelling steps, and in this way computer-aided design does not change the way architects design “computerisation” (Menges 2012, pp. 1, 2). On the contrary, computational design is completely different. Menges (2012, p. 2) argues that computation allows designers to process information such that new information is created. Menges (2012, p. 2) points out that the transition from computer-aided design to computation requires a shift “(a) [from] modelling objects to modelling processes, (b) from designing shape to designing behaviour, (c) from defining static digital constructs to defining computing systems capable of reciprocal data exchange and feedback information”.

The current architectural revolution is a consequence of using computers in architectural design. For Picon (2010, p. 10), the immediate impact of using computers in design is manipulating complex geometries, such as blobs and folded surfaces, giving an impression that architecture is entering a new stage. Now, architects are trying to go beyond the computer-produced forms by using parametric design principles, programming and algorithms instead of commercial software. Alternatively, Kotnik (2010, p. 3) argues that the digital trend is leading architecture to an intellectual
revolution, and will change the way architects think, even though few people know about it. That is an indication of what the so-called digital culture in architecture entails. Using computers in architectural design could be considered as a culture because it is synonymous with virtual habits and rituals, and because it influences our conduct and our representations of the world (Picon 2010, p. 50).

Using digital to produce something new and spectacular is only one aspect of a bigger issue. This large issue could embrace other important aspects, which architects need to consider and understand. They need to grasp the difference between the top-down and bottom-up designing approaches; they also need to know how to reduce the whole to parts, and they need to know how to change from local interaction patterns to overall global arrangement of the parts (Kotnik 2010, p. 3), as shown in Figure 4.

Picon (2010, pp. 12, 13) identifies three impressions from the development of the computer’s use in architectural design. Firstly, the development of digital techniques has reshaped our experience of the physical world. That means the use of digital equipment
not only redefined our vision through digital zooming, but also our approach to hearing and touching. The second is the question of the individual. By the emergence of the digital culture in architecture, importance is given to the individual and their preferences and choices. That means digital architecture is becoming more dependent on the contemporary individual interest of sensory dimension and the mediations established between the individual and the environment. The third is the growing importance taken by occurrences, events and scenarios. That refers to all events – real or virtual, scheduled or simply envisaged – which ensure achieving the expected performance, including but not limited to events like circulation systems and scenarios of urban development in design. Using digital techniques provides a better understanding and measurement of these events, occurrences and scenarios than using traditional geometric tools and materials. Although this may be true and may open up new architectural possibilities, for Picon (2010, p. 14) this may cause some pitfalls or dangers. Materiality could become a deadlock, and due to individuality collective values may become difficult to preserve and we could lose our historical changes as the past does not matter anymore. Picon claims that this will come with the temptation of satisfying senses and fulfilling global requirements without asking about the limitations of digital.

Using architectural digital design techniques is conceived in different ways. For Picon (2010, p. 38), using digital in architectural design is conceived as transforming architectural design into computational practice. That implies the hybridisation of reality and virtuality, as in predictability and unpredictability, standardisation and uniqueness (Picon 2010, pp. 50, 51). It is also conceived as a method of processing information, which gives birth to patterns that could be observed both in nature and in human organisations, and will fill the gap between the natural and artificial, spatial and social (Picon 2010, pp. 33, 35). Other scholars have conceived it differently. Parisi (2012, p. 166) claims that using digital software will change the Euclidean grid to a morphogenetic form of relations changing over time, while Dikova (2012, p. 17) argues that when architectural design follows technological approaches, a new morphology and new context will emerge, and as a result, design might turn into algorithms – information patterns. Walliss et al. (2014, p. 72) emphasise that digital designing technologies provide designers with new techniques and processes to conceive and construct forms and
systems, and to achieve a higher level of complexity in performance, representation, spatiality and materiality. Finally, Bratton (2009, p. 92) believes that architects should stop designing new buildings and rather focus on building new software programs to make better use of existing structures and systems.

It is hard to find scholars who are against using digital techniques in architectural design. Most scholars who seem to be antagonistic are worried about some aspect or the consequences of using digital techniques. For example, even though using digital techniques will put few parameters under the designer’s control, and greater parameters under the computer’s control (that makes the design more efficient), the designers’ freedom will be limited (Mitchell 2004, p. 79). Most of these concerns started to disappear as the use of digital techniques became indispensable. Opposition against using computers in architectural design was common in the late 1990s until the early 2000s, but now it is hard to find such opposition. Frampton (1996) argues that with digital, architecture became a question of forms and buildings generated on a screen, but the designs will be utopian fantasies if they do not meet the requirements of the real world. Maeda (1999, p. 10) was perhaps one of the last scholars who talked about either rejecting or opposing the digital.

5.6.2 What does contemporary advanced architecture look like

Before digital technologies were used in architectural design, buildings’ forms were regular and simply consisted of straight and sometimes curved lines. Kolarevic (2004a, pp. 6, 7) argues that complex curves were ignored by architects until the 1990s. This ignorance was due to a shortage in technological equipment, particularly the three dimensional software which makes smooth curves easily “smooth architecture”. Kolarevic used the term “topology” to describe digital outcomes whether they are curvilinear (blobby) or rectilinear (boxy), and they should be a result of the surrounding circumstances (morphological, cultural, tectonic, material, economic and environmental). For Kolarevic, using digital technologies makes complex forms possible. In contrast, Picon (2010, p. 10) describes the digital techniques’ outcome as the crisis of traditional tectonic, which represents a new meaning of building parts. From his point of view, these
crises are being manifested in famous buildings such as Toyo Ito Sendai Mediatheque, Foreign Office Architects’ Yokohama Terminal in Japan or Herzog & de Meuron’s Beijing Olympic Stadium in China. Similarly, Haddad (2012, p. 33) highlights that using these techniques may lead to “extremely sophisticated yet very simple forms”.

For the most part, the computational outcomes are linked to algorithmic logic and emerge as a consequence of the surrounding environment. Usually the resultant forms are linked to computational terms and/or sometimes to the fabrication of new techniques. According to Parisi (2012, pp. 167, 168), computation in architecture relies on the computational control of the capacities of algorithms to create the perception of spaces. Thus its outcomes have emerged as folds, morphologies, smooth surfaces and real-time evolving structures. Parisi (2012, p. 169) also claims that the smooth architecture of computation is the result of continuous changing by responding to real data from the given environment. This shows that the outcomes are mostly different and complex. In more detail, Agkathidis (2012, p. 2) points out that contemporary building forms could be twisted, lofted, triangulated, drilled, knotted and/or framed. These forms could be constructed using digital techniques such as cross segmentation, accumulation, frameworks, loops and foldings, which also indicate what new architectural forms look like (Agkathidis et al. 2010, p. 3). Table 5 shows examples of each of these forms.
Table 5: Examples of contemporary building forms

<table>
<thead>
<tr>
<th>Architectural forms</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twisted</td>
<td>Turning Torso 2005 in Sweden</td>
</tr>
<tr>
<td>Lofted</td>
<td>Petaling Jaya Commercial City 2011 in Kuala Lumpur, Malaysia</td>
</tr>
<tr>
<td>Triangulated</td>
<td>Tel Aviv Museum of Art 2011 in Israel</td>
</tr>
</tbody>
</table>
Drilled
BanQ 2008 in Boston, United States

Knot
The Knot House 2011 in Sydney, Australia

Framed and Cross Segmentation
Metropol Parasol 2011 in Sevilla, Spain

Accumulation
White Noise 2011 in Maribor, Slovenia
Frameworks
(Irregular Triangulation)

ABC Museum 2011 in Madrid, Spain

Loops

Mobius Strip Building 2013 in Taiwan

Folding

Folded-Plate Hut 2009 in Osaka, Japan
5.7 Outcome of digital design techniques in Saudi Arabia

This section previews some current Saudi architectural projects, specifically the ones that have been designed as iconic buildings by foreign or international architects. Saudi Arabia has a unique architectural heritage that has been developed over centuries. Historically, designs and materials were dictated by traditions, climate, geography and available resources. In contemporary Saudi architecture, Saudi architects are looking to connect their traditional principles and Islamic concepts to the modern context. However, the majority of the new iconic Saudi buildings have been designed by international architects. This poses a challenge to foreign architects, as they need to discover Saudi architecture’s characteristics to achieve them.

The King Abdulaziz Centre for World Culture (see Figure 5) and the Qasr Al Hokm Downtown Metro Station (see Figure 6) are two striking examples designed by Snøhetta, an international architecture, landscape architecture, interior design and brand design office based in Oslo, Norway and New York City, United States. The King Abdulaziz Centre for World Culture in Dhahran began construction in 2007 and is expected to be completed in 2016. It is an initiative by the Saudi Aramco Oil Company to promote cultural development within the Kingdom (Snøhetta 2015a). The Qasr Al Hokm Downtown Metro Station in Riyadh was started in 2012 and will be completed in 2017. The Riyadh Development Authority aims to build a signature metro station to be an efficient public transport hub in a densely populated city to reduce traffic congestion and to provide a vibrant public space for all Riyadh citizens to enjoy (Snøhetta 2015b).
The Museum of the Built Environment by FXFOWLE (see Figure 7) and the King Abdullah Financial District Men’s and Women’s Portal Spas by Worksbureau (see Figure 8) are both designed by international architecture offices from the United States, and both projects are located in the King Abdullah Financial District. The Museum of the Built Environment was designed in 2014 at the request of the Rayadah Investment Company.
The form was hewed from natural rocks, which are formed by erosion and other surrounding geographical factors (Fefowle 2015), whereas the King Abdullah Financial District Men’s and Women’s Portal Spas was designed in 2011-2012, also at the request of the Rayadah Investment Company, and was completed in 2014. The project is seen as geologic formations rising from the land, and they hover over a stone base (Worksbureau 2015).

Figure 7: The Museum of the Built Environment, Riyadh
SOM and HOK are popular international architecture offices in Saudi architectural circles. They have designed a reasonable number of buildings, especially during the last decade. Recently, SOM designed the King Abdullah Financial District Conference Centre (see Figure 9) while HOK designed the King Abdullah Petroleum Studies and Research Centre Community Mosque (see Figure 10). SOM designed the King Abdullah Financial District Conference Centre at the request of the Rayadah Investment Company, opened in 2014. The building is designed as an extension of the angular desert landscape, and its organic profile and faceted skin stitch together the building and the adjacent terrain (SOM 2015). In contrast, the King Abdullah Petroleum Studies and Research Centre Community Mosque was designed in 2014 by non-Saudi architects (HOK 2015) to be a new Saudi mosque experience. It is important to know that, even though HOK is an international office, it succeeded in meeting all the mosque’s design requirements.
Figure 9: King Abdullah Financial District Conference Centre, Riyadh

Figure 10: King Abdullah Petroleum Studies and Research Centre Community Mosque, Riyadh
The King Abdullah Financial District Metro Station in Saudi Arabia (see Figure 11) and King Abdullah Petroleum Studies and Research Centre (see Figure 12) are the first two buildings designed by Zaha Hadid in Saudi Arabia. The Metro Station will open in 2017 with a configuration of three-dimensional lattice defined by a sequence of opposing sine-waves which are generated from the repetition and frequency variation of the station’s daily traffic flows and act as the spine for the building’s circulation (Hadid 2015a). Similarly, the King Abdullah Petroleum Studies and Research Centre was designed at the request of Saudi Aramco in 2009 and is still under construction. The centre is located in a desert landscape, emerging as a cluster of crystalline forms which evolve in response to environmental conditions (Hadid 2015b).

Figure 11: King Abdullah Financial District Metro Station, Riyadh
Figure 12: King Abdullah Petroleum Studies and Research Centre, Riyadh
5.8 Conclusion

In summary, this chapter highlights what constitutes digital design techniques. It provides a platform for architects who intend to enter the world of digital architecture, especially those who are unfamiliar with these techniques, how to use them, what they look like, what skills they need to learn, and what is the expected outcome. It discussed crucial aspects such as architectural digital generative behaviours, how design processes have shifted by using these techniques, the new digital frontiers that architects need to know, coding and scripting languages, and contemporary advanced architecture – how architects conceive it and what it looks like. The last section of this chapter reviewed some recent examples of digital design techniques and their outcome in Saudi Arabia. This allows Saudi architects to see the implementation of these techniques in Saudi Arabia by international or foreign architects. Whether or not Saudi architects are able to use digital design techniques is discussed in the remaining chapters.

Architectural digital generative behaviours are mostly sourced from nature. They are evolutionary behaviours, which allow designs to evolve through computational evolutionary search by means of algorithms to arrive at a variety of iterations. Architects need to explore generative mathematical concepts such as chaos, recursion, fractal, packing, tiling, flocks, schools, swarms and crowds to use these generative behaviours. The majority of these behaviours are controlled by self-organisation systems. Using these techniques has shifted the design processes. When architects add the computational possibilities, such as scripting and generative techniques, a broad shift has occurred, resulting in changes to architecture itself and the role of architects. Architects need to be familiar with the computational media skills and have the ability to integrate design, fabrication and construction. They also need to use computers as exploration, not exploitation, tools.

This implies new digital frontiers between architects and the use of digital design techniques. These frontiers manifest themselves in algorithms, geometric calculations, fabrication materials and machines. This investigates what is beyond the boundaries of traditional architecture. It is crucial to understand that using algorithms implies
procedures to transform input data into output architectural form. Furthermore, equally important is that fabrication machines and materials are one of the challenging aspects of digital design. Fabrication machines can automatically transfer digital forms from the design world into material realisation. Computer numerical control machines are the most popular with cutting, subtractive and additive techniques.

Despite the availability of computers and fabrication machines, the essence of computation is confirmed by coding and scripting languages. It is now fundamental for architects to understand coding languages, to know their benefits, how to access them, techniques, the role of algorithms in coding, their relationship to computation, and why and how to use scripting. As a result of these techniques, contemporary architectural practice has changed. For the majority of architects, digital design techniques outcomes are complex, sophisticated, curvilinear, rectilinear, smooth, and yet simple. They include twisted, lofted, triangulated, drilled, knot and/or framed forms.

To establish the need to accept the digital in Saudi culture, architects need to change the way they look at digital design; they need to know and understand that digital design is about computation, not computerisation. As these techniques may or may not be introduced to Saudi culture, Saudi architecture, and Saudi architectural education. Digital design techniques are yet to be introduced or fully used by Saudi architects.
Chapter 6: Perception of digital design techniques among Saudi architecture staff and students

6.1 Introduction

This study is qualitative and uses interview data to build up its argument and evidence. Section 6.2 explains the research methodology including the research strategy, system of inquiry, research methods and techniques. Section 6.3 focuses on the data analysis starting from coding systems to the data presentation. Section 6.4 shows the interview procedures. Section 6.5 provides a general overview of the perception – both positive and negative – of digital design techniques among Saudi architecture staff and students. Section 6.6 addresses digital design techniques from the interviewees’ cultural and architectural perspective. Section 6.7 identifies potentially different relationships between the technical aspect of digital design techniques and Saudi architecture.

6.2 Research methodology

6.2.1 Research strategy

In any system of inquiry there are various methodologies or choices for structuring the research. According to Groat and Wang (2002) the system of inquiry is a very general framework, containing the research strategy (methodology) and tactics (techniques). Figure 13 outlines the research structure based on Groat and Wang’s diagram. To correspond with this view, this study is developed under epistemology as its system of inquiry. The research’s strategy or methodology is qualitative, and it takes the ethnography approach as one of the qualitative research branches. The data collection tactics or techniques are interviews (fieldwork). The following process outlines the development of the research methodology:
6.2.2 System of inquiry

Each study has its system of inquiry that represents a different paradigm for making claims about knowledge. The system of inquiry of this study is epistemology which is the study of how a person obtains knowledge or, more generally, the theory of knowledge (DeRose 2005, p. 1). It usually addresses the question of what you know? and, how do you know? Honderich and Masters (2005, p. 123) explain epistemology questions as:

- the origin of knowledge;
- the place of experience in generating knowledge, and the place of reason in doing so;
- the relationship between knowledge and certainty, and between knowledge and impossibility of error;
- the possibility of universal skepticism; and
- the changing forms of knowledge that arise from new conceptualization of the world.

Steup (2005) notes “epistemology is the study of knowledge and justified belief”. It is linked to empiricism and verificationism as a part of building true and solid knowledge. Empiricism can be defined as “a broad-based philosophical position grounded on the fundamental assumption that all knowledge comes from experience and advocates the collection and evaluation of data” (Fellows & Liu 2009, p. 84), a position very similar to O’Leary’s definition (2004, p. 10), whereas the idea of verificationism is focusing on
“linking some sort of meaningfulness with (in principle) confirmation” (Creath 2011). Therefore, this study is based on answering the research question and assumptions, and on providing all the possible evidence, which is collected from various sources. It also depends on reality, building its claim on the basis of real data being collected from the study field, which is universities in Saudi Arabia. After answering the research questions, the research verifies them through analysis.

6.2.3 Research strategy and method

Method is the study of the process of inquiry (Kaplan 1973, p. 23). It focuses on the research process and it forms the overall plan of the research study. This research is guided by the qualitative research method which contains multiple approaches such as grounded theory and ethnography. Ethnography is the approach used for this study.

Denzin and Lincoln, authors of *The Discipline and Practice of Qualitative Research* (2000, pp. 4,5), offer a generic definition, which Groat and Wang (2002, p. 176) summarise as follows:

Qualitative research is multimethod in focus, involving an interpretive, naturalistic approach to its subject matter. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them. Qualitative research involves the studied use and collection of variety of empirical materials.

Based on the definition, Groat and Wang (2002, pp. 176-178) identified four crucial elements:

- an emphasis on natural settings: this means that the object of inquiry should not be removed from the venues that surround them – in other words, “reality”.
- focus on interpretation of meanings: by employing methodological practice that embraces interpretation and meaning in their context.
• focus on how the respondents make sense of their own circumstances: to present holistic portrayal of the setting or phenomenon under study as the respondents themselves understand it.

• the use of multiple tactics: the researcher can use multiple tactics, but not every tactic is exclusively qualitative.

As this research is mainly qualitative, it corresponds with the four elements above. Most data collection takes place in the Kingdom of Saudi Arabia, in particular in three Saudi universities. In terms of data interpretation and meanings, data is interpreted in accordance with the local meaning and by the researcher who is part of this context – as an architect and academic in Saudi Arabia. The respondents are an important part of architecture circles in Saudi Arabia; they are architecture school staff and students who describe the phenomenon as they are living with it. Finally, data is collected through interviews and focus groups.

Ethnography is adopted by a variety of disciplines such as sociology, organisational studies, educational research and cultural studies. Ethnography research is designed to explore cultural phenomena in its setting. Therefore, ethnography and case study research are very similar. According to Groat and Wang (2002, p. 182) ethnography “lays particular emphasis on the immersion of the researcher in a particular cultural context and on the attempt to ascertain how those living in that context interpret their situation”. Thus, ethnography is significant to this research as it relies on the participant’s view to collect data as a primary mode.

Why the research methods and approaches are qualitative and ethnographic? Because this study is related to cultural, social, educational, and theories, there is no need to use statistics, numbers or charts (Quantitative data) to answer the research questions. In this type of studies, qualitative methods are considered by many scholars and researchers, and will allow more investigations through some techniques such as interviews and focus
groups. Moreover, the reviewed literature does not have strong connections to the research method (does not influence the research methodology). This is due to a lack of technological research in Saudi culture, a lack of research on the development of computer use in Saudi Arabia architectural education, and the literature in Saudi architectural education is limited. Therefore, the literature review provides important information on knowing and understanding the new digital design techniques to Saudi culture. All the selected articles were talking about the role of digital design techniques in architectural design, its relation to mathematics, computation and generative systems, and digital theories and approaches in architectural design. The used literature established from the beginning of 1990 when computers started to influence the way architects think and design, and continued until 2015, showing the undergoing construction of some iconic buildings in Saudi Arabia.

6.2.4 Tactics and techniques

Based on the qualitative research characteristics mentioned above, the use of interviews and focus groups are the main tactics of this study. There are no exclusive tactics for qualitative research; any tactics are suitable as long as they support the research questions and the mode of the research design (Groat & Wang 2002, p. 178). Groat and Wang (2002, p. 11) define tactics as specific techniques used to collect data, whereas technique is defined as a way of collecting data (O'Leary 2004, p. 85). As there is little difference between the two terms in interpretation, the term tactic is used in this study.

The study hypothesises that digital design techniques will advance Saudi architecture and architectural education, but the views of Saudi academics on these techniques are unknown. Interviews and focus groups are conducted with academics and students in Saudi universities; and their views and expectations about digital design techniques in relation to Saudi culture and architecture education are analysed. The following process shows the development of the research tactics.
6.2.4.1 Interviews

Creswell (2013, p. 191) highlights that the positives and negatives of using interviews to collect research data are significant. It is positive as it is useful when interviewees cannot be observed directly; they provide historical information and allow researchers to control the line of questioning. On the other hand, it is negative because some interviews provide indirect information which will be filtered; provide information in a designated place rather than a natural field setting; and potentially bias interviewees, as not all people are equally articulate and perceptive.

It is assumed that data collected from a variety of sources would give multiple windows and help construct a rich view to help answer the research questions. The interviews target people who have some information or background on the use of digital design techniques in architecture, as well as people who do not. It targets Saudi academics involved in practice or practitioners involved in architectural education and it targets people with authority who are empowered to make decisions in the same universities. It also targets Saudi computer science students. The interviews provide some information about the current, future and the past notion and perception of digital techniques in Saudi architecture. The interviewees offer personal views on the nature, use and benefits of introducing digital techniques. The interviews also provide information about the cultural and educational challenges of using digital techniques. This could be positive or negative and it is useful to include these views in the interviews.

In each interview, a series of questions are posed including what do you know about digital design techniques?, what is your view about the techniques?, what is the current design technology employed in Saudi architectural education?, why does Saudi architectural education not yet use digital design techniques?, who is using digital design techniques in Saudi architecture circles?, are digital design techniques a forward step for Saudi architecture education or are they irrelevant?, and what reasons prevent digital design techniques being used in Saudi architectural education?

The interviews are with staff and students in three Saudi universities: Umm Al-Qura University (Western Region), King Saud University (Central Region), and King Fahad University of Petroleum and Minerals (Eastern Region). Ten people from each university
are interviewed – five teaching staff and five students (or until reaching the saturation point). Each interview is scheduled to take 45-60 minutes and is divided in two sessions in two days. This allows interviewees to rethink and do some internet search about digital design techniques. It also allows the researcher to revise interviewee responses and to form a mental map for the second session (see Appendix 2). Interviews are also conducted with computer science students at the Faculty of Design, Architecture and Building at the University of Technology, Sydney in a pre-booked private studying room (see Appendix 3). The interviewees are postgraduate students, mostly Saudi PhD candidates, and each interview is in one session (semi-structured).

Initial interviews with all respondents are structured interviews, providing the same questions to all participants. Follow-up interviews with all individuals are semi-structured (qualitative interviews). In structured interviews, Yin (2011, p. 133) points out that the researcher asks formal questions – usually listed. The researcher needs to adopt the interviewer role to extract responses from interviewees and maintain consistent behaviour when interviewing each individual. Semi-structured (qualitative) interviews are different. Creswell (2013, p. 190) states that in qualitative interviews the researcher engages in face-to-face interviews with participants and that involves unstructured and open-ended questions to extract the interviewees’ views and opinions. Similarly, Yin (2011, p. 134) highlights that in qualitative interviews there is no prepared question list, thus researchers must have a mental map of the study’s questions and the posed question should differ according to the interview’s context and setting. Moreover, researchers do not need to maintain uniform behaviour for every interview, which allows opportunity for two-way interaction where participants can ask questions.

6.2.4.2 Interview protocol

According to Creswell (2013, p. 194) it is better for researchers to develop an interview protocol to ask questions and record answers during the interview. This protocol includes date, time, place, interviewer, interviewee, and instructions to follow and questions (both for structured and unstructured interviews).
This study’s protocol started with contacting three Saudi universities and receiving confirmation to conduct the interviews (see Appendix 4). The interviews took place in the end of the second semester 2014–2015 at the three universities including ten days – 20th–30th December 2014 at King Fahad University of Petroleum and Minerals, 1st–10th January 2015 at King Saud University, and 15th–25th January 2015 at Umm Al-Qura University. All interviews were conducted by the researcher in offices, meeting rooms, the architecture department’s library or pre-booked classrooms. The heads of the architecture schools at King Fahad University of Petroleum and Minerals, King Saud University and Umm Al-Qura University were asked to nominate about ten interviewees from each university. Each interview was conducted following instructions such as introducing the researcher, introducing the study and its goals, the interviewee role, information sheet and consent form, note book, recording device and pre-questions to start with (see Appendices 5 and 6).

6.2.4.3 Seminar and workshop (focus group)

To support and verify the data collected from the interviews, a focus group interview is needed. The focus group was attended by Saudi architecture students who are studying overseas in Australia and their responses were analysed to serve the research objectives.

Six architecture students who are doing their degrees at Australian universities – The University of Technology Sydney and The University of Sydney – participated in the focus group.

Creswell (2013, p. 190) advises that in qualitative interviews the researcher engages in a focus group interview with six to eight interviewees in each group. Data could be collected from a number of focus groups or one focus group, depending on the amount of collected data the researcher needs (Yin 2011, p. 142). In this study one focus group was enough. Moreover, conducting this focus group requires the researcher to have some special skills. The group is focused because the selected individuals have had some experience or presumably share some common views, and the interviewer should be considered as a “moderator” to allow every member in the group to express his opinion (Yin 2011, p. 141). The members should be purposefully selected (Morgan 1997, p. 6). To be a moderator the interviewer needs to manage the discussion proficiently. For
example, a person may dominate the group discussion, thus the interviewer needs to politely impose a firm style on discussion to control the talkative person. When the entire group is silent, the interviewer needs to find words to restart the group conversation (Yin 2011, p. 142).

The main objectives of the seminar and workshop were to:

- introduce digital design techniques to the focus group members from the study’s perspective.
- raise the awareness of the importance of digital design techniques.
- achieve a common perception of digital design techniques to determine the necessity of their introduction.
- identify the gap and suggest solutions to the study assumptions.
- identify the aspects that may prevent the introduction of digital design techniques.
- draw the expected future of digital design techniques in Saudi Arabia.

The seminar focused on some fundamental information about digital design techniques, whereas the workshop was designed to show real use of these techniques. The seminar covered the background, theories and frontiers of digital design techniques, digital design techniques as a multidisciplinary approach, the common design and fabrication techniques, scripting, and some current digital design technique projects as examples in Saudi Arabia. The hands-on workshop focused on introducing some common digital design techniques. The seminar and workshop were concluded by an open conservation focusing on the seminar and the workshop objectives (see Appendices 7 and 8).

### 6.2.4.4 Sampling

Sampling – both interviewees in Saudi Arabia and the focus group in Sydney – refer to the selection of samples, such as specific units and the number of them or, as Yin (2011, p. 87) describes them, broader and narrower levels of sampling. Yin (2011) states that sampling challenges stems from the need to know which specific unit to choose and why,
as well as the number of the unit’s members included in the study. In this study, the broader selected samples are both three Saudi universities from three different regions and three different approaches, and the focus group in Sydney. The narrower level sampling is academics and students in architecture departments at three Saudi universities.

There is general agreement among scholars that there is no unified formula to determine the qualitative research sampling number. According to Yin (2011, p. 88), “there is no formula for defining the desired number of instances for each broader and narrower unit of data collection in a qualitative study. In general, larger numbers can be better than smaller numbers because a larger number can create greater confidence in a study’s findings”. Unlike Yin, Creswell (2013, p. 189) states that saturation is another viable approach to collect data which means that the researcher stops collecting data when it reaches saturation. In other words, when gathering data, it no longer sparks new ideas, insights or reveals new properties.

This study is initiated by interviewing people from three Saudi universities, with at least five academics and five students from each university. Yin (2011, p. 88) highlights that members of qualitative research are chosen deliberately or through “purposive sampling”. Similarly, Creswell (2013, p. 189) points out that the idea behind qualitative studies is to “purposefully select” participants. In both views, the idea of purposefully selecting participants refers to having participants who will provide most relevant and useful data about the study topic. This encouraged the researcher to select participants who have some information about digital design techniques, holding an attitude either positive or negative about digital design techniques, or in a decision-making position.

6.2.4.5 Summary of interviewees
Interviews were conducted with a total of 54 staff and students. Table 6 summarises interviewees at King Fahad University of Petroleum and Minerals, Table 7 summarises interviewees at King Saud University and Table 8 summarises interviewees at Umm Al-Qura University. Table 9 summarises focus group interviews with Saudi architecture
students studying in Australia, and Table 10 summarises interviews with Saudi computer science students studying in Australia.

Table 6: King Fahad University of Petroleum and Minerals interviewees (academics and students), College of Environmental Design, Architecture Department

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Position/ year</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Amer Alkharoubi</td>
<td>Lecturer</td>
<td>Architecture and Graphic Design</td>
</tr>
<tr>
<td>2</td>
<td>Jamal Qawasmi</td>
<td>Associate Professor</td>
<td>Design Computing &amp; Visualization</td>
</tr>
<tr>
<td>3</td>
<td>Mohammad Babsail</td>
<td>Assistant Professor, Head of School</td>
<td>Architectural &amp; Sustainable Design, Digital Design Applications &amp; BIM, Energy Modelling, Renewable Energy Applications within Architecture</td>
</tr>
<tr>
<td>4</td>
<td>Omar Al Mahdi</td>
<td>Lecturer</td>
<td>Architecture Design, Urban Design, Public space &amp; Place identity</td>
</tr>
<tr>
<td>5</td>
<td>Riyadh Ashmeel</td>
<td>Lecturer</td>
<td>Architecture and Urban Design</td>
</tr>
<tr>
<td>6</td>
<td>Ziyad Ashor</td>
<td>Lecturer</td>
<td>Digital Fabrication</td>
</tr>
<tr>
<td>Students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Amr Aldaain</td>
<td>5th year</td>
<td>Architecture</td>
</tr>
<tr>
<td>8</td>
<td>Ibrahim Alsuwet</td>
<td>4th year</td>
<td>Architecture</td>
</tr>
<tr>
<td>9</td>
<td>Wahag Ahmad</td>
<td>4th year</td>
<td>Architecture</td>
</tr>
<tr>
<td>10</td>
<td>Yosef Sabri</td>
<td>5th year</td>
<td>Architecture</td>
</tr>
<tr>
<td>11</td>
<td>Yousef Amoudi</td>
<td>4th year</td>
<td>Architecture</td>
</tr>
</tbody>
</table>

Table 7: King Saud University interviewees (academics and students), Architecture and Planning College, Architecture and Building Science Department

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Position/ year</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Abdulaziz Abu Suleiman</td>
<td>Assistant Professor, Head of School</td>
<td>Urban planning, Urban Design &amp; residential areas planning</td>
</tr>
<tr>
<td>2</td>
<td>Anas Almughariy</td>
<td>Assistant Professor</td>
<td>Urban &amp; Architecture Design</td>
</tr>
<tr>
<td>3</td>
<td>Mohamad Abolmajd</td>
<td>Professor</td>
<td>Architecture Theory &amp; Architecture</td>
</tr>
<tr>
<td>4</td>
<td>Mohamad Hussain Ibrahim</td>
<td>Assistant Professor</td>
<td>Architecture and Urban Design</td>
</tr>
<tr>
<td>5</td>
<td>Mohamad Sharif Alataar</td>
<td>Assistant Professor</td>
<td>Computer applications and architectural design Integration</td>
</tr>
<tr>
<td>6</td>
<td>Saud Alfulaij</td>
<td>Lecturer</td>
<td>Architecture Design</td>
</tr>
<tr>
<td>7</td>
<td>Wael Albusi</td>
<td>Lecturer</td>
<td>Architecture Design</td>
</tr>
<tr>
<td>Students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Abdulrahman Alsamhan</td>
<td>5th year</td>
<td>Architecture</td>
</tr>
<tr>
<td>9</td>
<td>Ahamd Albazai</td>
<td>5th year</td>
<td>Architecture</td>
</tr>
<tr>
<td>10</td>
<td>Fahad Alasker</td>
<td>5th year</td>
<td>Architecture</td>
</tr>
<tr>
<td>11</td>
<td>Mohamad Alamri</td>
<td>4th year</td>
<td>Architecture</td>
</tr>
<tr>
<td>12</td>
<td>Nawaf Alromaiah</td>
<td>4th year</td>
<td>Architecture</td>
</tr>
</tbody>
</table>
Table 8: Umm Al-Qura University interviewees (academics and students), Faculty of Engineering and Islamic Architecture, Department of Islamic Architecture

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Position/ year</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Academics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Abdullah Karban</td>
<td>Lecturer</td>
<td>Planning &amp; Architecture Design</td>
</tr>
<tr>
<td>2</td>
<td>Adel Bin Yassin</td>
<td>Assistant Professor</td>
<td>Architecture Design</td>
</tr>
<tr>
<td>3</td>
<td>Adnan Shahrani</td>
<td>Lecturer</td>
<td>Architecture</td>
</tr>
<tr>
<td>4</td>
<td>Ahmed Shehata</td>
<td>Associate Professor</td>
<td>Computer Aided Design &amp; Environmental Design</td>
</tr>
<tr>
<td>5</td>
<td>Jameel Alsafafi</td>
<td>Associate Professor, Head of School</td>
<td>Architecture</td>
</tr>
<tr>
<td>6</td>
<td>Majdy Mohammed Hariri</td>
<td>Professor</td>
<td>Architecture Design</td>
</tr>
<tr>
<td>7</td>
<td>Mohamad Bas</td>
<td>Lecturer</td>
<td>Advanced Architecture Design</td>
</tr>
<tr>
<td>8</td>
<td>Mohamed Taha Saqqaf</td>
<td>Assistant Lecturer</td>
<td>Architecture Design</td>
</tr>
<tr>
<td>9</td>
<td>Mohammed Saifuddin</td>
<td>Assistant Lecturer</td>
<td>Urban &amp; Architecture Design</td>
</tr>
<tr>
<td>10</td>
<td>Nabeel Koshak</td>
<td>Assistant Professor</td>
<td>Computer Aided Design &amp; GIS</td>
</tr>
<tr>
<td>11</td>
<td>Omar Osrah</td>
<td>Lecturer</td>
<td>Architecture</td>
</tr>
<tr>
<td>12</td>
<td>Saeed Bargawi</td>
<td>Lecturer</td>
<td>Urban Design</td>
</tr>
<tr>
<td>13</td>
<td>Tareq Abu Ouf</td>
<td>Associate Professor</td>
<td>Architecture Design</td>
</tr>
<tr>
<td>14</td>
<td>Wadi Bargawi</td>
<td>Assistant Professor</td>
<td>Architecture Design</td>
</tr>
<tr>
<td>15</td>
<td>Wajdy Atwa</td>
<td>Lecturer</td>
<td>Architecture</td>
</tr>
<tr>
<td></td>
<td><strong>Students</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Abdullah Fuda</td>
<td>5th year</td>
<td>Architecture</td>
</tr>
<tr>
<td>17</td>
<td>Abdulrahman Gadi</td>
<td>5th year</td>
<td>Architecture</td>
</tr>
<tr>
<td>18</td>
<td>Hussain Albishri</td>
<td>5th year</td>
<td>Architecture</td>
</tr>
<tr>
<td>19</td>
<td>Ibrahim Kabli</td>
<td>5th year</td>
<td>Architecture</td>
</tr>
<tr>
<td>20</td>
<td>Obaid Al Jabali</td>
<td>5th year</td>
<td>Architecture</td>
</tr>
</tbody>
</table>

Table 9: Focus group interviewees: Saudi architecture students who are studying overseas in Australia

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Ongoing degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mohamad Qattan</td>
<td>Master student at University of Sydney</td>
</tr>
<tr>
<td>2</td>
<td>Saeed Bargawi</td>
<td>PhD candidate at University of Sydney</td>
</tr>
<tr>
<td>3</td>
<td>Sabri Khibari</td>
<td>Master student at University of Technology, Sydney</td>
</tr>
<tr>
<td>4</td>
<td>Salah Gamdi</td>
<td>Master student at University of Sydney</td>
</tr>
<tr>
<td>5</td>
<td>Trad Benabood</td>
<td>Master student at University of Technology, Sydney</td>
</tr>
<tr>
<td>6</td>
<td>Wajdy Atwa</td>
<td>Master student at University of Technology, Sydney</td>
</tr>
</tbody>
</table>

Table 10: Interviewees: Saudi computer science students who are studying overseas in Australia

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Ongoing degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ahamad Angawi</td>
<td>Master student in Computer science at University of Technology, Sydney</td>
</tr>
<tr>
<td>2</td>
<td>Bahjat Faqeh</td>
<td>PhD candidate in Computer science at Macquarie University</td>
</tr>
<tr>
<td>3</td>
<td>Mohamad Ikram</td>
<td>PhD candidate in Computer science at University of Technology, Sydney</td>
</tr>
<tr>
<td>4</td>
<td>Saud Nassir</td>
<td>PhD candidate in Computer science at University of Technology, Sydney</td>
</tr>
<tr>
<td>5</td>
<td>Mohamad Alshehery</td>
<td>PhD candidate in Computer science at University of Technology, Sydney</td>
</tr>
</tbody>
</table>
6.2.4.6 Fieldwork

Fieldwork requires establishing and maintaining relationships with people and being able to talk to them comfortably. According to Yin (2011, p. 110), developing this relationship is a personal challenge in doing qualitative studies, and it needs some skills to be able to cope with the uncertainties of fieldwork. Yin (2011) also highlights that the fieldwork is a real-life environment with people in their everyday process. Thus it is important for researchers to pay attention to the space, time and social relationships of people. Yin (2011) also suggests that researchers should prepare properly for fieldwork, which could include information, material and questions.

In this study, the researcher established relationships with academics and students in three different universities through the heads of the three architecture schools. The researcher was introduced by the head of each school to academics and students, and then the researcher started by interviewing the head of each school first to give the interviewees an indication of security and confirmation to talk comfortably. The interview protocol and recording device were prepared to show seriousness and professionalism.

6.2.4.7 Gaining trust and establishing rapport

Trust and rapport were established through negotiating a time and place for meeting each interviewee based on their choice of location to allow relaxed conversations to take place with no voice recording (only at the beginning) to enhance the interviewee’s sense of trust. In these conservations, some information about the interviewees’ role in this study was provided. Places such as cafés, classrooms, offices and library rooms were suggested to put each interviewee in a comfortable and familiar environment. The interview questions were designed to gradually develop from structured to unstructured and from open general questions to more specific ones (Fontana & Frey 2003) to encourage the interviewees to talk freely. In order to achieve ongoing discussions, the interview questions were developed in seven levels moving from open to specific.
6.2.4.8 Collecting materials

Interview material was collected by using an audio recorder, as the transcription of all interviews is necessary to identify evidence of the relationship between the study’s aspects. Accordingly, an audio recording of each interview is required. This was declared prior to the start of the interview. A digital recorder was used and introduced at the beginning of each interview. The device requires no adjustment and is able to record a significant amount of time.

6.3 Analysis

Data analysis reflects the qualitative data collection, with a focus on coding responses, validation and qualitative data presentation.

6.3.1 Coding

Coding is the process of sorting and storing data in groups and/or chunks of text, each chunk representing a category. Coding means using the collected data by breaking it into segments – sentences or paragraphs – then labelling these segments with names (codes). According to Tesch (1990 in Creswell 2013, p. 198), there are eight steps to make codes:

1. Make sense of the whole by reading all transcriptions carefully.
2. Pick one interview, e.g. the most interesting one, and go through it asking “What is this about?” Think about the underlying meaning and write the ideas in the margin.
3. Repeat step two with several interviews, then make a list of topics and cluster similar ones.
4. Take this list and go back to your data. Make abbreviations of each topic (as a code). Then write the codes next to the appropriate segments.
5. Find the most descriptive words of your topics and convert them into categories. Reduce the listed categories by group the ones that are similar to each other’s. Draw lines between the categories to show interrelationships.
6. Make a final decision about the abbreviation of each category and sort them alphabetically.
7. Assemble data from each category in one place and analyse them.
8. If necessary, recode the existing data.

According to Creswell (2013, p. 198), codes fall into three categories: first, codes on topics, which readers would expect to find based on the literature and common sense; second, codes that are surprising or not anticipated since the beginning; and third, codes that are unusual, of conceptual interest to readers. Moreover, researchers could develop their codes in three ways according to Creswell (2013, p. 199). First, codes could emerge from the collected participants’ information; second, codes could be predetermined and then fit the data to them; and third, codes could use the combination of emerging and predetermined codes.

Even though Yin’s approach is slightly different from Creswell’s in “analysing” or “coding” qualitative research data, it is still useful and relevant. Yin (2011, p. 177) argues that most qualitative studies follow five phases of a cycle: (1) compiling, (2) disassembling, (3) reassembling, (4) interpreting and (5) concluding. Usually analysis starts with compiling data from the fieldwork. That means putting data in some order and the outcome could be called a database. In the second stage, data is broken down into small pieces, which is disassembling the process and could be repeated many times. In this stage researchers can label each piece with a unique name (code) to be recognised. Then these pieces (codes) can be grouped into different clusters, which could be a reassembling process. In the fourth stage the reassembled data is used to create new narratives with accompanying tables and graphics where relevant; this could be considered interpreting. In the final concluding stage researchers must draw the conclusion from the entire study, which should relate to the interpretation of the previous stages. Overall, these five stages should have recursive and iterative relationships.

In this study, the coding system focuses on some significant aspects such as influences and interactions of digital design techniques on Saudi culture and Saudi architectural education. It also includes the current designing techniques and computer applications
used in Saudi architectural education: how Saudi academics and students look at digital design techniques now; what are the expectations, and possibilities of introducing these techniques now; and where we should start this introduction.

6.3.2 Data analysis

Data analysis software is commonly used, as analysing and coding manually is laborious and time consuming. Thus Creswell (2013, p. 195) claims that qualitative research software has become popular as it helps researchers to organise, sort and search information in text, image and databases. There are several computer qualitative software programs with similar features. For this study, Nvivo 10 was chosen for its practicality, power and popularity. Although the researcher needs to read every single line in the text and assign code, this process is faster and more efficient than traditional coding, especially with large databases – 54 interviews. The researcher is able to go through all the texts to find particular, same-coded passages to judge the interviewees’ responses, and compare them and/or compare codes. Nvivo is used for its capability to store and organise data, sort long text or paragraphs, coding, inquire about the relationship between codes, and import and export data to other software.

The process is that raw data is gathered from interviews and transcribed in English. Then the data is prepared and organised for analysis in a format that is compatible with Nvivo 10 which means that all text must be organised in headings and subheadings. Then the researcher reads through all data and, at the same time, assigns each passage to a predetermined code.

6.3.3 Validation and accuracy

It is important for researchers to provide or present their procedures for validation. Creswell (2013, p. 201) describes that “qualitative validity” is the researcher’s duty to check the accuracy of the findings by using certain procedures. Then Creswell (2013) lists eight primary validation strategies to choose from, and recommends using multiple strategies. In this study, two validation strategies are used. First, different data sources
are triangulated through examining evidence from three sources and used to build justification. The justification is based on several sources of data or perspectives from participants. This process adds validity to the study. Second, member checking is used to determine the accuracy of the qualitative findings by taking the final reports (or any part of their interviews) to the participants to see if the participants feel that they are accurate. Polished or semi-polished parts of material are taken to the participants, not raw material.

In this study, the data is collected from three different sources, King Fahad University of Petroleum and Minerals, King Saud University and Umm Al-Qura University, which allows building justification from three different perspectives. After all interview data was transcribed and translated, it was sent to participants with English language to ensure the accuracy of the data (see Appendix 9).

6.3.4 Qualitative data presentation

Yin (2011, p. 234) notes that “how best to present qualitative data to communicate effectively with audiences therefore still remain a challenge”. Researchers should know the difference between the narration of the participant’s words and the presentation of long and direct transcribed passages representing the participant’s own perspectives and meaning. According to Yin (2011, pp. 236-247), there are many different tactics to present qualitative research data such as interspersing quoted passages within selected paragraphs, and tabular and graphic presentation. The interspersing quoted passages occur as a part of the entire study narrative flow. Equally important is to present the qualitative data in other modes, which appear as tables and/or figures. This makes the data more understandable than a continuous long narrative alone. Qualitative data tables show words, but not numbers, and are known as word tables, whereas graphics include any kind of drawings, such as graphs and schemas.
6.4 Interviews and the participants

Interviewing for research purposes should follow a scientific procedure and require special skills. The interview procedure of this study started by introducing the interviewer, the study itself and its contribution and objectives, the interviewee’s role in the study, and the consent form and information sheet, followed by explaining the interview questions’ seven levels and two sessions. In the first session questions from level one to three were asked and in the second session questions from level four to level seven were asked. The levels were in sequence from general to specific to more specific. The targeted interviewees were academics and students from three Saudi universities, Saudi architecture students who are studying overseas, and computer science students.

An interview-based method with diversity in sources was used to collect the research data. The interviewees were from a Saudi architectural background except the computer science students. They had different views and different positions regarding introducing digital design techniques and their influences and interactions. As expected, there were interviewees who accept and welcome digital design techniques, while there were others who reject and refuse introducing them.

The interviews with staff and students from three Saudi universities were focusing on raising a series of questions. It started with “Can I start by asking you what you know about digital design techniques and what you think about these techniques in relation both to Saudi culture, and to their potential use as an educational device and an architectural tool within Saudi Arabia”. Depending on what each interviewee said about them, the questions were changed to ask, for example, “While you’ve just said that you agree with digital design techniques in Saudi Arabia, can I ask you on what basis you like them, on what basis you think they are appropriate, and thus what cultural and/or social perspectives make you accept them”. Alternatively, “While you’ve just said that you don’t agree with digital design techniques in Saudi Arabia, can I ask you on what basis you don’t like them, on what basis you think they are not appropriate, and thus, what cultural and/or social perspectives make you reject them”. Then if the interviewee liked digital design techniques, and said they should be included in Saudi Arabia, then the
question asked, “Can you tell me why and on what basis you think this would be a positive educational development and needed now”, or vice versa.

Regardless of the interviewees’ positions the question then asked “What is the current level of computer usage in Saudi architecture and Saudi universities, and why?”. The next question then asked, “Are digital design techniques currently employed within Saudi architectural education; at what level(s) and in which universities; and is this – perhaps in the future – a necessity, and what are the ways to use them?”. After that, the questions flowed according to the interviewees’ position and opinions regarding digital design techniques introduction and their influences and interactions in Saudi culture.

After explaining the general research project as a detailed analysis of both digital design techniques and their potential use as an architectural designing tool in Saudi Arabia, the questions started with level one which asked about what the interviewees know about digital design techniques and their role in improving architecture. That splits the interviewees into three categories: (a) the ones who know about digital design techniques, (b) the ones who do not know about digital design techniques, and (c) those who might know about digital design techniques but are antagonistic about them, and thus wish to reject them. In relation to (a) and (c) – the ones who know about them – the questions continue, but for (b) the questions stop and were followed by a brief explanation about digital design techniques and their role in changing architecture. The questions for all interviewees then asked about what the interviewees think about digital design techniques from both Saudi cultural and architectural perspectives. Then the questions asked about how technology use evolves in Saudi culture.

In level two, the questions ask about the current computational involvement in Saudi architectural education and the reasons behind that, whether they were cultural or technological. In level three, the interviewees were asked about the reasons and the consequences of using foreign architects or experts to design and construct some buildings digitally in Saudi. Then level four asked about the gap between Saudi culture and Saudi architectural education and the use of digital design techniques. There were
also questions about the role of Saudi culture, architecture and architectural education, and the role of the technological skills in this gap. Level five asked about the current relationship between Saudi culture, Saudi architecture, Saudi architectural education and use of digital design techniques, followed by more specific questions in level six about the consequences of introducing digital design techniques to Saudi culture and Saudi architectural education and whether the introduction will be easy, hard, or with conflict. Finally, level seven asked very specific question about the possibilities, methods and the future of implementing digital design techniques in Saudi Arabia.

The interviews with Saudi architecture students who are studying overseas were slightly different as they were more like a seminar and workshop, or a focus group. The seminar and the workshop were titled “Digital design techniques and Saudi Architecture: introducing and understanding”. The seminar started with digital design techniques background, their theories and frontiers, digital design techniques as a multidisciplinary trend, the common design and fabrication methods, using digital design techniques, scripting, and some recent examples of digital design technique projects in Saudi Arabia. This was followed by a digital design techniques hands-on introductory workshop to introduce some of these common techniques, and then finished with an open discussion focusing on the seminar and the workshop aspect in relation to the research interests to collect the attendees’ feedback. For example, some of these questions asked about: what we know about digital design techniques in Saudi Arabia; how we would know about digital design techniques in Saudi Arabia; the cultural restriction and/or trusting digital design techniques outcome; difficulties and opportunities of introducing digital design techniques; antagonists and conflicts of interest; the idea of local and international architects; and providing equipment and infrastructure. The purpose of choosing those interviewees is because of their potential experience and encounter with digital design techniques, or at least having more understanding about them. The interviewees did their Bachelor degree at Saudi universities and they are now doing a higher degree at an overseas university (in Australia), therefore they know more about both teaching patterns and used technologies.
Further interviews with computer science students were quite different in aims and contents. Interviewees were Saudi students who did their Bachelor or Masters degree at Saudi universities and are now doing a higher degree at an overseas university (in Australia). The interview questions were in five stages and each stage asked about some specific information. The purpose of these interviews was to find out important information about learning and using programming (scripting) such as how long does it take, what knowledge is required, and how difficult is it. It also looked for information about programming education at Saudi universities – not architectural – and the overseas universities. The interviews thus investigated what the computer science students know about programming in architecture, what difficulties will face architects, what will prevent or limit teaching programming, and the possibilities of teaching programming within design studios. Moreover, it questioned the Saudi cultural perception of programming, that is what are the cultural aspects that prevent it or make people avoid it. Finally, it went through the possibilities of using computer science departments to teach architecture students at Saudi universities, how different is programming in architecture, and the potential difficulties that would face programming language lecturers when they teach architecture students.

6.5 Perception of digital design techniques among Saudi architecture staff and students

Three different kinds of participants were involved in this study. Throughout the interviews, six categories of Saudis’ perception of digital design techniques were found. Each one is different and unique in terms of what the interviewees know, what they think, and their positions. They were about the different notion of how the interviewees look at digital design techniques. There were interviewees who accept digital design techniques and others who reject them. The ones who accept digital design techniques are the majority. Some of them know these techniques and want them to be introduced, while others do not know them and then want them to be introduced – with conditions in some cases. Whereas the ones who reject digital design techniques were a minority, some of them do not know digital design techniques and then reject them, but surprisingly others who know these techniques also reject them (see Figure 14).
The seminar and workshop participants were coded into one of these six categories based on their responses. In general, they have some information about digital design techniques and then the seminar and the workshop increased their knowledge, which makes them more positive, and they would like to see the introduction of digital design techniques.

Figure 14: Six categories of perceptions of interviewees (Saudi staff and students) on digital design techniques

When the interviewees are asked about what they know about digital design techniques, how they know and what their position is, there were some who already knew about them and they wished to introduce them as soon as possible for many reasons. Three examples are reviewed and discussed. Mohammad Babsail, the head of architecture school at King Fahad University of Petroleum and Minerals (interviewed 2014), commented:

DDTs are about using computers to develop, improve ideas or translating ideas that developed manually into 3D computer models. The first part is taking sketches to draw and montage them using computers. The second part is developing full design using computers. The advance part is developing design digitally using mathematical and physics equations, such as generative design. I have this information about DDTs because I did my master and PhD overseas.
Babsail knows important information about digital design techniques, but the question is how he acquired this information. He highlighted an important aspect to this study. Gaining knowledge overseas seems to be fundamental. He supports introducing and using these techniques in Saudi Arabia because:

The main reason is the rapid technological development in the architecture field. The whole world will be linked digitally in the near future, thus there is no doubt introducing and using DDTs is fundamental now to Saudi society. By using these techniques, forms will become better. Designing buildings digitally does not mean you are abandoning your culture or values. There will be construction structure and spaces, which are very similar to any traditional building. Using DDTs could be beneficial and improve the old traditional techniques. We could discover that building with bricks and mud have wider possibilities. I see that these techniques may add to local traditional architecture new style and value.

Babsail raises a number of issues. First, being updated and keeping pace with technological development is very important and needed. Second, by using these techniques, building forms will improve. Third, using digital techniques does not necessarily conflict with local culture and values. Fourth, using these techniques could be useful and will improve the old traditional techniques. Finally, using them within the Saudi cultural context may result in new styles and values. These points show why digital design techniques are important and should be used from the interviewee’s perspective, but they are also important to this study.

A second interviewee who also knows these techniques and supports introducing them to Saudi culture is Ziyad Ashor, a teaching staff at King Fahad University of Petroleum and Minerals (interviewed 2014). He did his Masters degree in the Southern California Institute of Architecture at Los Angeles, specialising in digital fabrication (how to convert digital models to real models), and he is the only staff member in this area at King Fahad University of Petroleum and Minerals. When asked about digital design techniques, Ashor said:

DDTs are about generation architectural design using computers, specifically through programming languages called (scripting). Architects must master DDTs and be witty in scripting. That may make it difficult for the old architects’ generation. DDTs are a positive thing, especially if they integrate industry, construction and
materials. This way, design associates with implementation, manufacturing and construction materials from the beginning.

Ashor made some valuable points. Architects need to conquer using these techniques, especially scripting, and these seem to be difficult to the architects from the old generation. These techniques could also be beneficial if they allow architects to integrate industry, construction and materialisation from the early stages of design. Indeed, it is hard to criticise these three points as they are not wrong, but considering the situation in Saudi Arabia now they may be hard to achieve.

Wajdy Atwa, a teaching staff at Umm Al-Qura University (interviewed 2014), has a slightly different view and commented:

DDTs are a new trend in the architects’ world. Through my study at University of Technology, Sydney, I discovered that designing software give perceptions and dimensions of the unexpected future, very different from what I have learned in Saudi (manual drafting and montaging). DDTs facilitate design process and save time. From my point of view, they should be included as a subject in our architectural education plans. They also will not affect our culture negatively.

Atwa’s points are noteworthy: he mentions using these techniques will provide an impression of the unexpected future. Saudi architectural education is different and does not offer digital design techniques yet. These techniques make the design process easier and time saving. Moreover, they need to be taught at Saudi universities and they will not impact the culture. These views are representative of what the interviewees who know digital design techniques mentioned and recommend. Some of these points are fundamental and should be considered, whereas others are difficult to achieve for reasons that are discussed later.

The second category of the interviewees are those who have information about digital design techniques (they know) and they are willing to accept them, but with some conditions and/or concerns. Most of the interviewees in this category know these techniques because they did their degrees overseas. Indeed, most of these conditions and/or concerns stem from cultural, architectural and practice issues such as when digital design techniques should be introduced to students, the non-readiness of Saudi
architecture practice and construction and the need to examine digital design techniques outcomes first. There is not enough time to introduce them in the current curricula and increase the current staff knowledge of digital design techniques. Hence, digital design techniques should be used to serve the culture and the identity; they should be used in a way to save the human sense of space; they should be introduced by Saudis; and they should suit Saudi society requirements. Five interviews are discussed as examples of this category.

Amer Alkharoubi, a teaching staff at King Fahad University of Petroleum and Minerals (interviewed 2014), did his Masters degree in graphic design. He is arguing to introduce these techniques at the final year of study, when the students became knowledgeable about the architectural theories and design basics. He is also concerned about one of the controversial issues of using digital techniques, which is who will be the real designer if using digital design techniques? In terms of culture, he is not expecting that digital design techniques will conflict with Saudi culture, but, because they are not prevalent in Saudi Arabia, their outcomes may be very expensive and limited to iconic buildings and rich people. He also noted other architectural design techniques that are much easier than scripting, but they are not popular in the Arab world. There are also limitations in the qualified contractors who are able to construct these kind of buildings.

For Riyad Ashmeel, a teaching staff at King Fahad University of Petroleum and Minerals (interviewed 2014), the condition was different. Ashmeel commented:

I am supporting the idea. We are now a 2015-2016 generation, which is supposed to be open to the world and accept new ideas, and assess them in order to determine its suitability to us. From my perspective, we cannot accurately judge DDTs if we do not experiment with them. In my opinion, there is nothing wrong with introducing DDTs, but we need to try them first and display its results.

It seems there is no problem with introducing these techniques, but there is a need to assess and examine their outcomes. This could be understood as a need for an introductory period with enough time to introduce digital design techniques.
However, Mohamad Alataar, a teaching staff at King Saud University (interviewed 2014), considered the introduction of digital design techniques from a different angle. He argued about the lack of time. The current curricula in Saudi Arabia is very dense, therefore there is not enough time to insert digital design techniques within the curricula. Hence, they should be introduced as a new degree in architecture. Even though Alataar mentioned other conditions, such as the need to increase the Saudi staff knowledge of digital design techniques, he still insisted on the lack of time issue. This is potentially different from what Adnan Shahrani, a teaching staff at Umm Al-Qura University (interviewed 2014), posed. He suggests that if digital design techniques do not suit Saudi identity and values, they will be rejected. These techniques need to work within the cultural framework, but if they would not, they will not be accepted. Tareq Abu Ouf, a teaching staff at Umm Al-Qura University (interviewed 2014), has another view, stating that introduction of digital design techniques should provide the human sense of space. They should be used to increase the spatial relationship (between the space and its users) and to offer human scale. This could imply that digital design techniques’ outcomes should not celebrate huge buildings that do not respect the human scale. Digital design techniques should also be introduced by Saudi architects because they are the only people knowledgeable about the cultural requirements, and know what is suitable.

The third category represents the interviewees who do not know digital design techniques, but, after a brief explanation, they accept them and really want them. Most of the interviewees have some information about the popular software used by architects recently, but not digital design techniques. These interviewees do not know because they are from the old architecture school generation, or because they have not received any digital design techniques information from their educational providers. Nonetheless, they are ready to embrace digital design techniques for important reasons. For example, Mohamad Ibrahim, a teaching staff at King Saud University (interviewed 2014), stated:

These techniques are a tool to achieve a goal, i.e. produce visually enjoyable architecture, which responds to the users’ needs and sustainability. They will open new horizons. However, the architect who refuses using DDTs is like someone who refuses to use a car and prefers cabriolet carriage riding.
Looking at these reasons indicates how the interviewee reacts positively, even if he does not know these techniques. However, that does not mean these impressions are all correct. Hussain Albishri, a final year student at Umm Al-Qura University (interviewed 2014), offers a very enthusiastic impression. After a short talk about digital design techniques, he thought that these techniques are able to create forms, analyse circulation, and do many other things – and he highly supports this trend. He then stated:

I thought myself one of the best designers before I meet you, and I did not know there are such digital techniques. I am one of those who loved these techniques and I want to master them; also I am looking at them positively and they will be a significant forward step.

That may show the great enthusiasm among Saudi architecture students to know and to use these techniques. Albishri is an example of what Saudi students know and think about digital design techniques.

The fourth category includes the interviewees who do not know digital design techniques, but after a brief explanation, they accept and want them, but with some conditions. It appears that the interviewees do not have information about digital design techniques for the same reasons of the previous category, and after a little conversation about these techniques they were happy to embrace them, but with some conditions and concerns. For some, they support introducing these techniques, but they prefer the old school manual designing techniques. For others, digital design techniques will be beneficial, but we need to control the way of using them. The following shows some examples of these conditions and concerns.

Yousef Amoudi, a final year student at King Fahad University of Petroleum and Minerals (interviewed 2014), supports digital design techniques, but he prefers students to design themselves “manually”. He thinks it is better for students to not use designing software to improve their way of thinking and designing. He also believes that:

our architectural environment needs lots of work and knowledge to move to the DDT world. Still, there are people who did not use technology or are accustomed to use old techniques. This is causing a gap between them and new technologies.
Most interestingly is what he mentions about how programmers will take the role of architects. It could be said that manual skills should not be dispensed and students should only develop their manual skills (not the computer skills). The Saudi architecture environment should be ready to embrace digital design techniques and the architects’ role should be protected. For Saud Alfulaij, a teaching staff at King Saud University (interviewed 2014), digital design techniques are positive, will make design better and easier, and they will be the future of Saudi architecture, but we need to control and adopt them to fit our culture. The condition here is different from the interviewees in this category and at the same time, it is similar to others in the other categories.

Fahad Alasker and Ibrahim Kabli, final year students at King Saud University and Umm Al-Qura University (interviewed 2014), are arguing for the same thing. They support introducing these techniques, if the designer is always in control of the design. Both of them emphasise the role of the architect in the design process. Kabli says that:

I think the DDTs are something complementary. For example, you can produce an idea by using a traditional way and then try to improve it through using DDTs. I am looking at them positively and a forward step. But, the introduction should be conditioned by changing some universities’ aspects in order to achieve the positive consequences of DDTs and development.

Being something complementary is another condition, but changing some aspects at Saudi universities is a crucial aspect that needs to be looked at. Initially, these aspects could be changes in teaching staff, in the computer facilities (software and hardware), modelling and fabrication facilities, and curricula. These aspects – and others – are discussed in the next chapters.

The fifth category are the interviewees who do not know digital design techniques and, after a brief introductory talk, they reject and do not want them. In this category, the interviewees were from the old generation school of architecture and they are very strict in terms of using the old schools’ designing techniques. Hence, they do not know about digital design techniques for the same reason. It appears that the interviewees in this
category carry an antagonistic position and they refuse using digital design techniques. The following shows the reasons behind this reluctance.

AA, a teaching staff (interviewed 2014), says:

As you know, I am one of the old architectural design school. I do not know that much about using computers to design. What is worrying me is dispensing with the architect’s role in the design process; they will become computer engineers rather than designers. I am also afraid of transferring our built environment to a science fiction-like environment. I do not know if we really need to do this jump to be modernised or we need to stick to our traditional architecture, which best suit us. We need to keep our traditions, values and styles; we need also to raise the new architects’ generation awareness of these values rather than chasing Western technologies and styles.

He clearly states the reasons that may cause refusing introducing and using these techniques. There is nothing wrong if someone does not know digital design techniques for some reasons, such as maintaining traditional architecture, or being anti-Western style and technologies. The other reasons, however, are negotiable and controversial. For instance, using digital design techniques may not dispense with or convert the architects’ role and not necessarily produce ‘weirdo’ buildings. Moreover, from AA’s point of view, digital design techniques are negative, but they could be positive in the case of producing virtual architecture, which may belong to the belief these techniques will only produce unusual architecture. At the end of the interview, he stated:

What you are talking about is very unacceptable. I think we do not want to use these techniques because they are not a part of our culture. They are invented by Western people for Western people but not for us. We have different culture, environment and requirements. I do not think this introduction will happen easily.

AZ, a teaching staff (interviewed 2014), is similar. He does not know about using computers to generate design or even to provide help to generate design. From his point of view, what Saudi architecture and architecture schools are producing now is acceptable, and it is possible to design using Saudi creative traditional techniques, which are used throughout the history of architectural design and have never caused any problem. Similarly, he claims if using digital design techniques will take the architects’ designing role, he would prefer to not use computers. Moreover, satisfaction with the
current Saudi architectural environment could be another reason. He argues that Saudi culture does not know about digital design techniques, and that Saudi practice is running perfectly now and that there is no need to introduce these techniques. He also thinks that Saudi architectural education is progressing and developing steadily with decent use of computers – “I think we are doing well”. Accordingly, the introduction of digital design techniques will have challenges based on AZ’s view. Introducing digital design techniques requires replacing the old expert scholars at Saudi universities, those people who carry knowledge, theories, local values and experience. They will be replaced with young architects who are eager to use these digital design techniques and neglect this old knowledge. The other issue is that digital design techniques produce very futuristic buildings that are not buildable in reality. This could sometimes conflict with Saudi cultural and architectural requirements. Saudi culture and architecture need simple basic buildings, buildings that suit human needs. Finally, AZ lists twelve reasons to justify why digital design techniques should not be introduced:

First, we do not know enough about DDTs. Second, they are out of our interest (I mean culturally, teaching staff and educational plans). Third, DDTs will be dispensing the architects’ role in the design process. Fourth, introducing DDTs will increase cultural requirements and will reduce employment opportunities in practice and education. Fifth, this will necessitate new job positions and re-structuring our educational systems. Sixth, DDTs produce very futuristic buildings that are not buildable in reality. Seventh, sometimes DDTs conflict with Saudi cultural and architectural requirements. Eighth, DDTs in some ways could conflict with Islam. Ninth, computers cannot think and design in the same way that we do. Tenth, DDTs are something new that we do not get used to it. Eleventh, DDTs are the best to design iconic buildings only. Finally, we need to stick to our cultural and architectural values, not DDTs.

The sixth category and the last category is for those interviewees who know digital design techniques and reject them for some reasons. They have a different architectural mindset. The reasons for rejecting digital design techniques are similar to the other interviewees who also refuse them. For example, they worry about the human or architect’s role in the design process. Yosef Sabri, a final year student at King Fahad University of Petroleum and Minerals (interviewed 2014), comments, “Personally, I am an opponent. I like to use my free hand skills instead of using mathematical equation to design. I dislike them”. He is linked very strongly to the traditional designing techniques and believes in them to the extent that makes him reject digital design techniques, even if they are better and/or
convenient. Sabri believes that digital design techniques constitute a new school of architecture contrasting the traditional way of design. It focuses on using computers as a designing tool. He also believes digital design techniques are negative if they take the human aspect out of the design process, that is by a press of a button the design is ready with no intervention from the designer. In addition, for him digitally designed buildings look like futuristic or science fiction architecture, especially Frank Gehry and Zaha Hadid designs. This is also reflected in building materials and construction techniques. These reasons are just an illustration of why Saudi architects could refuse or reject using these techniques.

The other kind of interviewees were Saudi architects who are studying overseas and have attended the digital design techniques seminar and workshop. According to the information that the interviewees have provided, they are not very different from the six categories listed above. In general, all know digital techniques because they are completing their degrees overseas and they are all willing to consider the idea of introducing these techniques to Saudi culture, architecture and architectural education. Most of the discussion was about the advantages and disadvantages of digital design techniques, their outcomes, the way to introduce them, and the potential limitations and obstacles that may face the introduction.

Equally important are the interviews with the Saudi computer science students. The highlighted topics were: programming as a basic skill among computer science students in Saudi; how hard programming is and what knowledge is needed; Saudi culture and programming; programming in architecture as an important part of digital design techniques; what architects need to be able to use digital design techniques; and the possibilities to use computer science departments to teach architecture students.

In general, and based on the interviewers’ information, programming is a fundamental and basic skill that computer science students and engineers must master in Saudi Arabia or worldwide. It is not an impossible skill to learn how to program. Students need to know the programming language principles, programming logic, and some other skills such as
mathematics and English. Saud Nassir, a PhD candidate in computer science (interviewed 2015), commented:

To study programming you need a guide, whether it is a lecturer, tutor or online course. Someone to guide you because you cannot start programming on your own. You may learn the basics but may miss industry practice and even how to design your code and write it in an efficient reusable way. In other words, programming requires styles and things that you may not be able to find in textbooks.

From Nassir’s perspective, programming is not a self-learning skill; an experienced guide is needed to facilitate this knowledge to learners. When talking about this skill among Saudi society, Mohamad Ikram, a PhD candidate and teaching staff at Umm Al-Qura University, and Ahmad Angawi, a Master of computer science student (interviewed 2015), state that Saudis avoid programming for three reasons: outside of the society interest, difficulty and English language. In addition, when asked what computer science specialists know about programming in architecture, and what architects need to enter this world, Bahjat Faqeh, a PhD computer science candidate and teaching staff at King Abdulaziz University (interviewed 2015), replied:

Programming is now involved in almost all disciplines, to the extent that no discipline could survive without it. I believe that programming now is everywhere and computer science people are there to make your work and life easier. In architecture, architects need to do basic programming skills to learn the logic and then to do programming for architecture design subjects.

For this study, this is an important point to be considered. It indicates that programming as a knowledge exists at Saudi universities and in more than one discipline, but does not explain why it is not yet introduced to Saudi architectural education. What architects may need to employ this skill according to the interviewees is not very different from what the computer science students do. Furthermore, what will happen if the computer science departments at Saudi universities help architecture students by teaching them? Nassir (interviewed 2015), answered:

There is a gap between computer science tutors and architecture students. The gap is about applying the same knowledge in different disciplines. The computer science lecturer is able to tell architecture students how to use programming languages, but he might not be able to know how architects will make benefit of it. They are both using different terminology and references. I think it is better to have an architect who is a specialist in programming to teach architecture students.
This expectation has raised a significant point, which is the gap between the two disciplines.

Overall, when the interviewees’ responses are measured, there were about 15 reasons to accept introduction of digital design techniques with no conditions (just accept) and 16 conditions need to be considered to accept introduction of digital design techniques. On the other hand, there were about 17 reasons to reject this introduction (see Table 11).
<table>
<thead>
<tr>
<th>#</th>
<th>Category</th>
<th>Position</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ACCEPT DDTs</td>
<td>JUST ACCEPT DDTs</td>
<td>Being up to date.</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>Buildings’ form will be better.</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>DDTs will not conflict with culture or values.</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>DDTs are useful and could improve old traditional techniques.</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>Using DDTs within Saudi context may result in new style.</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>Architects need to master DDTs especially scripting.</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>DDTs will integrate industry, construction &amp; materialisation from the early stages of design.</td>
</tr>
<tr>
<td>8</td>
<td>CONDITIONS TO ACCEPT DDTs</td>
<td></td>
<td>Provide a vision to the unexpected future.</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td>Make design process easier and time saving.</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>DDTs need to be taught at Saudi universities.</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td>Produce interesting architecture.</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td>DDTs response to the users’ needs and sustainability.</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td>Open new horizon.</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td>Reluctance means lagging behind.</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td>DDTs create forms, analyse circulation &amp; many other things.</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>JUST REJECT DDTs</td>
<td>When DDTs should be introduced (in what educational level).</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td>We should be ready (Saudi practice, constructions &amp; education are not ready).</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td>We need to try and examine DDTs outcome first.</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td>Need time (there is no enough time to insert DDTs within the current curricula).</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td>Increase Saudi staff DDTs’ knowledge.</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
<td>Use DDTs to serve the cultural needs and local identity.</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
<td>Use DDTs to serve the human sense of space.</td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
<td>DDTs should be introduced by Saudis.</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
<td>Should suite the Saudi society’s requirements.</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td>Should not dispense with the old architecture schools’ skills.</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td></td>
<td>Student should develop their skills away from DDTs first.</td>
</tr>
<tr>
<td>27</td>
<td></td>
<td></td>
<td>Saudi architecture environment should be ready to accept DDTs.</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td>The architect’s role should be protected.</td>
</tr>
<tr>
<td>29</td>
<td></td>
<td></td>
<td>Designers should always be in control of the design.</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td>DDTs should be complementary techniques.</td>
</tr>
<tr>
<td>31</td>
<td></td>
<td></td>
<td>Should change some Saudi universities’ aspects.</td>
</tr>
<tr>
<td>32</td>
<td>RESONS TO REJECT DDTs</td>
<td></td>
<td>Do not know how to use DDTS.</td>
</tr>
<tr>
<td>33</td>
<td></td>
<td></td>
<td>DDTs will dispense with the architects’ role.</td>
</tr>
<tr>
<td>34</td>
<td></td>
<td></td>
<td>Produce ‘weirdo’ architecture (futuristic, science fiction, iconic).</td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td>DDTs are not part of Saudi culture (from the west to the west).</td>
</tr>
<tr>
<td>36</td>
<td></td>
<td></td>
<td>Saudi culture has different requirements.</td>
</tr>
<tr>
<td>37</td>
<td></td>
<td></td>
<td>Having no problem with the current traditional techniques in all levels “satisfaction”.</td>
</tr>
<tr>
<td>38</td>
<td></td>
<td></td>
<td>DDTs will replace old experts and academics.</td>
</tr>
<tr>
<td>39</td>
<td></td>
<td></td>
<td>DDTs will conflict with Saudi cultural &amp; architectural requirements.</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td>DDTs are out of the Saudi interest.</td>
</tr>
<tr>
<td>41</td>
<td></td>
<td></td>
<td>DDTs will increase the cultural requirements.</td>
</tr>
<tr>
<td>42</td>
<td></td>
<td></td>
<td>DDTs will impose new jobs &amp; re-structure the current educational system.</td>
</tr>
<tr>
<td>43</td>
<td></td>
<td></td>
<td>Computers cannot think &amp; design in the same way human do.</td>
</tr>
<tr>
<td>44</td>
<td></td>
<td></td>
<td>DDTs are new &amp; we do not get used to them.</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td></td>
<td>We should stick to our culture and architectural values.</td>
</tr>
<tr>
<td>46</td>
<td></td>
<td></td>
<td>Prefer free-hand skills rather than using scripting to design.</td>
</tr>
<tr>
<td>47</td>
<td></td>
<td></td>
<td>DDTs is a new school of architecture contradicting with traditional schools.</td>
</tr>
<tr>
<td>48</td>
<td></td>
<td></td>
<td>DDTs will take out the human aspect of design (will produce inhuman buildings).</td>
</tr>
</tbody>
</table>
6.6 Digital design techniques from the interviewees’ cultural and architectural perspective

This section discusses how the interviewees consider digital design techniques from a cultural and architectural perspective. During the interviews, four types of interviewees were found: first, the ones who think that Saudi culture will accept digital design techniques; second, the ones who believe that digital design techniques may conflict with Saudi culture and thus will be rejected; third, the ones who believe that Saudi current architecture will accept digital design techniques; and finally, the ones who believe that Saudi architecture is not ready now to embrace digital design techniques. Following is detailed analyses of these views.

6.6.1 Saudi culture will accept digital design techniques

Most of the interviewees were positive and assumed that Saudi culture will accept digital design techniques for reasons related to the cultural and government desire to move forward and to be developed and modernised. Babsail (interviewed 2014) claims that Saudi people like to see and use new technologies. From his point of view, there is no doubt that there will be positive acceptance if these techniques are introduced in an easy way, particularly at the architectural schools’ level. What comes to mind is the idea that Saudi culture will encourage this introduction. For Abdulrahman Gadi, a final year student at Umm Al-Qura University (interviewed 2014), many Saudis have travelled overseas and seen the outcomes of digital design techniques and that is one of the reasons that makes Saudi culture more likely to accept these techniques. Encountering and/or exposing Saudis to these techniques’ outcome via travelling could contribute to an easy introduction. Moreover, these techniques will be accepted if they enhance Saudi architecture and, at the same time, they will not contradict the cultural framework. Mohamad Baz, a practitioner and teaching assistant at Umm Al-Qura University (interviewed 2014), said:

If DDTs are introduced as a tool that can be used to improve local architecture within our customs’ and traditions’ framework, they will be accepted. We really need to put Saudis’ hands on these techniques to produce suitable architecture.
This is not only related to the society's willingness to change, but it is also linked to the government plan to move forward with these techniques. Mohamed Saqqaf, a practitioner and an assistant teaching staff at Umm Al-Qura University (interviewed 2014), commented that:

At the government level, DDTs will be accepted, as the country is pushing to be recognised globally. The evidence is the new Riyadh Metro station, which is designed by Zaha Hadid.

As shown in Section 5.7, there are many new buildings under construction now in Saudi Arabia that are designed digitally and by famous international offices and architects which gives a strong sign that these techniques are useful and Saudi culture will accept them.

Based on the interviewees, there are four reasons that make Saudi culture accept digital design techniques: the desire to explore and use new technology; exposing Saudi culture to digital design techniques outcome through travelling; digital design techniques will improve local architecture; and government initiatives to take a forward development step. It is important to know that being an open culture is one of the main reasons that makes Saudi culture accept these techniques.

6.6.2 Digital design techniques may conflict with Saudi culture
The second aspect that has been raised is digital design techniques may conflict with Saudi culture and thus will be rejected. The interviewees who argue for that are a minority; they may have a fear of these introductions or they are antagonistic or against it for cultural reasons. Abdullah Karban, a teaching staff at Umm Al-Qura University (introduced 2014), stated “If digital design techniques do not conflict with the Islamic principles and values, we will welcome this technology”. He is looking forward to introduce digital design techniques, but he is also afraid of the introduction’s cultural and architectural consequences. Others, such as Wahag Ahmad, a final year student at King Fahad University of Petroleum and Minerals (interviewed 2014), are looking to digital design techniques as something irrelevant which will threaten Saudi culture and history.
Moreover, AZ and AA (interviewed 2014) argue that digital design techniques are negative, that they will impact the cultural and architectural values, and therefore that they should be rejected. AZ justifies why they should not be accepted. He stated:

Saudi culture and architecture have special requirements. For example, as an Islamic nation we need high levels of privacy, we need to minimise window size to increase privacy and decrease sun penetration. I think these techniques will not be the best to provide all our needs. It could be possible that DDTs could conflict with Islam in some ways. Our religion commands us to build moderate environments. We do not need to celebrate ornament or sculptures of human, animal or any creature. We need to build buildings that are humble/modest.

From the perspective of AZ and AA, digital design techniques will not comply with the principles and requirements of Saudi culture, of society, religion and environmental needs. They will fail to produce moderate and abstemious buildings, and will produce unusual buildings (for Saudis). That could be the case for the interviewees here, and this is a way they reject them, but it is not the reality of use of digital design techniques. These techniques are tools that could be used to serve and solve perhaps all given designing problems. They could be used to produce a normal and usual building, to serve the cultural and religious needs, and to comply with the local weather and environmental circumstances.

6.6.3 Saudi architecture will accept using digital design techniques

The third point is that Saudi architecture will accept using digital design techniques, but in the form of iconic buildings, which most likely are designed by international architects. There are many examples of iconic buildings that are under construction now in Saudi Arabia and they are all designed by international offices. For example, Mohammed Saifuddin, a practitioner and a teaching assistant at Umm Al-Qura University (interviewed 2014), commented:

Umm Al-Qura University now is constructing Makkah Techno Valley with the help of three foreign consultants, which are Gensler, Nikken Sekkei and HOK, which all are using digital designing technologies. The most important thing for the owner is fast production. Often the focus is on the architecture offices' name, their experience, creativity side and the configuration in most Saudi major projects. Now the vision is directed to build distinctive and exotic forms. We are aiming to construct iconic buildings such as King Abdullah University of Science and Technology (KAUST) and King Abdullah Al-Jawhara Stadium.
One of the Saudi government goals now is to construct unique, distinctive and iconic buildings, but why by using only foreign architects? According to Baz (interviewed 2014), there are three reasons: firstly, for reputation; secondly, the admiration of and fascination with digital design techniques’ outcomes; and thirdly, Saudi Arabia does not have qualified architects in this field. For final year students at King Fahad University of Petroleum and Minerals Amr Aldaaish, Ibrahim Alsuweti and Yosef Sabri (interviewed 2014), the reasons why Saudi architecture accepts iconic buildings and foreign architects are similar. They argue that Saudi architecture accepts iconic buildings, which are designed by foreign architects using digital design techniques because Saudis are seeking reputation and fame, like imported architecture, and lack of confidence in local architects. Will this reliance on international offices help Saudi architecture to develop? This question is answered in the next section. According to the interviewees, Saudi culture and architecture will accept digital design techniques to construct iconic building through using only foreign architects, and the reason could be that Saudi architecture is not ready yet to introduce and use digital design techniques.

6.6.4 Saudi architectural environment is not ready to embrace digital design techniques now

The fourth aspect is that the Saudi architectural environment is not ready yet to embrace digital design techniques as construction techniques are also not yet known in Saudi Arabia. Thus, there is a reliance on foreign architects and/or digital design techniques became exclusive for foreign architects in Saudi Arabia. Nevertheless, the situation has started to change recently.

Saudi architecture is not ready because there is no overarching environment for digital design techniques. This environment is where these techniques are known, common, and used by Saudi architecture circles such as government, practice and education. For example, Ahmed Shehata, a teaching staff at Umm Al-Qura University (interviewed 2014), suggests that the Saudi Ministry of Hajj has an overarching GIS environment, and all Hajj offices are working to use, update and develop this environment. Another example is, to apply for a permission certificate to construct a building from the Holy
Makkah Municipality, all the building drawings must be submitted to the municipality in AutoCAD format. According to Shehata, digital design is an integral environment which consists of government, practice, education, software, hardware and a way of thinking. Unfortunately, this environment is not ready yet or not available in Saudi Arabia. Jamal Qawasmi, a teaching staff at King Fahad University of Petroleum and Minerals (interviewed 2014), highlights why this environment may not currently exist in Saudi Arabia:

I think the environment is not ready. The reason is there is no political desire or plan to use and teach DDTs. For example, in Jordan the economic situation was modest. The solution was a policy to provide IT education at Jordan’s universities. This is what I mean by political desire. There are huge projects under construction now in Saudi Arabia. However, there is no desire or policy at the national level to introduce digital techniques. Therefore, all large and complex projects were designed overseas. Saudi architectural offices have the ability to use computers only to draw. Now, we need to put policies, objectives and plans to introduce DDTs immediately.

The example Qawasmi provides may be useful to this study, but what is the way to reach and convince the government to adopt digital design education and what is the framework to follow? Other interviewees have offered different reasons such as digital design techniques do not exist yet in Saudi because of their high cost. However, Nabeel Koshak, a teaching staff at Umm Al-Qura University (interviewed 2014), expects that digital design techniques will be ready soon through increasing university, community and practice awareness.

Digital design techniques’ construction techniques which are part of the suggested overarching environment are not known in Saudi Arabia. This is also an important point that may cause Saudi architectural environment to not be ready. Shehata (interviewed 2014) argued:

Is the Saudi construction industry able to construct and implement DDTs? The answer is I doubt. If there is a wonderful form on the computer screen, I am sure the form will be constructed badly and the reason is that Saudi construction industry is not ready yet. For example, computers produce fragmented forms, which often consist of a periodical or not periodical unities. This will challenge Saudi construction industry.
The Saudi building and construction is not ready to construct digital design techniques outcomes. Ibrahim (interviewed 2014) claims that Saudi architects do not have enough experience in this field or do not know about these techniques at all. Thus, there are no Saudi architecture offices which are able to use digital design techniques to design and construct iconic buildings. Moreover, Ahmad (interviewed 2014) comments that foreign architects are superior, as they know how to use digital design techniques and how to build their outcome. Furthermore, Babsail (interviewed 2014) says that Saudi practice is not ready to accommodate these digital skills in design and construction. Nevertheless, this is not a general rule. In Saudi, construction contractors are classified to construct different levels of buildings. There are class (A) contractors who can build large sophisticated buildings, but they are few. Saqqaf (interviewed 2014) believes that:

I am sure there are big/famous Saudi offices starting to enter this field – DDTs – strongly in terms of design and construction. It is possible to reach up the international popularity in order to become internationally recognised, offices must be aware of all the recent techniques.

Because Saudi architecture is not ready, using digital design techniques becomes exclusive to foreign architects and international architecture offices. There are several reasons why Saudis are using foreign architects to design their buildings digitally such as Saudi architects are not qualified re digital design techniques, and lack self-confidence, and foreigners are digital design technique experts, qualified, reasonable and low cost. When Koshak (interviewed 2014) was asked why Saudis use foreign architects he replied that this is a very wide question. “I can summarise it in one thing, which is oil.” We completely relied on it. That could be an overall notion, where oil wealth makes using foreign architects affordable. In contrast, Omar Osrah, a teaching staff at Umm Al-Qura University (interviewed 2014), highlighted other reasons:

Unfortunately, there are no qualified Saudi architects… if we have the qualified architects, decision-makers do not want to risk 20 or 50 million by using qualified Saudi architects with no experience in this field. Moreover, almost all Saudi society trusts non-Saudi architects, to their degrees and experience in this area.

To some extent, this is true. Among the three Saudi universities there was only one teaching staff member who was a specialist in digital fabrication. He had just returned to Saudi Arabia in 2014 after he finished his Masters degree at Southern California Institute
of Architecture at Los Angeles. The Saudi specialists in the field are few and new. The other issue is that Saudi society does not trust Saudi architects and prefers foreign architects because they are digital design technique experts and cost less. This is also the argument of other interviewees such as Ahamd Albazai (a final year student at King Saud University), Anas Almughariy (a teaching staff at King Saud University), Alfulaij and Alkharoubi (interviewed 2014). They state that Saudi society and decision-makers do not believe in Saudi architects’ ability to design unique huge buildings. Hence they trust foreign architects and their experience. They argue that Saudis are not knowledgeable in this field, so it is better to use foreigners who understand digital design sources. They also claim that using foreign architects is reasonable, reliable and costs less.

Omar Al Mahdi, a teaching staff at King Fahad University of Petroleum and Minerals (interviewed 2014), added that:

using foreign architects in Saudi relates to their expertise, credits and international practice licenses. For example, if a foreign architecture office has a license to prove its ability to design using DDTs professionally, it will be allowed to practice in Britain, America and Australia.

This is a critical point to justify why Saudis are using foreign architecture offices. In contrast, Saaed Bargawi, a teaching staff at Umm Al-Qura University (interviewed 2014), argued:

Do we use them for their technological proficiency, or because they are internationally famous and we like to show off? I think we are focusing on using famous names, not because they are digitally professional.

Even though this view contradicts the previous one, it still important and meaningful to this study. Both points should be considered to justify why Saudi Arabia is using international offices. This is not only the case in Saudi Arabia, but also the case in other countries.

Saudi are using international architects for many reasons. Qawasmi (interviewed 2014) stated that “Saudi construction industry is not encouraging, politics do not have a desire,
and education is not teaching these techniques. Therefore, it is fair enough to use foreign architects now”. This justifies why Saudis are using foreign architects. If Saudi architecture is not ready, why not use someone else to do it, to learn from, or at least to imitate.

It is noteworthy to know how Saudis are looking at using foreign architects, and whether is it positive or negative. It could be positive if Saudi architects are able to fully benefit from the foreign experts’ experience. In contrast, it will be negative if the foreign expert cannot meet the Saudi cultural and environmental requirements.

Using international offices could be positive to Saudi culture and architecture. The majority of the interviewees have admitted the positive influence of using foreign offices. The main reason was to learn these techniques from them, but there was also a condition which suggests that their outcome should be restricted and monitored to comply with Saudi cultural requirements. Abu Ouf and Kabli (interviewed in 2014) commented that using foreign architects is positive, but they should teach these techniques to university students. For Abu Ouf it was more like the need for foreign coaches to coach local soccer teams. Similarly, and with examples, Saifuddin (interviewed 2014) said:

Absolutely positive, a foreign designer is a person who can use new technology and transmits it to us. I do not see any cultural opposition. A foreign designer can successfully design a normal mosque, but he needs some time to understand religious and cultural requirements. The Holy Mosque is a special case; it is a huge building accommodating two or three million people. The foreign designer’s visions were deficient as he used the stadium design principles. Contrary, when you look at Al Jamarat Bridge, it is an engineering solution. We need to do a computer simulation to solve the problem, so any architect in the world can deal with it. There is a huge difference between Al Jamarat Bridge and The Holy Mosque.

Saifuddin gives two important examples of how foreign architects could misunderstand Saudi requirements and, at the same time, they can achieve these needs if they are assimilated. This is what makes some interviewees put a condition on using international offices. For instance, Jameel Alsalafi, the head of architecture school at Umm Al-Qura University (interviewed 2014), commented that using international architects is
something positive, but Saudis need to reconsider its cultural dimensions; it must be within Saudi cultural boundaries. According to Saifuddin, the condition is achievable.

On the other hand, using international offices could negatively affect Saudi culture and architecture. The minority of the interviewees have admitted the negative influence of using foreign offices. According to the interviewees, that could be negative because the international architects are not able to design a typical Saudi house. They will not succeed even if they have learned about the local Saudi culture. AZ (interviewed 2015) claimed, “their work could be acceptable at the level of iconic public buildings, but definitely they will not succeed if they design typical Saudi residential house”. Osrah (interviewed 2014) also added:

It is not positive, even if the foreign architect has learned about us, he is not good as the architect who is living in this environment and knows the culture and society. Foreign architects have the skills, but do not have the essence of our culture.

The reasons are related to the fact that foreign architects are only able to design and construct iconic buildings in Saudi, but not Saudi housing, which contradicts with the other facts that those architects are skilled in digital design techniques and can use that to design for Saudis if they understood the cultural needs or if they work with Saudi architects.

6.7 Digital design techniques technical knowledge and architecture

6.7.1 Architects’ views on technical knowledge

This section addresses Saudi architects’ perception of what technical aspects they need to know about using digital design techniques. As a technical notion Saudi architects, architecture educators, and students need to know that digital design techniques require high computation skills which could include knowledge in English, mathematics, programming languages and software. They also need to know that there is a difference between an architect with digital design technique skills and a computer programmer, but they could use a programmer to get help. The majority of the interviewees agree that programming skills, English and mathematics are the three main aspects to enter the
world of digital design techniques. For example, Alkharoubi (interviewed 2014) commented:

Programming language (scripting) is the main aspect. In addition, English language, physics and mathematics are very important factors. These four things are the most difficult things in the programming world. I expect these aspects will scare students off using DDTs. This is why pushing students to learn 3D modelling is easier.

This was the same argument of Adel Bin Yassin, a teaching staff at Umm Al-Qura University, and Kabli (interviewed 2014). Equally important is what Alataar (interviewed 2014) encounters when he teaches computer skills to architecture students. He commented:

I guess DDTs will potentially be difficult, especially with students. There will be language problems. Most of our students do not use English. For example, I am having a hard time introducing the software’s interfaces. Students need to learn some terms, memories, the commands’ icons, and to understand the command functions. The students’ English language capabilities do not allow them to use Building Information Modelling software. Thus, they will not be able to use programming languages, which require fluent English and mathematics and programming language knowledge. Moreover, I am always stressing in not teaching students how to use certain software, but to teach them how to think using the software. Teaching a concept not a software. For example, if I introduced the term Extrude or Sweep, students will ask “where to find these commands on the AutoCAD or Rivet interface?” We are still sticking in this level and cannot move to programming now. Do you think a student in this level can write a code or script?

This comment shows how Saudi architecture students are currently using computers in architecture design and what knowledge they need to enter the world of digital design techniques.

Osrah (interviewed 2014) adds some significant points that architects need to know. He highlights that the software copyright is a fundamental issue in Saudi, as digital design techniques software is not free. That means architecture schools and offices need to offer these software, and this is not guaranteed. Osrah also points out that using software requires certain skills and experience in other support disciplines, so being a typical architect is not enough to use Grasshopper or Processing. Unfortunately, Saudi architects are missing these skills, because they do not learn them at university. Architects also need
to know that a collaboration between them and computer science specialists is needed. The problem in this point is neglected or not known among Saudi architects. According to Wadi Bargawi, a teaching staff at Umm Al-Qura University (interviewed 2014), Saudi architects do not realise that they can use programmers to help them find architectural solutions through programming. The problem is twofold: Saudi architects do not know that they can use programmers to help them, and Saudi programmers also do not know that they can help architects. Bargawi also adds that it is possible for an architect to be a programmer, but a programmer cannot be an architect, which emphasises the role of architects even in computational design.

English language competency differs between universities. For instance, King Fahad University of Petroleum and Minerals interviewees do not see English as a problem because they have their curricula in English. Ashor (interviewed 2014) claims that English language it is not an obstacle now, as all architectural software interfaces are now in English. When architects know the role of software in drawing, modifying, generating and time saving, they will learn the software quickly. Whereas it is a major problem to King Saud University and Umm Al-Qura University students because they have their curricula in Arabic. Obaid Al Jabali, a final year student at Umm Al-Qura University (interviewed 2014), said “of course English is a problem, Umm Al-Qura University does not use English for teaching”. For other interviewees English is not a problem because it is used within the framework of architecture terminology. In other words, it does not require fluency, only a limited number of certain words. Abdulaziz Abu Suleiman, the head of architecture schools at King Saud University (interviewed 2014), argued, “I do not think English language is a barrier because we will use it within certain frameworks, and it is possible to learn it quickly and easily”. Therefore, English language is an individual matter: it varies from person to person and from university to university.

In contrast, some interviewees see no problem with the technical requirements of digital design techniques. This issue is encountered in almost all disciplines and could be defeated easily, usually through providing the missing knowledge and the eagerness of students to learn. Ashmeel (interviewed 2014) said, “I do not see digital design technical
skills as obstacles, in each discipline you will find such requirements”. They are something normal and expected, thus an adequate education is needed. Nawaf Alromaih, a final year student at King Saud University (interviewed 2014), commented “there is no technical problems, we just need to be ready and have enough knowledge”. Moreover, Saudi architecture students are able to learn these skills quickly and this is something usual, and makes some interviewees unconcerned about the technical aspects of digital design techniques. According to Shehata (interviewed 2014), the student's ability to learn how to use the software interfaces is the same as using programming or scripting, they have unexpected ability to learn. Even though technical issues still exist, they could be overcome. S. Bargawi (interviewed 2014) claims that “the technical reasons are a big part of digital design introduction. They will be obstacles, but we can overcome them through architectural education”. Similarly, Abu Ouf (interviewed 2014) states, “I do not see digital design techniques difficult with practice. Honestly, Saudi students have no problem they can penetrate any software. They only need computers and someone to guide them”.

Saudi architects confirm their need to improve or learn English, mathematics and programming languages. They also highlight the need for a collaboration between architects and computer science specialists. They see these needs as something normal that must happen, but it will be easy to achieve.

6.7.2 Computer science specialists’ views on technical knowledge

Because computer science students in Saudi are the most exposed to programming and technical skills they were chosen to participate in this study. They have provided some crucial information about programming required knowledge, how they have studied scripting, and how they see coding in architecture.

According to the computer science students, there is some required knowledge to master programming. Almost all of the computer science interviewees highlighted the same aspects, which are summarised in the following points:
1. Architects need to know and understand how computers think.
2. Architects also need to have enough information about programming language.
3. Architects need to have fluent English.
4. Architects need to understand the structure and logic of the language itself.
5. Architects need to solve problems using programming.
6. Architects need mathematics as something fundamental.
7. There are many programming languages. Architects need to master one, then it will be very easy to learn the others.

Computer science students studying programming need to do at least five to six subjects which usually takes from two to three years to master this skill. For instance, Ikram (interviewed 2015) commented:

I did Programming One, Programming Two, Advance Programming, System Software and Software Engineering. They were five compulsory subjects that all computer science students have to do. Programming One describes what programming means, defining functions, pointer, variables and integers. In addition to how to save data, how ram memory works, and the difference between decimal and integer variables. We started to use loops and IF statements. This is to build up the students’ knowledge and to understand programming (the knowledge that no programmer can survive without it). In Programming Two we started to build full function and design some easy/basic programs. In Advance Programming we did two functions, calling functions, classes, copying functions from different script, and programming a hardware to make it work. For example, how to program a sensor to control an automatic door (open/close). System Software was about computer engineering, how scripts work through the hardware. In the last subject, we design some programs to solve problems. For example, designing a filter to fix pixelated calligraphy/image.

This was the actual process that computer science students went through to master the technical skills. According to them, the process was long and hard. Faqeh (interviewed 2015) argues that learning programming is not about the time spent and how many courses or languages, it is about assimilating programming logic:

If you understood the programming logic, you can master as many programming languages as you like and of course you need a lot of practice.

He highlights the experience aspect of programming, which comes through use and practice. In addition, programming is not a skill that any person can master without a
guide or teacher. According to Nassir (interviewed 2015), studying programming requires a guide, whether it is a lecturer, tutor or online course. In other words, programming require styles and elements *not found in textbooks.*

Furthermore, computer science specialists agree that programming in architecture is different, even though it uses the same principles and logic. They also agree that programming will be difficult for architects especially at the beginning. Mohamad Alshehery, a PhD candidate (interviewed 2015), argues that programming in architecture will be based on computer science, but with a different structure. Similarly, Ikram (interviewed 2015) claimed:

> We will use the same programming principles or the same language. However, we may have different functions or structures. If someone asks me to script to an architect, I need to go to find some architecture programming blogs or forums to understand his needs. I need some time to understand the architects’ needs. I think any programmer can help architects, but it will be better if architects themselves know how to program. I think yes it is different.

It is not an easy task for a computer science specialist to program for architecture. There is a misunderstanding or gap between them, thus it is better to be an architect with digital design technique skills or to work closely with a programmer to explain every single detail. That does not mean dispensing with the collaboration between architecture and computer science, but it might be difficult. According to Faqeh (interviewed 2015), architects need to do basic programming skills subjects to learn the logic and then to do a programming for architecture design subject, which will be very difficult at the beginning. However, it would not take more than a couple of months to understand the logic. Architects need to start programming in a separate subject to learn the basics and then they need to do another subject to link architectural requirements with programming.

The computer science interviewees provided noteworthy advice for architects. Now architects need to learn these technical skills to maximise their computational capability. It is interesting that programming as a technical skill exists at Saudi university computer science departments, *but not in architecture schools.*
6.8 Conclusion

At the end of this chapter it is important to highlight the important aspects found through the interviews with Saudi educators and students. There were six categories that show how Saudis regard digital design techniques. The main two categories are people who accept digital design techniques and others who reject them, but these two are divided into six categories (see Figure 14). The reason some people know about digital design techniques while others do not know is due to overseas education and English competency. The other issue was how the interviewees were looking at digital design techniques from cultural and architectural perspectives. Some people think that Saudi culture will accept these techniques and this is related to the desire to move towards development and modernisation. Others think digital design techniques may conflict with Saudi culture and therefore could be rejected because they could not meet the special Saudi cultural and architecture requirements. Others believe that Saudi architecture will accept digital design techniques just because they are able to produce iconic buildings, which relates to reputation, admiration and fascination, and because there are no digital design qualified Saudi architects. The last group thinks that digital design techniques might get rejected because the Saudi architectural environment is not ready to embrace digital design techniques now.

This chapter also investigated technical knowledge of digital design techniques among Saudis. They need to know that to use digital design techniques, high computation skills are needed, including supplementary knowledge such as English, mathematics, programming languages and software. According to some interviewees, such knowledge is hard to master, especially for architects. In contrast, other interviewees believe that this digital design knowledge is achievable. However, the computer science specialists argue there is some required knowledge to master programming, summarised in seven points (see Section 6.7.2). This was a picture of perception of digital design techniques now. The relation between Saudi culture, architecture and digital design techniques is discussed in the following chapter.
Chapter 7: Saudi culture and architecture and relationship to digital design techniques

7.1 Introduction

Saudi culture and architecture have been changing since the unification of the Kingdom of Saudi Arabia. The chapter analyses the current Saudi architecture, how it is changing to be more global, and expectations. It also investigates the relationship between current Saudi architecture and digital design techniques. This includes why outcomes of digital design techniques are now in Saudi Arabia, but not by Saudi architects; why Saudi architects cannot use digital design techniques; the designing techniques in use now; and the clash between conservatism and the desire to advance Saudi architecture. Then it studies how Saudi culture may respond to the introduction of digital design techniques and the reasons that potentially prevent introduction of digital design techniques. Finally, it points out ways to introduce digital design techniques at the Saudi cultural and architectural levels.

7.2 Perception of current Saudi architecture

This section explores current Saudi architecture, using the interviewees’ perception to highlight important aspects of Saudi architecture now. It discusses the changes in the current Saudi architecture, how it is different, and its connection to the outside world. It also discusses the global style of current Saudi architecture and the expectations and reality of current Saudi architecture.

7.2.1 Changes in Saudi architecture

Most architecture in the world is changing consistently. This is due to political, economic, social and some other reasons, but the focus here is on technological reasons, in particular, how new technologies have changed Saudi architecture. Saudi architecture has changed rapidly since the oil exploration. It became more flexible in terms of accepting changes
and looking forward to improve. It became significantly different from its past and many of its aspects have changed. It also became more linked to the overseas world.

As a result of these changes, a gap between traditional Saudi architecture and current Saudi architecture has occurred. The reason for the gap, according to Saifuddin (interviewed 2014), is:

In 1962 the first generation of Saudi architects such as Abdulqadir Koshak, Omar Gadi and Mohammed Saeed Farssi could not connect what was existing with the new. The gap occurred between the Saudi builders and Saudi architects in the oil boom days. New construction materials and techniques have emerged; unfortunately they could not use them to accommodate the local architecture thus the gap occurred. With the accelerated development and changes, a lot of local and traditional architecture disappeared and they do not reflect the modern architecture. We are gaining a global architecture style. We should blame ourselves and the previous generation.

Similarly, Baz (interviewed 2014) supports the same reason for changing Saudi architecture. To some extent, this was the story of how Saudi architecture has changed during the oil boom. The story also proves the difference between the old Saudi architecture and the current Saudi architecture. Other reasons for change in Saudi architecture include embracing Western architecture styles, and importing and copying other designs from other environments. Al Mahdi (interviewed 2014) commented:

Some Saudi architecture offices adopt Western architectural style, which rely on Western values and society needs. This causes weakness in Saudi architecture and failure to provide the Saudi cultural requirements. Architecture is human thinking and a way of living. It is not just a science such as mathematics. Unfortunately, Saudi architecture is merged with Western architecture in non-appropriate ways. Thus, the current Saudi culture and architecture are not connected strongly.

Adopting Western styles may not be the best way to achieve the Saudi requirements, but merging Saudi architecture with Western architecture could be better if they are combined in an appropriate way that serves the Saudi requirements, which could be the right way to change Saudi architecture. Equally important is what Osrah (interviewed 2014) states. He says that contemporary Saudi architecture is something that came from another environment and was imposed locally, the society’s desires could not be achieved. This is because local architectural offices are providing ideas that are copied from other
countries, and this makes the current Saudi architecture look different. As a result, what is happening now in Saudi architecture is a hybridisation of Western and local architecture, but not all the attempts were successful. Alromaih (interviewed 2014) comments that some buildings reflect Saudi identity clearly, whereas there are some other irrelevant buildings.

Saudi architecture has changed dramatically especially after the oil boom, which is still in effect. The other reason that could be considered significant is non-Saudi architects who are involved in changing Saudi architecture over the last few decades.

7.2.2 Global style

Due to the rapid Saudi architectural development, the Saudi built environment is heading towards a global style, a style that has never been part of the Saudi culture. Most of the current buildings do not carry the native characteristics of local Saudi architecture. Mostly, the architects who design the existing Saudi buildings are not Saudi and thus they produce ‘outlandish’ architecture. The taste for local Saudi architecture is also disappearing. Very few Saudis are still interested and willing to build their houses using the local traditional style. The buildings’ exterior and interior are not very different from other international architecture. These points have been highlighted by the interviewees when asked about the current situation of Saudi architecture.

Almughariy (interviewed 2014) argues that the local designing and building techniques, which are consistent with Saudi culture and environment, have disappeared: “We are heading to an international style”. According to Alasker (interviewed 2014), most of the teaching staff and the architects working in Saudi are not Saudis. Therefore, the dominant and prevalent architecture style is international. For example, balconies are not popular in Saudi buildings because they do not suit the Saudi environment and culture (Abdullah Fuda, a final year student at Umm Al-Qura University, interviewed 2014). Moreover, this could relate to the poor feeling for and appreciation of local Saudi architecture. Saudis
now are not using the local techniques and elements which derived from the past. In this way, the style could be called *global*. Koshak (interviewed 2014) said:

> We are missing the Saudi architectural taste due to social and cultural structural changes. The architectural and creativity appreciation became very limited. Our buildings now are not related to our culture and the local environment.

Only a few Saudis are willing to revive the essence of local architecture and use it now. The reason could be the social and cultural changes. Even though there are some attempts to use some elements and principles of the traditional Saudi architecture, the overall shape is still global, in other words, with no Saudi identity. Baz (interviewed 2014) claims that Saudi buildings are very similar to Western buildings and then Saudis add some elements from local architecture such as “Roshan” (see Figure 15). This indicates the *improper* use of Saudi traditional elements in the current context of Saudi architecture. Some architects are using these elements just to celebrate traditional architecture, but the overall appearance and the interior are global.

![Figure 15: Typical Saudi house with (Roshan) traditional elements attached (Albarqawi 2013, p. 4.35)](image)
The current Saudi architecture is struggling to find a clear vision. Some architects are calling for the new Saudi style, whereas others are calling for traditional Saudi architecture. However, the reality shows a style that is not related to authentic Saudi local architecture. It shows an international architecture, which could suit other cultures in different countries. This is what makes the difference between the reality and the expectation of current Saudi architecture.

7.2.3 The expectation and reality of current Saudi architecture

The expectation of the current Saudi architecture imagines the ideal form of an architecture that emerged from the local culture and, at the same time, matches society needs and the local environment. What is expected is an architecture that connects and links Saudi culture, traditional architecture and Saudi environmental needs. Alfulaij (interviewed 2014) states that it is expected to have a current architecture that connects the three main aspects of Saudi architecture: culture, environment and local architecture. However, the reality is completely different; these aspects are not connected in a satisfying way. Ashmeel (interviewed 2014) said “Unfortunately, there is no reflection of Saudi culture on Saudi architecture. Do not forget that architectural taste is not controlling Saudi architectural practice, but it is controlled by cost and construction’s speed”.

The architectural taste of local architecture is missing and Saudis are thinking about cost and construction. This could be unsatisfying for the expectations, but it becomes normal, as Saudis get used to it. Albazai (interviewed 2014) adds that Saudi architects know how to design for different cultures, but there are no Saudi cultural aspects reflected in the current built environment. What is happening is acceptable, but it is not the optimum to suit the Saudi culture and environment. Equally important is Osrah’s view (interviewed 2014). He believes that Saudi architectural markets, recent projects and architectural education are moving to the edge and nothing is moving towards improvement. Recent projects are not compatible with Saudi users, so what is the solution? This shows that the reality of the current Saudi architecture is lower than the expectation.
The reason for meeting the expectation mainly stems from Saudi society’s lack of awareness of what architecture means. They do not understand or assimilate what architecture is. Qawasmi (interviewed 2014) upholds that Saudi architects need to increase society awareness about the importance of architecture as a discipline or job. They also need to talk about architecture in a language that society can understand through newspapers, magazines and television. There is a gap between society and architectural perception. This could be one way to introduce digital design techniques to Saudi culture and Saudi architecture. Babsail (interviewed 2014) states “the public does not understand what architecture is. I mean the vast majority think architecture is a box shape building where they can live, work or pray”. If this is the reality of current Saudi architecture, it will be very important to raise public awareness and to link the three aspects of Saudi architecture. Abu Suleiman (interviewed 2014) suggests:

There are attempts to provide society, culture and religion requirements in our urban environment. Some of these attempts succeeded and the others failed. We must know that linking these three elements is a necessity and there will be no development and prosperity without them. I think DDTs are the best linking solution.

7.3 Saudi architecture and its relation to digital design techniques

There are four different aspects to consider in current Saudi architecture and digital design techniques. First, outcomes of digital design techniques are now in Saudi Arabia, but Saudi architects have not done them; second, Saudi architects are not able to use these techniques now; third, what designing techniques Saudi architects are using instead of digital design techniques; and fourth, the clash between conservatism and future desires, such as how Saudi architecture may respond to the introduction of digital design techniques.

7.3.1 Outcomes of digital design techniques are in Saudi Arabia but not by Saudi architects

Outcomes of digital design techniques are present in Saudi Arabia, but not by Saudi architects. As shown in the earlier chapter, there are a number of new iconic buildings
under construction in Saudi Arabia. Most of them are designed by international architecture offices using the latest digital design techniques.

The reason most new Saudi iconic buildings are designed by foreign offices using digital design techniques is manifested in the interviewees’ responses. Most of the answers focused on the fact that there are no Saudi architects specialised in this field, and digital design techniques are something new and not known until now in Saudi architecture circles. Ashmeel (interviewed 2014) believes that Saudi architecture has not entered the competition in this field until now, therefore there are no Saudi architects in this field. In addition, in Saudi Arabia the architectural practice is a long way from using these techniques. Similarly, Abu Suleiman (interviewed 2014) highlights that the large and complex government projects are designed using these techniques by professional foreign architects. This is because local companies and famous architecture offices rely on international expert offices to design local projects. Ibrahem (interviewed 2014) also emphasises that Saudi architects do not have enough experience in this field or do not know about these techniques at all. Now, Saudi architecture offices are not able to use digital design techniques to design and construct iconic buildings. The reason Saudi iconic buildings are designed by international architects is very obvious. There are no digital design techniques among Saudi professional architects, and therefore using international offices is required.

The potential impact of using foreign architects to design Saudi iconic buildings is that it reduces Saudi architects’ opportunities to enter this field. The impact could be negative as international architects do not know or have enough information about Saudi culture and environment. Ashmeel (interviewed 2014) describes that using foreign architecture offices will impact Saudi architects, as they have not been given a chance to prove themselves. Aldaaish (interviewed 2014) adds that foreign architects are not aware of the Saudi environment and culture requirements. Alsuweti (interviewed 2014) also notes that this will reduce Saudi architects’ chances and reputation. The interviewees highlighted the potential impact of using international architects.
Based on the interviewees’ views, introducing digital design techniques to Saudi architects could overcome the dilemma of using foreign architects and encourage self-sufficiency. According to Abu Suleiman (interviewed 2014) if there are Saudis specialised in this field, foreign architects will not have an opportunity to design Saudi buildings. If qualified Saudi architects have digital design techniques, foreign architects will not be required. Likewise, Qawasmi (interviewed 2014) points out that if we domesticate digital design techniques, Saudi Arabia will not need foreign architects.

7.3.2 Why Saudi architects cannot use digital design techniques

The problem is not that Saudi architects are not able to understand digital techniques, but most Saudi architects are not aware of them, and there are Saudi architects who know these techniques and able to use them. The other aspect is that there is no proper recognition for bright Saudi architects from Saudi architecture institutions. Saudi architects could be educated at and graduate from high-ranking overseas universities and will be like any foreign architect. Unfortunately, the reality is different. For example, Shehata (interviewed 2014), commented: “When two architecture offices (HDR and Saudi office) work together to design a building for Umm Al-Qura University, the Saudi office produced very low-level outcomes – in terms of the used technology. The issue does not relate to the Saudi architects, but to digital design techniques. In other words, Saudi offices do know how to use digital design techniques to design”.

The example shows that the currently used designing techniques cause a communication problem between local and international offices, but they still can work together. The problem is that the majority of Saudi architects do not know how to use digital design techniques and this could partly be because Saudi universities have not introduced digital design techniques yet. The other aspect is that there is no encouragement for Saudi architects to use digital design techniques in order to be recognised. Saudi architectural institutions do not differentiate between a Saudi architect with digital design experience and a normal Saudi architect who uses traditional designing techniques. This was Koshak’s (interviewed 2014) position. He argues that the government regulations do not recognise distinctive architects, which may be understood as not respecting architecture
practice. However, if all or some universities in Saudi Arabia do wish to teach digital
design techniques, then the situation inevitably will change. As Saudi architects with
digital design experience are not recognised, there is a reluctance to allow Saudi architects
to be digital design specialists, which makes digital design techniques unwanted.

7.3.3 Saudi architecture and current designing techniques

Saudi architects and architecture practices use traditional or normal designing techniques.
They use technology “computers” only to draw and to montage the final design version.
Digital design techniques are not prevalent or usual in Saudi practice circles. Atwa
(introduced 2014) commented:

Even through Saudi Arabia is currently witnessing an evolutionary leap,
unfortunately the vast majority are using traditional design techniques. I think we
need some time to be able to use DDTs. The public needs to know about DDTs and
their use. We rely on manual drawing and certain software, i.e. AutoCAD. They are
not as advanced as digital techniques.

Saudi architects are following the old traditional designing school and it is hard to find
someone who uses a different technique. Equally important is what Saqqaf (interviewed
2014) observed:

We use the normal and usual design techniques, but I have a desire to adopt this
technology in my office. There is no clear vision and information about DDTs, and
there are no Saudi specialists. You may work with us after you finish your study….There was an attempt by my office, but it was modest, we have tried to design
traditional windows digitally. Unfortunately, we get lost and could not find any one
to help us.

Because digital design techniques are not popular in Saudi, and because Saudi architects
are accustomed to using traditional techniques, Saqqaf’s attempt to design digitally was
not successful. His office is one of the leading offices using the common well-known
traditional designing techniques.

Despite the traditional designing techniques, computers are used in Saudi architecture,
but in a very basic way. Mostly they are used to make drawings, montages, calculations
and documentation. They are not used to help Saudi architects in the design process or to optimise the final design. Koshak and Qawasmi (interviewed 2014) state that digital design techniques are a very advanced trend and new for Saudi architects such that they do not have ideas or knowledge about them. Currently in Saudi Arabia the prevalent perception is that computers are a drawing tool only. This means that Saudi architecture offices have the ability to use computers only to draw. S. Bargawi (interviewed 2014) said:

> It is difficult to remember if there is anyone in Saudi practice who is using DDTs, and this evidence that proves that DDTs are still weak or not in use in Saudi Arabia. Thus, computers are used for drawing and montaging only.

The relationship between digital design techniques and Saudi architecture is very weak and they are not popular, and this is perhaps because most Saudi architects are still using old techniques. Introducing digital techniques will add to Saudi architecture and will be a step forward. This will also support positive diversity and variety to enrich the current Saudi architecture. More techniques in use will maximise the opportunity to produce new and relevant architecture.

7.3.4 Call for conservatism and the clash with the future

Figure 16 shows the potential clash point between the desire to move Saudi architecture forward, and conservatism as a trait that suppresses this desire. This is founded among the interviewees’ impressions, which could be part of how Saudi architecture will respond to introduction of digital design techniques. The clash could be demonstrated in three points. First, some Saudi architects think that digital design techniques will destroy Saudi traditional architecture. Therefore, they should be conservatives. Second, others think the use of digital design techniques in Saudi should be conditioned to make sure that digital design techniques do not harm Saudi traditional architecture. Third, the government approach is to protect the history of Saudi architecture.
Some architects claim that introducing digital design techniques will impact Saudi traditional architecture, and thus that these techniques are irrelevant, not important and threatening. This is one of the reasons causing the clash point. AZ (interviewed 2014) argues that digital design techniques produce very futuristic buildings that are not buildable in reality, and this conflicts with Saudi cultural and architectural requirements. AZ also comments “We have our way of design and it is hard to change to something new and different”. The problem is related to introducing a new style of architecture, which might conflict with Saudi architecture and the fear of changing the commonly used designing methods. Similarly, AA (interviewed 2014) believes that digital design techniques are “threatening our local architecture”. Coupled with that is Alasker’s (interviewed 2014) view that digital design techniques conflict with conserving local style and identity. By using digital design techniques, Saudi architecture is heading towards an international style, and that will result in strange building shapes. Alsuweti and Ahmad (interviewed 2014) point out that digital design techniques are new but irrelevant, we have not used them before, and they will assault Saudi culture and heritage.

Despite the conservatism notion, some architects claim that it is possible to use digital techniques in conjunction with traditional architecture to produce hybrid Saudi
architecture. According to Karban (interviewed 2014) digital design techniques are a trend resulting in very new architecture, which completely ignores local and traditional architecture in terms of form, essence and thought, and this will be threatening, but it is possible to mix digital and traditional. Nonetheless, digital design techniques may influence Saudi traditional architecture. They could also be mixed, but this mixing will be conditioned by achieving cultural and architectural needs.

Other architects believe that introducing and using digital design techniques in Saudi architecture should be conditioned to make sure they will not impact or influence Saudi traditional architectural “identity”. Thus, digital design techniques could be introduced in a way that both save and serve local architecture style and cultural requirements. Bin Yassin (interviewed 2014) said:

With DDTs, it is possible to turn Makkah or Jeddah to Chicago or New York, or to an area that does not belong to the surrounding society. From my point of view, if we do not control this trend, identity will be lost. In my opinion, the only way to control this trend is by customising it to suit the local society and architecture. I think there is no conflict between them and the Saudi culture, but we must adapt design to meet our society and architecture requirements. It must not be exaggerated forms, which do not suit our architecture. The best architecture for us is the one that respects our customs and traditions.

The concern is linked to controlling use of digital design techniques in a way that guarantees not affecting or influencing Saudi architecture values and principles. This was the theme throughout the interviews. For instance, Hariri, a practitioner and teaching staff at Umm Al-Qura University (interviewed 2014), claims that if digital design techniques kept Saudi identity, then why are Saudi architects not using them. Karban (interviewed 2014) argues that if digital design techniques can meet Saudi principles, it will become something positive. Furthermore, Shahrani (interviewed 2014) highlights that if digital design techniques saved Saudi identity and religion, they will be a good thing and not threatening. Slightly different is Saifuddin’s (interviewed 2014) view that “I wish to use digital design techniques to revive the big part of the old local architectural vocabulary that disappeared”. Even though the interviewees’ intention is to use digital design techniques, they are still concerned about saving, maintaining and reviving the old Saudi architecture. Conservatism is still suppressing their desires to go digital.
Government plans to conserve local Saudi architecture may have a role in this clash, as some government plans aim to save and revive the Saudi architectural heritage through education and local architectural competitions. This approach has been interpreted in different ways. Some architects think that introducing digital design techniques might contradict this government’s conservative plan. Bin Yassin (interviewed 2014) states that 20 years ago Prince Sultan Bin Salman had initiated one of the government’s plans to organise a series of seminars to consolidate local architecture through education. In general, it enhances the role of architectural education in consolidating local architecture, which is a great need for students and, at the same time, not easy. Waeel Albushi, a teaching staff at King Saud University (interviewed 2014), adds that there are many traditional awarded buildings in Riyadh, and this shows the government’s vision to conserve Saudi heritage architecture. Thus, reviving and consolidating local Saudi architecture requires using traditional techniques, not digital design techniques. While the Saudi government has this plan, it does not mean digital design techniques will contradict it and therefore they should be introduced. The government plan is not about introducing new designing techniques. Almughariy (interviewed 2014) states that there are others who support saving Saudi architectural heritage. Introducing digital design techniques is needed to help develop local architecture and to solve old problems.

7.4 Response of Saudi culture to digital design techniques

Saudi culture has an intimate relation to new technologies, even though it is trying to protect its core cultural aspects. This section discusses important points of how Saudi culture and society will consider digital design techniques and respond to them as something new is introduced. Young people seem to be more responsive to digital design techniques and will quickly grasp them. In Saudi society there are two kinds of people – open-minded, who will welcome digital design techniques, and antagonistic, who are against digital design techniques. Despite the existence of antagonistic views, for some, there is a great enthusiasm to use these new techniques. In addition, the response will follow other societies using digital design techniques. Finally, the response is sometimes conditioned with an easy and understandable introduction of digital design techniques.
Based on responses presented in the previous section, it is likely that Saudi culture will not face a major problem or obstacle in embracing and using digital design techniques. There is enough evidence to prove the culture’s ability and flexibility to accept these techniques. In general, many aspects of Saudi culture have changed; it becomes more flexible and modernised. Using digital technologies can become a culture within Saudi culture itself, especially for youth. Mostly Saudi culture positively responds to new technologies, negotiates the introduced technology, and sometimes controls it. Moreover, the culture encourages importing and using technologies, but it usually takes time to mix technology with culture, and often results in changing some cultural elements or changing the way of using technology. Therefore, there is evidence that Saudi culture is able to accept these techniques, and it is assumed that digital design techniques are tools which should not harm the culture.

The relationship between Saudi culture and digital design techniques is expected to take two forms. First, culture will respond positively to accept these techniques, and this is most likely to happen. Second, culture will resist or respond negatively and may reject techniques for reasons such as conflict, irrelevance or ignorance. As a positive reaction the following discussion considers the young Saudi generation and its obsession with digital design techniques, open-minded and antagonistic Saudis, enthusiasm, and easy and understandable digital design techniques.

Young generations are obsessed by new technology, including in Saudi Arabia. They like it more than older generations, and they understand it quickly. It seems to be easier for them to embrace digital design techniques than other generations. Al Mahdi (interviewed 2014) argued: “The young generation tend to use more technology. There is curiosity with a large positive response even at the architecture students’ level. The last five graduate groups prove that”.

That gives an optimistic indication of acceptance and easy introduction of digital design techniques, especially among youth including architecture students. To prove the idea of accepting digital design techniques in Saudi Arabia, Alaker (interviewed 2014),
comments that “Saudi culture will respond to the new digital design techniques very fast and easily, specially youth”. This highlights the fast and positive response of Saudi culture to these techniques and highlights the role of youth in this introduction. They are the most heavy ‘technology consumers’ and users, especially students.

As a part of the cultural diversity, there are usually proponents and opponents, and this applies for Saudi culture and its potential relation to digital design techniques. When introducing digital design techniques, the proponent group will be open-minded and looking forward to use them, whereas the opponent group will be more conservative and careful. Saifuddin (interviewed 2014) said:

The new generation is fluent in using technology; young people today know how to use computers very well and they will master using DDTs eventually. It is a different generation that is more creative, open-minded and entertaining. In contrast, in the current and the old generation, there are people who are younger than me (at the end of their thirties or forties) having problems with using technologies. They are in a leading position or decision-making and this could be problematic.

It appears the young and the contemporary generations support the idea of introducing these techniques, but there will be others who oppose them, and they are most likely people from the older generations. Karban (interviewed 2014) commented:

I cannot judge Saudi culture from one side; there are open-minded and conservative people. It is possible to face the same two categories when introducing DDTs. Any new technology will face difficulties then it will spread if it is useful and after being understood. This happens anywhere in the world, not only in Saudi Arabia.

That means introducing digital design techniques could be faced with either acceptance or rejection according to the recipient. The introduction could be also conditioned by the suitability of digital design techniques and being understandable. Usually, acceptance is tied to the young and rejection to the old. Obaid Al Jabali, a final year student at Umm Al-Qura University (interviewed 2014), highlighted:

The previous generations usually respond to new technology with rejection whereas the now young generation accept almost everything, but still there are some people (maybe young or old) who may reject DDTs as a conservative reaction.
Thus, being from either generation does not define being a proponent or opponent. The response is actually about what an individual knows about digital design techniques and believes about new technology.

There is a great enthusiasm and eagerness to use new technology including digital design techniques in Saudi Arabia. For culture, there is no problem with introducing digital design techniques as a new technology or a new way of design, but there will be a problem with using them. According to W. Bargawi (interviewed 2014):

Our relationship to technology is strong. The evidence is social networking statistics; they indicate that Saudis made up a large percentage of their users. We do not have problems with technology including DDTs, but our problem is in using technology. We respond quickly, but we face some problems in the implementation.

The problem is in using digital design techniques and whether they will impact core cultural aspects. When asked, Alsuweti (interviewed 2014) clarifies that “there is a great cultural enthusiasm to use digital design techniques, but that will not change the core culture”. This is an issue that concerns Saudis when introducing these techniques. If digital design techniques fail to address this issue, the enthusiasm may change to resistance. Some Saudis claim that using these techniques will increase the feeling of being high-status or proud. Alkharoubi (interviewed 2014) claims that “using computers in Saudi now is a kind of luxury rather than a necessity. So what you think about using the new digital design techniques?” Similarly, Albazai (interviewed 2014) argues that “Saudis will be proud of using these techniques”. Apparently, using digital design techniques will raise people’s status and the architects’ status as well. This could be one way of digital design techniques that will influence Saudi culture. If using digital design techniques is a luxury, and shows proudness and high-status before they are introduced, what will happen after digital design techniques become prevalent in Saudi Arabia is unpredictable.

Following the footprints of others, especially Western culture, is one of the Saudi culture traits. Saudi culture and Saudi architects have the desire to import, test and use digital design techniques. Ashmeel (interviewed 2014) commented that “our society embraces
new technology; which people have followed internationally or locally”. That means Saudis are not willing to take the risk of introducing something very new, such as an innovation for the first time. They usually wait to see how other societies use new technology and the consequences, and then they make a decision whether to take it or leave it.

The other aspect is digital design techniques themselves: they should be easy and understandable. When asked about how Saudi culture will respond to digital design techniques, Ashor (interviewed 2014) believes that “if digital design techniques were easy and understandable, we will accept them. But, if they are very complex and require high skills, we will reject them”. The cultural response to digital design techniques is conditioned with being easy and able to be understood by Saudis. Almughariy (interviewed 2014) described this situation:

What is happening in reality is different, young generations are enthusiastic to keep up with technology in general. Embracing entertainment and social networking technology is easier than embracing DDTs (this will be difficult and slow). There is a fear from any new technology if it is unknown, difficult/challenging and not able to be understood.

With the youth obsession with new social networking applications such as Facebook, Twitter and WhatsApp, introduction of digital design techniques is likely to be achievable yet difficult and slow. Even though digital design techniques are difficult, Saudi culture will not reject them completely. There should be a way to work with this issue, as discussed later.

7.5 Aspects preventing introduction of digital design techniques in Saudi Arabia

As shown in the previous chapter the Saudi architectural environment is not ready to embrace digital design techniques, which prevent their introduction to Saudi architecture. In summary, there is no overarching environment for digital design techniques; construction and fabrication techniques are not known; and use of digital design techniques is exclusively by international architects in Saudi Arabia. Equally important
is that there are some Saudi cultural aspects preventing introduction of digital design techniques. Culture could prevent technology from being introduced through conflict with core cultural or sensitive aspects. The result might be a negative reaction against digital design techniques and it may manifest in reluctance and/or rejection. This section studies reasons which may contribute to preventing the introduction of digital design techniques to Saudi culture such as being outside their interest, conflicting, irrelevance, ignorance, fear of the new and not understanding architecture.

Being outside their interest may include not caring about the new techniques. Digital design techniques are very difficult, and rely on others to provide new technologies. That could refer to the feeling of real connection to digital design techniques or the feeling of the used technology. For some Saudis technology is something useful, but outside of their interests. They care about the final product they are using or will use, but not about the technology or the techniques that have been used to produce it. Karban (interviewed 2014) clarified that:

The ones who are aware of the architectural design schools or techniques are very few within the Saudi society. In fact, there is no matter if you are designing a project manually or digitally, the final product is the matter.

Using digital design techniques, or using traditional techniques, would mean nothing for some Saudis. They only care about achieving the final result, not about how to achieve it. Similarly, Kabli (interviewed 2014) says “society looks at the final product not at the used techniques. Whether the technique was digital or traditional there is no difference. Society will not distinguish that’. He adds the ‘not distinguishing’ aspect, which means there will be a part of Saudi society who will not even distinguish digital design techniques. Nevertheless, that does not mean digital design techniques will not be introduced and it will not prevent introducing them. It is expected digital design techniques will be introduced, but they may not be distinguished by a part of Saudi society.

Other Saudi aspects that may make digital design techniques outside of the interest are the difficulties of using them and depending on others through outsourcing. When asked
“Do you think there are cultural aspects that would prevent programming or make it difficult?”, Angawi (interviewed 2015) answered:

Programming is something out of interest to Saudi society. You know programming is something difficult, but not impossible. I can say, in Saudi society programming is being neglected because we rely on the West to get this done for us.

Similarly, Nassir (interviewed 2015) answered:

As Saudis, we are good at outsourcing (using foreign workers or companies) rather than doing the work ourselves. The thing is about using foreign workers rather than investing in local talents which minimises the enthusiasm among Saudis.

As programming is one of the main pillars of digital design techniques, the difficulty of using these techniques might delay introducing them, but not suspend them forever. The difficulty of digital design techniques is something that can be overcome. Thus, solving this issue will contribute to Saudi Arabia being self-sufficient in architecture, so there will be no need for others (outsourcing), and this will increase confidence among Saudis to enter this world.

A cultural conflict might be an aspect that could prevent introducing digital design techniques to Saudi culture. Conflict with cultural aspects may be manifested in two areas: male and female separation and privacy. One of the Saudi culture traits is separating men and women in almost all life aspects, even education, which might prevent educating Saudis overseas or exchanging students with overseas universities. According to Qawasmi (interviewed 2014):

We have new virtual design studio courses, but there are some restrictions, culture is the first. For example, we have conducted a virtual design studio in Jordan in conjunction with Saudi University, at the end, the studio was cancelled because, in Saudi culture, boys and girls must be separated. They are not allowed to stay together in the same classroom. Therefore, we must resolve the cultural side. This will prevent us contacting other leading universities in this area.

That could be one of the major issues preventing introduction of digital design techniques, but it can be dealt with and solved. The other issue is privacy, which is one of the most
important Saudi cultural requirements. It is assumed that using digital design techniques will not provide the privacy desirable for Saudis. For AZ (interviewed 2015):

Saudi culture and architecture have special requirements. For example, as an Islamic nation we need a high level of privacy. I think these techniques will not be the best to provide all our needs.

Indeed, these techniques may fail to provide privacy for some people, but in reality the techniques could optimise and maximise privacy to the extent that Saudi architects would not achieve without digital design techniques.

From some interviewees’ perspective, conflict will happen if digital design techniques influence the culture itself or some important aspect of it, and/or if they cannot meet the cultural requirements. When asked, “Do you think digital design techniques conflict with culture or Islam?”, AA (interviewed 2015) mentions, “our culture and religion are moderate and abstemious. If using digital design techniques will not comply with these principles, a conflict may occur”. That could be the case with Saudi culture from his point of view, but this could happen with any new introduced technology in any culture. The Islamic religion could be affected by introduction of digital design techniques as well. When asked the same question, AZ (interviewed 2015) stated:

This could be possible in some ways. Our religion commands us to build moderate built environment. We do not need to celebrate ornament or sculptures of human, animal or any creature. We need to build mosques that are humble/modest.

That is just an impression of how digital design techniques may affect the culture. It could happen, but the reality is different. Other interviewees’ views contradict AZ’s concern. Amoudi (interviewed 2015) argues “I do not expect that. Digital design techniques will not conflict if they are able to meet our cultural and religion requirements. A conflict would not happen”. As shown, the conflict may occur in terms of some cultural aspects and this can be dealt with, but not the culture itself to the extent that it may make Saudis reject introducing these techniques.
Being irrelevant and/or ignored (unknown/ignorance) are two other reasons that might prevent introduction of digital design techniques. These techniques could be irrelevant to Saudi culture as they are unknown and new. For Alsuweti (interviewed 2014), “Digital design techniques are actually irrelevant to us as they are something new and we do not use them before”. Being new or unknown is usual and normal when introducing something for the first time, but not necessarily irrelevant. It is assumed that irrelevant means not relevant, not applicable or pertinent to Saudi culture. From W. Bargawi’s perspective (interviewed 2014), being irrelevant means having no relationship to Saudi culture. He states “local culture looks at digital design techniques as different technology, which has no relationship to our past and roots, although digital design techniques can be used within our traditional or local architecture”. What he said is accurate and relevant to this study as digital design techniques are still new and have no relation to Saudi culture. Ignorance of digital design techniques is also an important issue to consider. It is presumed that there is ignorance of digital design techniques among Saudi society as very few Saudis have ideas or know about these techniques. Alromaih (interviewed 2014) supports this assumption. He claims “If a normal person does not know about the current designing techniques used in Saudi architecture offices, so how about digital design techniques”. Saudi culture still has no strong relation to digital design techniques, therefore they are still irrelevant and/or ignored.

Preventing introduction of these techniques could also refer to the fear of new technology. This is a natural human reaction when they do not know, see, use or hear about something and/or they see, use or hear about it for the first time. Alsuwet (interviewed 2014) argues, “Being a new thing [digital design techniques] makes people afraid”. Being new could lead to unfamiliarity with or lack of knowledge of these techniques, therefore they are not understood and difficult, leading to fear or rejection. As Ashor (interviewed 2014) describes, “Any person who is not familiar or not aware of these techniques will reject them. Because he is facing difficulty in understanding and assimilating how they work”. Because digital design techniques are not pervasive within Saudi culture there will be a fear of using them. Alkharoubi (interviewed 2014) commented:

Digital design techniques or scripting are not popular in Saudi culture for several reasons. For example, fear from this software, as they are very difficult. In other words, we do not use what we do not know.
Therefore, if the society is afraid of the new techniques, it will react carefully. For example, if a digitally designed building is presented to a Saudi owner he may criticise and reject the design, as he does not have previous experience. Yet there is no desire or fear of trying something new (including its cost). This is the cultural reaction, as Osrah (interviewed 2014) describes it. In general, there is a fear of using something new and unknown in Saudi culture and this is a normal and expected reaction, which may cause a lag or delay. This issue will dissipate as soon as society learns more about the introduced techniques.

Not understanding architecture may also prevent introduction of digital design techniques. If the society is not aware of what architecture is and does not appreciate a different or good-looking design, introducing digital design techniques will be prevented. Alsalafi (interviewed 2014) believes that:

We do not have strong awareness of architecture; the majority are looking for cheap design without looking to its pitfalls. However, there is awareness in the government sector especially with big projects, but the problem is the decision-makers. They are fans and saturated with Western ideas, which are irrelevant to our environment and culture.

Most of the interviewees admitted the lack of architecture awareness among Saudis. When Saudis use an architect to design their buildings, the majority are looking for something easy, affordable and practical, regardless of its relation to the local architecture and environmental requirements. There is also an ignorance of the process, the styles and the methods of architectural design. Alkharoubi (interviewed 2014) commented:

The public do not understand what architecture is. They think that once the architect opens his/her computer he/she will find the design ready. You can sell an entire building design for four thousand riyals. The public are not willing to pay to use DDTs.

It is not usual to find someone who is willing to pay a high cost to design a building and the focus is often oriented to produce ordinary buildings as this is usually what Saudi clients ask for. Ashor (interviewed 2014) says “I think clients can decide what techniques the architect will use. They are looking for traditional buildings and at the same time inexpensive”.

215
These six aspects which could prevent digital design techniques among Saudi society are normal and expected. Introducing new digital architectural designing techniques will not mean much to society members in the beginning and will be outside of their interest. There will be a conflict with some cultural aspects such as male and female separation and privacy. There will also be no relation to the culture (irrelevant) and therefore ignorance, which will cause a fear or resistance as well. The Saudi culture is not aware of or does not appreciate architecture and is looking for normal, practical and inexpensive designs. From the study view, these aspects are anticipated and will occur, but they will not prevent introduction of digital design techniques. They will dissipate once society realises the importance and the power of these techniques. An introduction plan or strategy to make Saudi culture aware and knowledgeable of digital design techniques is discussed in the following section.

7.6 Methods for introducing digital design techniques

Methods to introduce digital design techniques are presented, based on the interviewees’ perceptions and suggestions. Finding these ways is part of solving the clash point between the desire to move Saudi culture and architecture forward and conservatism (see Figure 16). This section explores methods to introduce digital design techniques at the Saudi cultural and architectural levels.

7.6.1 Saudi cultural level

The ways to introduce digital design techniques to the current Saudi culture form a great overlap between raising awareness and convincing society. There are six ways: raising public awareness, having an introductory period, having an easy and smooth introduction, convincing the Saudi society, showing the outcome of digital design techniques, and respecting local culture.

As a way of introducing digital design techniques to Saudi culture, the interviewees mentioned the word “awareness” 47 times throughout the interviews, which highlights
the importance of raising public awareness of these new complex techniques to accept them smoothly. Bin Yassin (interviewed 2014) advised, “raising public awareness is the key to almost everything”. Most, if not all, of the interviewees suggested raising awareness through lectures, conferences, exhibitions and public space presentations. For example, Alkharoubi (interviewed 2014) commented, “We must begin introducing digital design techniques through lectures and conferences, and discuss this issue at Saudi level”. He suggested conducting public lectures and conferences in addition to dealing with the introduction of digital design techniques as an issue that needs a national plan. For Shehata (interviewed 2014), raising awareness and knowledge are the two first steps in the process of introducing digital design techniques and this will be by presenting some successful examples. He argues, “We need to raise people’s awareness and knowledge through presenting some successful examples. We need to go through awareness, knowledge, presentation, admiration, and then participation”. The process will start with increasing public awareness and will finish with acceptance and participation. The other way to increase the awareness is via exhibitions and public space presentations. Almughariy (interviewed 2014) stated, “We need to raise public and architects’ awareness. This could be through exhibitions, shopping malls and public spaces presentations, in order to reveal the design techniques, philosophy and process”. It is not necessary to make these introductory lectures and exhibitions at universities; they could be at open and public spaces to maximise their influence. Based on the interviewees’ perception, raising the cultural awareness is important and needed to make this introduction happen.

For other interviewees, Saudi culture needs time to become aware of and accept these techniques even if they are difficult. An introductory period is needed to allow society to understand and grasp the role and the importance of these techniques. It is also needed as a way to make this introduction happen. According to Alsalafi (interviewed 2014), “first technology (including digital design techniques) should be planted, by the time of knowing and using it, it will produce something positive”. Saudis need to start using these techniques soon and this will allow enough time to accept them and then become something usual. For example, if Saudis started implementing digital design techniques now, after a period society will become familiar with them and they will accept them and
coexist with them. Koshak (interviewed 2014), says, “We need some time to increase awareness especially with culture. Starting with universities, community and practice”. Therefore, *time is a critical aspect in introducing digital design techniques* to Saudi culture or to other cultures as introducing a new element for the first time will take time to be accepted.

Introducing digital design techniques to Saudi culture should happen in an easy and smooth way, which will allow the public to understand and assimilate them. It is known that these techniques are quite technical, in English, and are used by specialists, but that does not prevent the public from knowing and understanding them. As mentioned earlier, if understanding and using these techniques is hard and complicated society will resist or reject them. Babsail (interviewed 2014) comments “To introduce new ideas, you should deliver it in easy ways such as public seminars”. This could be one way to pass the idea of digital design techniques to the public. Bin Yassin (interviewed 2014), similarly says, “We need to introduce digital design techniques in an easy and smooth way, and then there will be no problem”. There will be no problem if society understands and knows these techniques. To make understanding these techniques easy, they should be simplified and clarified to reach the public perception level. Osrah (interviewed 2014) believed:

> It is not appropriate to talk about theories and conferences on the academic level, we must try to explain and simplify these techniques through exhibitions, workshops and society participation. Perhaps, through encouraging people to be involved in model building or using software to feel the outcome of these techniques, which accelerate acceptance.

This way of simplifying the introduction of digital design techniques is needed. It will increase society involvement and awareness, and that could be another important way to make the introduction happen. To make a simple and conceivable introduction, it is better to start with non-technical (deep) information which will result in a positive reception and give good impressions. Saqqaf (interviewed 2014), argued:

> Saudi culture is still pure and will accept almost everything. You are witnessing all the changes that are happening now, so it is important to make this introduction easy and smooth. In other words, if you started your introduction right from the core it may get rejected. You may receive positive feedback if you started by explaining its role, benefits and values. Saudi culture is flexible, 15-20 years ago, society and
From the study’s perspective this is convincing and should be considered. Culture and society are not dealing with technical and professional information about digital design techniques. All they need to be aware of and to understand digital design techniques is some basic and easy information. They also need to be aware of important benefits and values of digital design techniques.

Convincing Saudi culture of these techniques is also another way to make this introduction happen. The society needs to know the role of digital design techniques to improve and advance local architecture. It is important to acknowledge that using these techniques will create more options and will reveal new solutions that will suit Saudi culture and environment. Ashmeel (interviewed 2014) states, “you must convince society now before introducing digital design techniques”. Similarly, Ibrahim (interviewed 2014) comments, “we need just to convince them of digital design techniques importance”. There is no doubt persuading Saudis of the new digital design techniques is a crucial issue. Society may think avoiding these techniques is a good idea because of their potential negative or inappropriate outcomes, but that could be a negative reaction and will not return any benefit to Saudi culture. According to Babsail (interviewed 2014):

Using DDTs helps to discover new solutions and new architectural trends. Bad design can be made digitally or manually, in the end, DDTs is a tool that can be used positively or negatively.

Therefore, convincing the society is also achieved through raising their awareness by involving and inviting them to public conferences and seminars. In these symposiums, they need to get a clear and easy idea about the way digital design techniques work, their outcome, their construction and materialisation, and their advantages and disadvantages. Fuda (interviewed 2014) mentions, “for the society, we need conferences to show these techniques’ capability, and its pros and cons”.
In addition, Saudi culture will need to see and feel outcomes of digital design techniques as a way to make this introduction happen. If there are successful built examples on Saudi land, society will feel the reality of digital design techniques and will be persuaded. The other way is through presenting the architecture offices’ and the students’ work at public spaces such as shopping malls and plazas. Babsail (interviewed 2014) claimed,

We want to get out to Saudi society and teach them what architecture means. Our students could go to shopping malls to present simple introductory things. The public likes to see new things and I expect these techniques will be accepted. There is no doubt that there will be positive acceptance, if these techniques are introduced in an easy way.

Similarly, Osrah (interviewed 2014) claimed,

The public must watch the products of these techniques. For example, make an open public invitation to attend students’ presentations. It is also possible to present students’ work at shopping centres or public places.

Outcomes of digital design techniques should be shown to the public whether by real constructed buildings, offices’ and students’ work, or even by public participation. They need to see, touch, try and examine these outcomes to be confident of their capability and suitability. Current and under-construction giant iconic buildings in Saudi, designed using these techniques and by well-known and famous architects (see Chapter 5), will allow Saudi culture to have enough knowledge and increase the possibility of trusting and using digital design techniques.

The sixth way to introduce digital design techniques is using them in a way that respects local culture, serves the culture and religion requirements and avoids conflict with the cultural sensitive aspects, and consolidates local culture, the techniques themselves, and local architecture. Saqqaf (interviewed 2014) argued,

We should respect local style and culture, and I think DDTs do not make any conflict with that. The new technologies also do not conflict with religion, especially if they support the principles and values of society, such as privacy. DDTs at the end is a technology that can be employed using local vocabulary/elements to produce completely new and different outcomes. By that, DDTs will be used to serve local environment, culture and religion.
It appears that using digital techniques will not conflict with the cultural values and traditions. At the same time, the techniques are expected to be used to serve the cultural requirements and possibly improve the culture itself. As an overarching view of the introduction methods, Osrah (interviewed 2014) commented,

> Here we need the universities’ role to change culture by raising awareness and pushing to keep pace with new things. Also, by clarifying its importance, power, and widespread. Perhaps, the train station in Riyadh, which is designed by Zaha Hadid, contributes significantly in this cultural shift.

Digital design techniques should be announced to the public through every possible way and/or techniques. The intervention of Saudi universities and/or government is needed to deliver the knowledge of digital design techniques to society. The six suggested methods are actually interweaved: if we start by raising public awareness, we need to do seminars and exhibitions, we need time, we need to introduce techniques easily, we need to convince society, we need also to show their outcome, and finally we need to use techniques in a way that respects local culture and improves it.

### 7.6.2 Saudi architectural level

According to the interviewees, there are six ways to introduce these techniques to Saudi architecture: use digital design techniques to support local Saudi architecture, have qualifying Saudi architects, provide information about digital design techniques through conferences and workshops to Saudi architects, establish research centres for digital design techniques, launch an overarching plan or strategy to introduce digital design techniques to Saudi architecture, and gradually introduce digital design techniques via experiments and tests.

Digital design techniques should be introduced in a way that supports Saudi architecture principles and values and should be used to produce a new Saudi architecture, to achieve Saudi architectural values, and to not dispense with valuable old Saudi architects. Al Mahdi (interviewed 2014) states that digital design techniques must be used to support local architects and to open the local competition field. The support could be in the form
of complying with the local architectural requirements – mixing technology and traditions. Thus, Saudi architects can compete with each other and using these techniques will flourish. Introducing digital design techniques to support local architecture could also include using Saudi architects to make this introduction, and at the same time updating and keeping older Saudi architects. Abu Ouf (interviewed 2014) claims that “we need these techniques to be introduced by Saudis not by foreigners”. Saudi architects will be the best to introduce digital design techniques because they are part of the culture and they know how Saudi architecture works. Alsalafi (interviewed 2014) commented:

The old generation who do not deal with technology must rethink improving themselves, or to work in collaboration with the new generation who master DDTs. They must coexist with each other, and therefore we do not lose any of them.

Both old architects and new digital design specialists are important, thus it is crucial to have the new digital design architects and at the same time to update and keep the old architects. This will minimise resistance or reluctance.

The other three ways to introduce digital design techniques to Saudi architecture could be through qualifying Saudi architects, providing information about digital design techniques through conferences and workshops, and establishing research centres for digital design techniques. There is a need to raise Saudi architects’ knowledge about digital design techniques and to qualify them, as they are the ones who will start making the change. This was the argument of Osrah and Ashmeel (interviewed 2014). They argue that Saudi architects must master digital design techniques and be qualified so they can make an impact and start to change. The other way is by providing information on digital design techniques to Saudi architects via conferences, workshops or any other channels. The majority of the interviewees have suggested these kind of channels to deliver knowledge of digital design techniques to Saudi architects. For example, Alsalafi, Alkharoubi, Alasker and Alromaih (interviewed 2014) believe that Saudi architects must receive information about digital design techniques and be informed of the capability, easiness and importance of digital design techniques. This is most likely through seminars, symposiums, newspapers, articles, YouTube videos and exhibitions.
The fourth way is introducing digital design techniques to Saudi architecture through research centres for these techniques where Saudi architects can engage, understand and test them. They will be able to assimilate digital design architectural and designing logic, and eventually they will be familiar. Al Mahdi (interviewed 2014) said:

We want to know the philosophy behind DDTs and why to use them. Digital architecture is evolving dramatically, thus we will be lagging behind. I think it is a must to establish research centres or institutes adjacent to this introduction.

It is suggested to convince Saudi architectural practice via an overarching introductory plan or strategy to introduce these techniques. This should happen gradually and slowly by experimenting and testing. This overarching strategy should be advocated by the government at the national level. Individual attempts are not enough and not feasible, there must be general awareness and strong argument to prove the importance and ability of digital design techniques. Ashmeel (interviewed 2014) comments “to introduce digital design techniques you must know how to convince practice and there must be a government overarching system at the national level to direct and plan digital design implementation”. Similarly, Shehata and Saqqaf (interviewed 2014) ask to establish an overarching digital design environment in Saudi, whereas Karban (interviewed 2014) emphasised that introducing digital design techniques to Saudi architecture should not be an individual work. Setting up and preparing this kind of environment takes time. It would not happen in one day, week, month or year.

Saudi architects need to experiment and test these techniques, they need to use them gradually. Albushi (interviewed 2014) believes that experimenting and testing digital design techniques to prove their benefits are needed to adopt them. This could be through the suggested research centres. Ashor (interviewed 2014) prefers gradual use of digital design techniques to make the introduction happen, starting by designing just architectural elements and then expanding to building forms. To start using digital design techniques in Saudi architecture, Saudi architects do not need to reinvent the wheel. Gadi (interviewed 2014) says they should start from where other architects using digital design techniques have stopped.
These six ways are not the only ones to introduce digital design techniques to Saudi architecture. They were suggested by the interviewees to support and justify their views, and they prove the potential acceptance of digital design techniques.

7.7 Conclusion

To conclude this chapter, it is important to note that new technology has a vital role in changing Saudi culture and Saudi architecture, but not digital design techniques. Saudi architecture has become more connected to the overseas world, new and global rather than local, and did not meet the expectations of Saudi architecture. Even through these changes, the relationship between Saudi architecture and digital design techniques is still limited to foreign architects and a few Saudi architects who studied overseas. Foreign architects have been used to design new Saudi iconic buildings digitally, because these techniques are not prevalent in Saudi Arabia. Meanwhile, Saudi architects usually use ordinary or traditional designing techniques and therefore do not know how to use digital design techniques. The relation between Saudi architecture and digital design techniques is also limited because of the clash between the sense of conservatism and the desire to move towards the future of new Saudi architecture. The new generation of Saudi architects wants to enter the digital world, but the conservatism of new and older generations is suppressing them.

Despite the current moderate relation between Saudi culture, architecture and digital design techniques, Saudi culture will respond to digital design techniques in two ways, either acceptance or rejection. The young generation seems to be positive, optimistic and eager. This requires an easy, understandable introductory method, following the pathway of others who have used digital design techniques. There is nothing in Saudi culture that will limit or reject introduction of digital design techniques. At the same time, there is no evidence that digital design techniques are harmful to culture. However, introduction of digital design techniques could be prevented due to cultural or architectural aspects, but that will not be a major obstacle. This could be overcome through the proposed ways to introduce digital design techniques at the Saudi cultural and architectural levels. At the
Saudi cultural level, the introduction needs action to increase public awareness and at the same time acknowledge the valuable Saudi cultural aspects. At the architectural level, it needs some effort to deliver knowledge of digital design techniques to Saudi architects, considering the local architectural values and an overarching plan.
Chapter 8: Saudi architectural education and relationship to digital design techniques

8.1 Introduction

The relationship between Saudi architectural education and digital design techniques is still modest, even though use of digital design techniques has increased and they are embraced by world-leading architecture schools and offices. Section 8.2 focuses on current Saudi architectural education. Section 8.3 investigates the relationship between Saudi architectural education and digital design techniques through the current knowledge of digital design techniques among educators and students, the gap between Saudi architectural education and digital design techniques, and perception of digital design techniques. Section 8.4 points out how Saudi architectural education may respond to introduction of digital design techniques, and whether digital design techniques will be accepted, easy or difficult, a necessity or not, and educators’ and students’ positions on this introduction as proponents or opponents. Section 8.5 explores the reasons that could prevent introduction of digital design techniques in Saudi architectural education. Section 8.6 highlights ways to introduce digital design techniques to Saudi architectural education through the roles of educators and students, education institutions and computer science specialists.

8.2 Current Saudi architectural education

Saudi architectural education aims to find a new Saudi architecture through mixing traditional architecture with new approaches and technologies. This section investigates the current designing techniques, technology, and infrastructure and software used in Saudi architectural education.

8.2.1 Current designing techniques

When the interviewees were asked what designing techniques are used in Saudi architectural education the majority had almost the same answer: Saudi architectural
education still uses the old school way of delivering architecture design knowledge and skills. King Fahad University of Petroleum and Minerals, King Saud University and Umm Al-Qura University are using very basic and traditional ways of design. At King Fahad University of Petroleum and Minerals Alkharoubi (interviewed 2014) described:

Currently, we are using manual techniques. We teach students the basic manual skills such as 2D, 3D, shade, shadow and others. Then move them to learn how to draw 2D using AutoCAD, then 3D modelling. Eventually, they will be ready to use these skills in design studios.

Al Mahdi (interviewed 2014) agreed that King Fahad University of Petroleum and Minerals uses traditional designing techniques, but combines that with engineering science, which is slightly different from other Saudi universities.

King Saud University and Umm Al-Qura University are similar to King Fahad University of Petroleum and Minerals in terms of the designing techniques used. Albazai (interviewed 2014) summarises the used techniques in one statement: “we use basic easy techniques, which start with developing ideas manually and then we move to use computers for drawing and montaging”.

At Umm Al-Qura University, S. Bargawi (interviewed 2014) comments that “we are using very old techniques. Spoon-feeding teaching is prevalent. And we rely heavily on old styles or mimicking existed designs”. Abu Ouf (interviewed 2014) also emphasises that normal designing methods are used in Umm Al-Qura University starting by collecting the project’s data, analysis, and understanding, then creating an idea, and developing it using free-hand sketches. The prevalent designing technique at the majority of Saudi universities is traditional. Computers are not in any way involved in creating design.

Using this normal traditional technique is related to several factors. First, Saudi architecture schools are still debating whether to continue using manual technique or computers in design, thus are still using manual techniques (Ashor, interviewed 2004).
Second, Saudi architectural education suffers from old curricula and not updated teaching staff. Sometimes, studio masters prefer simple and basic forms, which are easy to draw and model (Ahmad, interviewed 2004). Third, some Saudi architecture schools focus on what is called the “traditional tunnel or the bottleneck”, where students learn the main basic traditional techniques before they are allowed to use computers (Abu Suleiman, interviewed 2004). Fourth, it is uncommon to find teaching staff who use different techniques – other than traditional techniques (Almugharir, interviewed 2004). For these reasons, Saudi architectural education is not using digital design techniques. Although the focus is on normal techniques, there are signs of changes. For example, at King Fahad University of Petroleum and Minerals the architecture school approach now is to change the traditional drawing desks to flat desks where students can use computers (desktop and laptop) and do some sketches. Babsail (interviewed 2014) stated:

You will be surprised if I tell you that drawing desks are neglected at King Fahad University of Petroleum and Minerals. In our last studios’ renovation, we do not focus on providing drawing desks, as they are not often needed now. This is by virtue to design teachers. Now we have less teachers using classic design techniques. Students can now present their work on the projector instead of print it out.

8.2.2 Current technology

To confirm that technology use is limited to using computers for drawing and montaging purposes, interviewees asked what technologies are currently used in Saudi architectural education and why they use technology this way. Almost all the interviewees agreed that computers are used at Saudi architectural schools, but only for drafting and montaging.

Alromaih (interviewed 2014) points out that after students ensure the design idea is effective and good enough they move to use computers to draw and montage. Karban (interviewed 2014) adds that computers are used as drafting and montaging tools, and sometimes for analysis. Other interviewees such as Al Jabali, Gadi and Al Samhan (interviewed 2014) agreed that, in terms of technologies used at Saudi universities, computers are used in traditional “2D and 3D” ways, but the new digital design techniques, their software and programming languages are not used yet. This is not only the case in Saudi architectural education, even Saudi architectural practices are using computers for the same reason. Bin Yassin and Saifuddin (interviewed 2014) believe that
more than 90% of the architectural design process in Saudi architecture practices relies on computers to do drafting and montage. This shows that computers are the prevalent used technology among Saudi architecture practices and architectural education.

There are several reasons for using the available technology in this way. From the teaching staff perspective, Alkharoubi (interviewed 2014) claims that dealing with computers this way is easier and produces simple outcomes that can be sold and are convincing. Qawasmi (interviewed 2014) adds that students are not trained to use these techniques. They do not know the computers’ abilities, benefits and the possibility to use them as a designing tool (this also applies to teaching staff). Alsalafi (interviewed 2014) thinks that this could relate to the difference between the old and new architects’ generations, as the old generation is less interested to use technologies and they are the majority of the current teaching staff. Karban (interviewed 2014) feels that using computers in this way could be because computers are the best available tool and better than manual tools. Bin Yassin (interviewed 2014) holds that it is hard to find architects who are experts in digital design techniques.

The interviewed students also think that computers are the commonly used technology, and they are used this way because of the following reasons. Fuda (interviewed 2014) comments, “this is what we have asked for and we already have learned it”. Kabli (interviewed 2014) states that “we see the currently used techniques the best and cutting-edge”. Al Jabali (interviewed 2014) says “we believe this is the maximum level of development”. Aldaaish (interviewed 2014) claims “it is all about our lecturers, we follow our lecturer approach”. Sabri (interviewed 2014) believes that computers are used in a straightforward way (straight lines and curves), whereas using them to generate design is very difficult.

These reasons are summarised here. First, using computers in this way is easier and convincing. Second, students and teaching staff are not yet knowledgeable about digital design techniques. Third, there is a difference between the old and new architects’ generations. Fourth, using computers in the traditional way to draw and montage is the
best available at Saudi architectural schools. Fifth, it is hard to find Saudi architects who are digital design experts. Sixth, using computers for digital design is not prevalent and/or usual in Saudi architectural education. Seventh, using computers in a traditional way is considered as current cutting-edge available technology. Eighth, it is also considered as the current maximum level of the available technology. Ninth, these are the techniques imposed by the teaching staff at Saudi architecture schools. Tenth, using computers in other ways is difficult.

### 8.2.3 Infrastructure and software

In general, infrastructure mostly comprises moderate computer laboratories and printing machines, while the commonly used software includes AutoCAD, 3D MAX, Rivet and SketchUp. Other facilities such as laser cutters, computer numerical control milling, 3D printing, and some software such as Rhino and Maya are not always available (not prevalent). In other words, students may have not used them or have very limited access to them.

In Saudi architecture schools teaching staff and students use the commonly known architectural commercial software such as AutoCAD and 3D MAX. They use this software in a basic way which does not go beyond the software interface (Atwa, Baz and Almughariy interviewed 2014). Saudi architecture schools teach students how to use these software interfaces. Mohamad Abolmajd, a teaching staff at King Saud University (interviewed 2014), points out:

> Unfortunately, what is happening now is teaching students how to use commercial software to draw and montage their work – drafting, graphic and animation. We should let our students know more about these software capabilities in design.

Current teaching will not help students improve their knowledge about computers’ ability to help in the design process. Thus, Abolmajd recommends infusing this knowledge among students rather than merely teaching them how to use the software interface.
It was obvious in the interviewees’ reactions that infrastructure is not the same in all Saudi universities. One group of the interviewees sees no problem with the current available facilities, whereas a second group sees a significant shortage and a need for improvement. For instance, Babsail and Ashmeel (interviewed 2014) claim that the school of architecture at King Fahad University of Petroleum and Minerals offers laser cutter, computer numerical control and 3D printers at the FAB Lab. To use them they need to obtain access from the administration, so access is limited. Abu Suleiman and Albushi (interviewed 2014) argue that in terms of equipment and facilities Saudi architecture schools have the ability to offer the most recent new technologies, but there are no specialists to operate them. Some universities are better than others in available digital facilities, but the students’ access could be in some way restricted. A key issue is not about offering the new technological facilities at the Saudi universities, but about the people who use and/or operate them. Some universities have imported some very new devices to use for certain projects with international engineers, but after that nobody know how to use them and as a result, these devices stay abandoned and useless.

In contrast, the larger second group of interviewees complained about a shortage in Saudi architecture schools’ infrastructure such as computer laboratories, printers, laser cutters and 3D printers. What exists now is not enough, not updated and not advanced. Osrah (interviewed 2014) says, “we have poor infrastructure in Saudi universities”. Abu Ouf (interviewed 2014) also comments, “we do not have equipment and laboratories”. Similarly, Atwa (interviewed 2014) highlights, “our infrastructure is not ready, so we must provide it first”. Others argue that the existing equipment and facilities are not suitable and not advanced to meet the students’ current needs. Alfulaij (interviewed 2014) claims that the equipment in his department at King Saud University is not suitable now. Kabli (interviewed 2014) complains about not having highly equipped laboratories. Jabali (interviewed 2014) also suffers equipment shortage. This shows a major problem at some Saudi architecture schools which could prevent the introduction of digital design techniques.
8.2.4 Saudi architectural education plans

There are two groups of interviewees on current plans for Saudi architectural education. One group has some information or heard about plans to embrace or use digital techniques. In contrast, the second group does not know whether there are plans or not, and some think there are no plans at all. This section focuses on the first group and the ongoing change plans.

Saudi architectural education is in a change and development stage. The most recognised plan is to send overseas scholarship students to do their degrees in the most recent technology, techniques or knowledge. For example, Babsail (interviewed 2014) replies:

> Now, we are planning to enter digital design world through fabrication. Recently we have a new lecturer specialised in this field. He did his Masters degree in the US in 2014 and he is going soon to do a PhD, focusing on how to design and then how to produce this design even if it is very complex using machines such as laser cutters & CNC milling.

Alsalaifi (interviewed 2014) also declares that the architecture department at Umm Al-Qura University is planning to enter the world of digital design techniques, and to do so there are some sponsored lecturers studying overseas now. The plan to enter the digital world seems to be straightforward, but it could be slow. Shehata (interviewed 2014) describes that these are long-term plans, which require improving the faculty members’ knowledge in digital techniques and software through overseas scholarships. In contrast, Amoudi (interviewed 2014) believes that Saudi architecture schools are in progress and a development stage now, thus it is possible to hear about digital design introduction plans soon. There are also some changes at the administration and decision-makers level. Baz (interviewed 2014) noted that at King Abdul Aziz University two young architects are running the Department of Architecture now and they are trying to change the system to improve the graduate quality. This could be a very positive step to allow changes in approaches, thoughts and techniques.

Other interviewees mentioned diversity in the architecture schools’ approaches. Even though the broad plan is directed to enter the digital circle, not all Saudi architecture
schools should adopt the same plan or approach. Ashmeel (interviewed 2014) argues that there is diversity: each school has its approach and experiments. Some schools are embracing traditional approaches, others are following the Islamic approach, and others are holding international approaches. Mostly diversity is a positive sign; it allows mixing, improving, optimising and newness. These current plans to improve and change Saudi architectural education may be considered as very positive indicators as they support the goal of introduction and highlight the opportunity.

8.3 Saudi architectural education and relationship to digital design techniques

It appears there is no direct relationship between use of digital design techniques and Saudi architectural education now, despite there being some academics and students who know about these techniques. It is assumed there is a gap between digital design techniques and Saudi architectural education. Based on the interviewees’ views this gap is demonstrated and proves the limited relationship between them. Even though some interviewees think digital design techniques are the right techniques that should be embraced now, others think digital design techniques are not appropriate and will influence Saudi architectural education and Saudi architects. The following section discusses and investigates the current personal knowledge of digital design techniques, the gap between Saudi architectural education and digital design techniques, and the current perception of digital design techniques among Saudi architectural educators.

8.3.1 Current staff knowledge of digital design techniques

Among the three chosen Saudi architecture schools, some interviewees know about digital design techniques because they did their degrees overseas, through media, or because they are able to use English fluently – mostly staff and students from King Fahad University of Petroleum and Minerals. Even though they know about these techniques, they still do not know how to use them. For example, Ashor (interviewed 2014) completed his master of digital fabrication overseas, and says that digital design techniques are about generating architectural design using computers, specifically through programming languages, such as scripting. Ahmad (interviewed 2014), currently
a student at King Fahad University of Petroleum and Minerals who uses English fluently, comments:

I have watched a documentary about Frank Gehry’s work, and how he develops special software to make his own design. I thought this is something weird and I have not imagined that I will meet someone who will ask me about this technique.

Alsamhan and Albazai (interviewed 2014), currently students at King Saud University, did some of their studies overseas and use English fluently. They state that digital design techniques require programming skills, English language and mathematical knowledge. They have learned these skills by themselves through the internet and when they were studying overseas. Nobody in the university taught them or gave them any information about digital design techniques. Baz (interviewed 2014) also completed his masters overseas in advanced architecture and mentions that the idea of digital design techniques, in which architects go deeper into the computer world to use programming languages (coding) to assist them in architectural design, is not new. While few architects could use programming languages in the past, now they are available for all. Anyone, even non-architects, can use these languages such as Python, Monkey and Processing. This technology allows people to use computers to help and/or to think. Sometimes it produces surprising or unexpected results. This proves that, as a knowledge, digital design techniques are not yet employed at Saudi architecture schools, even if some architects have some information about them.

In contrast, other interviewees did not know anything about digital design techniques in Saudi architecture education. They do not know because they are from the old generation of architects, or were still students and had not received any information or knowledge about digital design techniques. They did their degrees locally, and do not use English fluently. For instance, Alsuweti (interviewed 2014) is currently a student at King Fahad University of Petroleum and Minerals who uses English fluently but nobody offers him any information about digital design techniques. He says:

As a student, I have not heard about DDTs. Our lecturers do not give any information about this topic. I also have not heard any of my friends talking about these techniques. You are the first person telling me about DDTs.
Hariri and Abolmajd (interviewed 2014) do not know these techniques because they are senior architects in Saudi Arabia. They have not heard about digital design techniques, they think these techniques are not current or prevalent in Saudi Arabia, and they do not see any of the implementation of these techniques. Others such as Alfulaij, Albushi and Karban (interviewed 2014) did their degrees locally and do not use English fluently. They also have no knowledge about digital design techniques. Albushi for instance, says that “I have been practising for 18-20 years. In all these years, I was a computer-aided design and computer-aided drafting user, I have not been exposed to digital design techniques”. Similarly, Alfulaij comments that “since I started the discipline, I usually use computers in last design phase. I have not heard about digital design techniques ever”. Students from King Saud University and Umm Al-Qura University also do not know these techniques. Alasker, Alamri and Fuda (interviewed 2014) also claim that they do not know digital design techniques and during the interview was their first time to hear about them.

8.3.2 Gap between Saudi architectural education and digital design techniques
First impressions from interviewees about the gap were surprising. Abu Ouf (interviewed 2014) commented that “Originally, digital design techniques do not exist now in Saudi. Therefore, there is no gap because the other side of the problem ‘digital design techniques’ does not exist”. Similarly, Saqqaf (interviewed 2014) said “Briefly, I will describe this gap as the distance from the Earth to the Moon. The education and technical skills are the reason”. They confirmed the gap, but the description was exaggerated. Based on the collected data the majority of the interviewees agree there was a gap. In general, the reason for this gap was Saudi architectural education and computer use skills. However, others see this gap as small and easily overcome. The majority of the interviewees agreed there was a gap and Saudi architectural education is behind it. Qawasmi (interviewed 2014) argued:

Architectural education is one of these reasons that cause the gap. Education sees only the traditional side of using computers and produces architects with no knowledge about the importance of these techniques. In addition, there is negative vision about technology especially from the old generation which I call the “old guard”. In fact, computers encourage creativity and produce complex ideas that are difficult to reach using traditional techniques.
The current Saudi architectural education focuses on the usual way of using computers (drawing and montaging) which make the new graduates unaware of digital design techniques, due to the negative vision of the senior academic “old guards” who think computers will decrease creativity and complexity. Bin Yassin (interviewed 2014) also blames Saudi architectural education for this gap. He claims that there is a gap for two reasons: first, because of the lack of academics competence in digital design techniques which he stresses, and second, because of the lack of financial support to equip laboratories with high performance computers. Babsail (interviewed 2014) believes that Saudi architectural education does not provide digital design teachers, computers and fabrication machines. As this is caused by the limitation of the financial support, this gap might be the most difficult to fill.

Other interviewees referred to computer use skills, claiming Saudi architecture educators and students suffer from poor computation skills. Alkharoubi and Shahrani (interviewed 2014) agree that poor computer using skills cause this gap. Ibrahem (interviewed 2014) described how computer skills caused this gap:

Actually, there is a gap, especially programming for architects. I can say there is no Saudi academics or lecturers who are able to teach these techniques. What is happening is teaching students how to use the commercial architectural software’s interfaces.

This shows that advanced computer skills are not offered to students; they only receive basic information about how to use commercial architecture software, causing the gap. Some Saudi students depend on their personal effort to learn by themselves. Albazai (interviewed 2014) highlights that students are always looking for new software to learn. For example, if there is a student using new software, it indicates that this student has learned by himself, as nobody has taught him how to use it at the university. Albazai believes that students can look for digital design techniques and learn how to use them by themselves. This gives an important hint to overcoming this gap.

A third group of interviewees see there is not a huge gap and it can be filled easily through self-confidence, knowledge and enthusiasm. Alataar (interviewed 2014) points out that
Saudi architects created this gap either by misusing computers or by undermining computers’ capability; we just need to link digital design techniques with design processes to fill the gap. Slightly different is Al Mahdi’s view (interviewed 2014) that knowledge of digital design techniques causes the gap, but it is not difficult to fill it, if architecture departments at Saudi universities adopt this trend and send scholarship students overseas to study this field. From the students’ perspective Ahmad (interviewed 2014) states that the lack of knowledge at all levels (students, teachers, clients and contractors) causes this gap, but we are able to fill this gap, as it is not very big. Sabri (interviewed 2014) emphasises that the majority have not heard about digital design techniques. However, according to architects’ ability to use computers in architecture, it will be easy to overcome this gap especially if architects master programming. This gap is not that big. Saudi architectural education and computers skills have caused this gap, but it is not hard to close it.

8.3.3 Perception of digital design techniques among Saudi architectural education

Abu Ouf (interviewed 2014) noted:

Computers are mechanical tools – they cannot think, link, integrate, and analyse by themselves. Computers perform only what I want, they can deal with geometries like point and line from a mechanical perspective.

Computers are not able to do tasks by themselves; they need a human “thinker” to command them. They only do what they have been asked to do. This includes using them for drawing and montaging, or for more complex tasks such as scripting. Interviewees conceived digital design techniques in two ways: first, people who are positive and think digital design techniques will help improve Saudi architecture, and second, people who are negative and think digital design techniques will dispense with the architects’ role.

Baz (interviewed 2014) argued that digital design techniques are “very positive and we need them today before tomorrow”, which is how the majority of the interviewees conceive these techniques now, even though some of them do not know much about them
or have heard about them for the first time. They confirm that computers are fast and can produce more accurate results than humans. Fuda (interviewed 2014) believes that digital design techniques will help improve design; humans cannot do long and complex calculations quickly like computers. Similarly, Alsalafi (interviewed 2014) thinks that digital design techniques are accelerator tools they will save time, and assist thinking and creativity. Thus, architects will get new outcomes as long as they have more information. In contrast, Saqqaf (interviewed 2014) expresses that digital design techniques will extend architecture beyond modernity, and they are thus a new school of thought. Their outcome is extraordinary, shows enjoyment, and carry new meanings and messages. Abu Suleiman (interviewed 2014) thinks that digital design techniques are the future of architecture everywhere, not only in Saudi Arabia. Therefore, it is easy to say that the overall perception of digital design techniques is positive, as they will expand architects’ thinking and open up great opportunities.

In contrast, other interviewees think digital design techniques are negative and will impact the architects’ role eventually. Despite thinking digital design techniques are negative, some of them seem to accept these techniques, but they worry about their role in the design process and their manual skills. AZ and AA (interviewed 2015) think that digital design techniques will dispense with the architect’s role in the design process. Architects will become computer engineers rather than architects, and they will produce a non-buildable futuristic architecture. Gadi (interviewed 2014) believes that it is not acceptable if computers design for us; there are concepts and values stemming from local culture, which should be considered while designing. He also thinks that it is possible to use the computer to solve problems such as circulation analysis or imagining ideas, but not to design instead of architects. Al Jabali (interviewed 2014) expresses that computers are complementary and only humans can develop ideas, and choose and decide the final form. Albazai (interviewed 2014) explains that using digital design techniques will destroy the discipline; we will open our field to programmers: “Architecture has moral culture and discipline which differs according to the context environment. We need to raise architects not programmers”. Others are concerned about architects’ manual skills. Ibrahim (interviewed 2014) believes that manual drawing is a very important expression tool for architects, and he is afraid to lose it. He illustrates that using Microsoft Office to write
does not mean dispensing with beautiful calligraphy forever. This means using digital
design techniques is acceptable, but it does not mean dispensing with the traditional hand
drawings. Almughariy (interviewed 2014) also claims that digital design techniques are
negative as they decrease architectural skills such as free hand drawing, communication
and analytical thinking. Slightly differently, Albushi (interviewed 2014) is concerned
about architects’ communications if digital design techniques are introduced. He argues
that if every architect has their own software, there will be communication problems
between architects, civil engineers and contractors. Civil engineers and contractors will
not be able to open or use the architects’ files. These examples illustrate why the
interviewees think digital design techniques could impact their roles in the design process
negatively.

The interviewees’ perception of digital design techniques highlight how they conceive
these techniques and how this will affect their introduction. The ones who were positive
have pointed out some important points that support this study’s goals, whereas the ones
who think digital design techniques are negative have highlighted some important aspects
that need to be considered and explained to introduce digital design techniques. It is
important to understand that digital design techniques will not dispense with the
architects’ role in the design process, but rather the design process will change. Digital
design techniques are tools used by architects, digital design techniques are not able to
produce anything by themselves, they will be under the architects’ control, and architects
will remain the thinkers. Second, architects will not become computer engineers; they
will stay architects yet with programming skills. Third, digital design techniques will not
terminate the architects’ manual skills; they may support or enhance them. Fourth, digital
design techniques are a new way of design; they are not working drawing tools.
Architects, civil engineers and contractors can use the same working drawing software to
communicate in ease. For example, after the architects finish the design process and have
the outcome ready, they can use building information modelling software such as
Autodesk Rivet to do the drawings and to communicate with others.
8.4 Saudi architectural education response to digital design techniques

Saudi architectural education is still under development. Even though it is experiencing difficulty in changing, it is moving with eagerness from being an old architecture school to be a modern and technological school. Osrah (interviewed 2014) comments:

Ten years ago, our university refused the idea of using computers as a tool, but over the time, it changed. In the near future, we will fully rely on digital tools and techniques. Then our existence without these skills will be difficult to the extent that affects finding jobs. Saudi universities are now under pressure to raise a qualified generation that knows how to deal with these new technologies.

The intentions and plans are to advance Saudi architectural education and this is not hard. The new generation of students is keen and enthusiastic about technology. Abolmajd (interviewed 2014) claims that “Our students love computers and they are able to do all drawing and montaging tricks. I think it will not be hard for them to use digital design techniques”. That shows the expected acceptance among Saudi youth; they are able to use computers for drawing and montaging and that makes understanding these techniques possible and doable in the near future. This section discuss how Saudi architectural education will respond to introduction of digital design techniques. Among the interviewees, some just accept digital design techniques, some think they are difficult, others worry about English and scripting languages, others debate their necessity, while others are proponents or opponents of digital design techniques.

8.4.1 Acceptance

In general, accepting digital design techniques is the prevalent view among the majority of the interviewees, especially young staff and students. Nonetheless, there are a few who reject digital design techniques, mostly senior or old architects. Abu Suleiman (interviewed 2014) says, “I think our students are ready to accept and welcome these techniques. I cannot see anyone who rejects these techniques”. Gadi (interviewed 2014) thinks that educational institutions will encourage and support introducing digital design techniques as soon as possible. Albishri (interviewed 2014) professes that he loves these techniques and wants to master them, and there will be a large number of students who want to learn these techniques as well. This proves the intense interest of the generation.
of young architects, but in terms of the senior architects, Aldaaish (interviewed 2014) claims that digital design techniques will be accepted easily by the young generation, \textit{but not the old generation}.

\subsection*{8.4.2 Easy or difficult}

Despite the majority of the interviewees declaring their acceptance of digital design techniques, there are three categories of views on the introduction and use of digital design techniques. The first group think it will be easy, the second group think it will be difficult, and the third group think it will be difficult at the beginning but easy by the end.

For some interviewees, use and introduction of digital design techniques will be easy. It will be something normal, as Saudi architects are able to use computers now they only need to push this a little bit further. This will be through Saudi architectural education according to the interviewees. Amoudi and Alsamhan (interviewed 2014) clarify that introducing digital design techniques to Saudi architectural education will be easy as any technology has been introduced before, such as computers, printers and laser cutters. It would be something normal, if equipment and qualified teachers are provided. By offering that there will be high acceptance and enthusiasm they are looking at the introduction with ease. But as mentioned before, there may be rejection, resistance and conservatism.

The second category of interviewees think that introducing digital design techniques to Saudi architectural education will be difficult for three reasons: fear of the unknown, education system difficulties, and administration problems. First, Almughariy, Alromaih and Alkharoubi (interviewed 2014) think that the introduction will happen with difficulty because of the fear of the new. Digital design techniques are still new and unknown techniques in Saudi Arabia, therefore Saudi architects and students prefer to use the techniques which they are accustomed to. Alkharoubi (interviewed 2014) adds that there is a reluctance to learn new and difficult techniques, with the possibility to learn something easy. In this case, students want to escape learning something new and
difficult, such as digital design techniques. Therefore, they may imitate the outcomes of
digital design techniques using 3D modelling software which is easier than learning
scripting itself. Second, the education system difficulties are manifested in the senior
architects’ approach against technology and the cost of digital design techniques.
Qawasmi and Jabali (interviewed 2014) argue that introduction of digital design
techniques will be difficult if the technology opposition issue among senior architecture
educators is not solved. Saifuddin (interviewed 2014) claims that we need to overcome
the educational system difficulties to introduce digital design techniques, especially their
cost. Third, convincing educational decision-makers will also make it difficult. Shehata
(interviewed 2014) believes that resistance to change is expected, but most of the
resistance will come from the decision-makers. Based on these views, it is likely the
introduction of digital design techniques will happen with difficulties or slowly, and will
take some time to happen.

In a more realistic notion the third group of interviewees think that even though the
introduction is difficult, it will take some time and will happen eventually. The difficulty
expected will be only at the beginning. This was the view of Shahrani, Albishri and
Babsail (interviewed 2014). They believe that this introduction will be difficult in the
beginning, and then it will become acceptable. Similarly, Albazai and Baz (interviewed
2014) point out that it will be “super slow” and it needs effort and time (and will occur
after many years), which is normal when introducing new techniques. It will take some
time – acceptance and resistance will take place – then the users will be accustomed to it.

8.4.3 Necessity
Interviewees have two opposing views on the necessity of digital techniques: one view
argues the necessity of introducing digital design techniques and the other one argues for
the opposite. The majority of the interviewees see the necessity of introducing digital
design techniques due to seven reasons. First, Alsuweti (interviewed 2014) thinks that
digital design techniques are a necessity because they are globally prevalent. Second,
Qawasmi and Shahrani (interviewed 2014) believe that digital design techniques will
allow architects to go beyond the normal and achieve optimisation. They allow architects
to explore what they cannot explore using manual techniques; they also help to optimise the final product. Third, Abu Suleiman (interviewed 2014) points out that Saudi architectural development will not happen without digital design techniques. Ibrahim (interviewed 2014) emphasises the importance of introducing digital design techniques in this statement, “The architect who refuses using digital design techniques is like someone who refuses using cars and prefer cabriolet carriage riding now”. This means refusing introduction of digital design techniques will be against development. Fourth, Alsalaﬁ (interviewed 2014) claims that Saudis are relying on foreign ﬁrms and this is making introduction a necessity. Fifth, Baz (interviewed 2014) declares that digital design techniques are needed because Saudi cultural requirements are not easy and they will facilitate achieving these requirements. Sixth, Bin Yassin, Al Mahdi, Saqqaf, Saifuddin and Koshak (interviewed 2014) prove that this introduction is a necessity to avoid being left behind and to keep pace with the digital global revolution. Seventh, Osrah (interviewed 2014) highlights that Saudi architecture needs a shift, thus digital design techniques are needed to improve the outcome.

In contrast, there are other interviewees arguing that the introduction of digital design techniques is not a necessity. Some interviewees think they are not necessary because they are not well known and because they can design without them. Others think they are not important because of their cost. The most reasonable group think it is not necessary to fully embrace digital design techniques now, but it is better to give students some information about them to keep pace with the digital development. Alfulaij (interviewed 2014) states that because digital design techniques are not known they are not important. Fuda and Gadi (interviewed 2014) think design is possible without digital design techniques, hence they are not important. Slightly different is Ashor’s (interviewed 2014) view since he believes that digital design techniques could not be necessary because of their cost, as new teaching staff, computers, fabrication machines and software are needed. At the same time, other interviewees such as Alkharoubi, Aldaaiish, Ashmeel and Sabri (interviewed 2014) see that it is not necessary to fully adopt digital design techniques now, but it is better to provide some background about them to avoid lagging behind and to give the students the freedom to follow the trend if they like.
8.4.4 Proponent or opponent

Baz (interviewed 2014) observed:

People will be in two groups – proponents and opponents. There will be people who want to dispense with our customs and traditions that we grew up with. While there will be conservative/extremist people who do not want development and new, there will be also moderate people.

Among the interviewees, there are proponents and opponents to introduce digital design techniques. The proponents are enthusiastic, think that digital design techniques are the way to the future, and will open new horizons. For example, Almughariy (interviewed 2014) says, “I am a proponent. Digital design techniques are our way to the future”. Albishri (interviewed 2014) comments, “digital design techniques are able to create forms, analyse circulation and do many other things. I highly support this trend”. Koshak (interviewed 2014) also states:

I am very proponent. Technologies always surprise us with new things that we never thought of before. In the past, people thought computers will kill creativity and humans must be creative. But, now I am sure these technologies can take us to things that the human mind cannot imagine.

There are others who support this trend, but they think digital design techniques are used to produce only iconic buildings and they are not the best to design dwellings. Ibrahem and Ahmad (interviewed 2014) argue that digital design techniques are not a bubble and will explode; they are tools and one of the latest trends. They are used to design major iconic buildings, but usual dwellings will remain designed in traditional ways. Even though they support introduction of digital design techniques, their point is debatable. Indeed, digital design techniques could be used to design an iconic building, normal building, an element on a building, and many other things.

On the other hand, the opponents think digital design techniques will ruin architects’ free hand skills and will transform architecture students to computer science engineers. For instance, Sabri (interviewed 2014) is opposed to digital design techniques because he likes and prefers free hand skills instead of using mathematical equations and scripting to design. AA (interviewed 2014) is also opposed to digital design techniques because he
does not know how to use them; they produce science fiction-like buildings; they will transform architects to computer science engineers; and they will threaten local architecture. It seems to be a personal decision whether to support or to oppose digital design techniques. However, opposing unknown techniques could not be the right decision. By comparing the two groups, the opponents are the majority.

8.5 Aspects preventing digital design techniques in Saudi architectural education

Preventing digital design techniques in Saudi architectural education is related to six different aspects. They are similar to the aspects that prevent introduction of digital design techniques to Saudi culture and architecture. However, the aspects here are extrapolated as major obstacles that would prevent introduction to Saudi architectural education. The aspects are (1) the current education situation, (2) ignorance and old mindsets, (3) English and scripting languages, (4) looking for old techniques through technology, (5) infrastructure and facilities, and (6) overqualification. Each one of these aspects is a group of sub-aspects (see Table 12).
Table 12: Aspects preventing digital design techniques in Saudi architectural education

<table>
<thead>
<tr>
<th>Main preventing aspects</th>
<th>Preventing reasons</th>
<th>Interviewees (2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The current education situation</strong></td>
<td>Intense architecture program.</td>
<td>Alsamhan</td>
</tr>
<tr>
<td></td>
<td>Teachers are not updated and have no idea about new architecture software.</td>
<td>Alsamhan</td>
</tr>
<tr>
<td></td>
<td>No courses about programming languages.</td>
<td>Koshak</td>
</tr>
<tr>
<td></td>
<td>Still using traditional techniques.</td>
<td>Koshak</td>
</tr>
<tr>
<td></td>
<td>Many people do not like to change.</td>
<td>Almughariy</td>
</tr>
<tr>
<td></td>
<td>Fear/wary that technology will remove them and take their place.</td>
<td>Almughariy</td>
</tr>
<tr>
<td></td>
<td>Consider digital design techniques as very complex.</td>
<td>Almughariy</td>
</tr>
<tr>
<td></td>
<td>Do not have digital design techniques specialists.</td>
<td>Almughariy</td>
</tr>
<tr>
<td></td>
<td>Digital design techniques conflict with the academics’ interests.</td>
<td>Almughariy</td>
</tr>
<tr>
<td></td>
<td>Having very traditional architecture schools.</td>
<td>Saqqaf</td>
</tr>
<tr>
<td></td>
<td>Architecture education does not encourage students to use computers to design.</td>
<td>Alfulaij</td>
</tr>
<tr>
<td></td>
<td>Technology evolves very quickly, while Saudi universities’ plan to evolve slowly.</td>
<td>Abu Suleiman</td>
</tr>
<tr>
<td></td>
<td>Changing curricula needs a long time.</td>
<td>S. Bargawi</td>
</tr>
<tr>
<td></td>
<td>Old teaching staff suffering difficulty to communicate with young generations, especially technology communication.</td>
<td>Alasker</td>
</tr>
<tr>
<td></td>
<td>Focusing on free hand drawings and using only one software, i.e. AutoCAD.</td>
<td>Alasker</td>
</tr>
<tr>
<td></td>
<td>Digital design techniques conflict with staff interests.</td>
<td>Karban</td>
</tr>
<tr>
<td></td>
<td>Conflict of interest.</td>
<td>Al Mahdi</td>
</tr>
<tr>
<td></td>
<td>Do not have enough time to introduce digital design techniques.</td>
<td>Alataar</td>
</tr>
<tr>
<td></td>
<td>Most professors are aged over 35 years. They need to improve their technological capability.</td>
<td>Abu Ouf</td>
</tr>
<tr>
<td><strong>Ignorance and old mindset</strong></td>
<td>Mostly we think the only relationship between design and computer is AutoCAD.</td>
<td>Shehata</td>
</tr>
<tr>
<td></td>
<td>Not appreciating these software’s abilities. Users are not aware of the purpose of which the software is designed to and they use it within particular limits that do not exceed montaging.</td>
<td>Shehata</td>
</tr>
<tr>
<td></td>
<td>We do not have sufficient experience.</td>
<td>Saifuddin</td>
</tr>
<tr>
<td></td>
<td>We have limited perception about the computer’s capability in architecture design.</td>
<td>Alfulaij</td>
</tr>
<tr>
<td></td>
<td>Old staff accustomed to manual techniques and this will limit digital design techniques introduction.</td>
<td>Alfulaij</td>
</tr>
<tr>
<td></td>
<td>Suffering old mentality in our universities, i.e. computers to dominate students' minds and imagination and will take the designer role.</td>
<td>Alkharoubi</td>
</tr>
<tr>
<td></td>
<td>We see digital design techniques as exaggerated philosophy/bragging.</td>
<td>Alkharoubi</td>
</tr>
<tr>
<td></td>
<td>Old architecture teachers think:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Digital techniques kill students’ manual skills.</td>
<td>Qawasmi</td>
</tr>
<tr>
<td></td>
<td>2. Computers produce beautiful and colourful forms only from outside, but the actual design is bad.</td>
<td>Qawasmi</td>
</tr>
<tr>
<td></td>
<td>3. Ignorance of the importance, mechanism and benefits of digital design techniques.</td>
<td>Qawasmi</td>
</tr>
<tr>
<td></td>
<td>Digital design techniques are seen as something secondary “not primary”.</td>
<td>Alsamhan</td>
</tr>
<tr>
<td></td>
<td>We are suffering conventional thinking and until now, there are people who are calling for manual work drawings.</td>
<td>Gadi</td>
</tr>
<tr>
<td><strong>English and scripting languages</strong></td>
<td>Opposition especially from traditional professors who rely on free hand sketches.</td>
<td>Saqqaf</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td>English language, physics and mathematics are the most difficult skills in programming.</td>
<td>Alkharoubi</td>
</tr>
<tr>
<td></td>
<td>Easier to teach 3D modelling, rather than entering programming languages.</td>
<td>Ahmad</td>
</tr>
<tr>
<td></td>
<td>Programming is the hard way to do design and we do not know anything about it.</td>
<td>Al-Janabi</td>
</tr>
<tr>
<td></td>
<td>Our students do not have strong mathematical ability.</td>
<td>Abu Suleiman</td>
</tr>
<tr>
<td></td>
<td>Complaining about acute shortage in technical skills.</td>
<td>Gadi</td>
</tr>
<tr>
<td></td>
<td>Nobody in this department knows how to program.</td>
<td>Aldaaish</td>
</tr>
<tr>
<td></td>
<td>Struggling to use and understand AutoCAD and 3D MAX, so digital design techniques will be much harder.</td>
<td>Al-Janabi</td>
</tr>
<tr>
<td></td>
<td>We still do not master the traditional software, so how can we master the advanced digital design ones.</td>
<td>Al-Janabi</td>
</tr>
<tr>
<td><strong>Looking for old techniques through technology</strong></td>
<td>Students are very good at manual drawings, so it is difficult for them to use the computers’ mouse instead. Thus, we are looking to convert hand drawing to AutoCAD lines by using tablets, which do not exist yet.</td>
<td>Albushi</td>
</tr>
<tr>
<td><strong>Infrastructure and facilities</strong></td>
<td>The current infrastructure is preventing us. We need to provide whole infrastructure including equipment, laboratories, experts and qualified teachers.</td>
<td>Alsalafi</td>
</tr>
<tr>
<td></td>
<td>We are suffering equipment shortage; our infrastructure is incomplete.</td>
<td>W. Bargawi</td>
</tr>
<tr>
<td></td>
<td>Equipment and infrastructure problems at universities level.</td>
<td>Amoudi</td>
</tr>
<tr>
<td></td>
<td>We have poor infrastructure at Saudi universities.</td>
<td>Osrah</td>
</tr>
<tr>
<td></td>
<td>We do not have equipment and laboratories.</td>
<td>Abu Ouf</td>
</tr>
<tr>
<td></td>
<td>Saudi universities do not provide powerful computers, as well as digital design software software are not free and very expensive to students.</td>
<td>Alfulaij</td>
</tr>
<tr>
<td><strong>Over qualification</strong></td>
<td>Saudi practice does not require and understand digital design techniques. Thus I will be overqualified and waste my time learning them.</td>
<td>Gadi</td>
</tr>
</tbody>
</table>

The current architectural situation could prevent digital design techniques. This is due to some important factors which stem from the educational system, educators and conflicts of interest. For the educational system, the educational program is very condensed and tight; there is no time to insert new digital design subjects. This does not always mean inserting new subjects, but it could be just a replacement. This is why some interviewees complain about not offering programming languages to architecture students. The educational system is also very traditional with a focus on free hand drawing, using traditional techniques, and does not encourage students to use computers to design. Equally important is that changes in the educational programs are very slow, while digital design techniques are evolving rapidly. The current teaching staff is old, mostly over 40 years and they are not willing to change and experience communication difficulties, especially when talking about new digital design techniques. In some cases, digital design techniques conflict with these teaching staff interests. Digital design techniques are out
of their specialisation area; they are accustomed to traditional design techniques and thus digital design techniques will threaten their opportunities and positions.

Digital design techniques seem to be ignored among Saudi architectural circles and this could be an aspect that prevents their introduction. This refers to the fact that some staff and students do not appreciate the power and ability of computers in architecture design. The prevalent notion is that the relationship between architecture and computers is computer-aided design. Users are not aware of the purpose for which the software are designed, and they use them within particular limits that do not exceed drawing and montaging. The old mindset could be another reason preventing this introduction. Some interviewees think that digital design techniques will dominate students’ minds and imagination and will take the designer role. These techniques will terminate free hand skills and will produce beautiful and colourful forms with no functions.

It is assumed that digital design technical skills will not be easy in Saudi architectural education and could prevent introducing them, especially English and scripting, because the difficulty of their technical skills. As mentioned in Chapter 6, there is an agreement that programming skills, English and mathematics are the three main aspects to enter the world of digital design techniques. These three aspects may prevent the introduction of digital design techniques, if they are not strong and prevalent among architectural teaching staff and students. The interviewees were concerned and worried about mastering them, and this could prevent the introduction or make it difficult and/or slow. In brief, these three skills are the most difficult and they discourage students from using digital design techniques. As a result, it becomes easier to push students to learn 3D modelling. Programming is also the hard way to do design, especially if the user does not have a strong mathematical background. Currently students are struggling to use and understand AutoCAD and 3D MAX, so digital design techniques will be much harder. This shows how Saudi architectural educators and students are worrying about these skills. The technical skills will be a critical issue. As mentioned earlier, not all Saudi architecture schools use English in daily teaching and architecture students have modest
mathematics and programming skills. Under these circumstances, the debates are raised about these skills as something that may prevent introduction of digital design techniques.

The other issue that could prevent introduction is that there are still some architects looking within new technology for something that can improve their traditional skills. They are looking for a technology that immediately converts their hand drawing into AutoCAD lines. They do not assimilate that these techniques are more advanced than just improving a skill such as free hand drawing. In this case, it is necessary to clarify benefits of digital design, the way to use them and their potential outcome to overcome concerns.

The currently available infrastructure and facilities at Saudi architectural education may prevent this introduction. The available infrastructure seems incomplete and not promising. Equipment, laboratories, software, experts and qualified teachers are needed. Teaching staff and students demand this equipment to facilitate introduction of digital design techniques. Even more, if Saudi architecture practices do not require digital design qualified architects, there will be no need to introduce these techniques or otherwise the graduates will be overqualified. But, if digital design techniques are gradually infused in Saudi architecture practice, qualification will be a must.

These are the reasons which may prevent introduction of digital design techniques to Saudi architectural education. Some of these reasons seem to be reasonable and acceptable while others are not, but it also seems they are normal and able to be solved.

### 8.6 Methods for introducing digital design techniques to Saudi architectural education

Finding ways to introduce digital design techniques is based on the interviewees’ suggestions and recommendations. The ways are manifested in four points: through educators, architectural education, architecture students and computer science specialists’ assistance.
8.6.1 Saudi architectural educators

The Saudi architecture educators will play a vital role in this introduction as they will transfer these techniques and their knowledge to students. Thus, they need to be aware of these techniques, pros and cons, and to improve their computational skills. Amoudi, Bin Yassin, and Alfulaij (interviewed 2014) agree that academics will play the main role—they will deliver digital design knowledge to students. Therefore, they need to be upskilled and updated no matter what age they are. Shehata and Abu Ouf (interviewed 2014) claim that teaching staff need to raise their technological skills and knowledge; age is not a barrier. This could be through research, exhibitions and conferences as Alkharoubi (interviewed 2014) has suggested. The more information they have, the bigger the impact on students, but this will not always require full digital design techniques proficiency. General information could be enough at the first stages. Educators need to motivate and encourage students to use these techniques. Babsail (interviewed 2014) believes that “the academics’ role is manifested in encouragement and not criticising. Initially it would be normal to produce funny outcomes”.

8.6.2 Saudi architectural education

Saudi architectural education will also contribute significantly to this introduction. To introduce digital design techniques Saudi architectural education needs both strategy and plans to follow, as argued by the majority of the interviewees, such as Baz and Alsuweti (interviewed 2014). For example, this plan could suggest adding or changing some curricula to focus on using computers to generate architectural iterations (Bin Yassin and Osrah, interviewed 2014). Koshak (interviewed 2014) adds that under the pressure of this plan teaching staff will change their approach, improve their digital skills, and keep pace with new digital techniques. The change plan should also include changing the educational pattern. W. Bargawi (interviewed 2014) states that the current education pattern should change. If education continues relying on spoon feeding and old techniques, it will not be able to improve. Moreover, the plan should also include a strategy to get help from computer science departments and mathematics departments, and to use the latest teaching techniques (Karban and Koshak, interviewed 2014). Saudi architectural education also needs to provide the required equipment including hardware and software, and digital design qualified teaching staff to introduce these techniques.
(Ashor, Saqqaf, Ibrahem and Gadi, interviewed 2014). From the study perspective, this introduction could be very difficult or will not happen without the Saudi architectural education intervention and support.

### 8.6.3 Saudi architecture students

Saudi architecture students could also have a role in this introduction. As a general notion the students’ role could be minimal, or they could contribute in this introduction through self-learning and research. Shehata, Hariri and Abu Ouf (interviewed 2014) believe that students are not part of the problem, they just need someone to show them how to use and benefit from these techniques. This could be in the case if digital design techniques are introduced officially. On the other hand, students are able to help in this introduction, they need to learn by themselves through the internet and increase their skills in mathematics, computer science and English (Alsuweti, Amoudi and Karban, interviewed 2014).

### 8.6.4 Computer science specialists

Computer science departments could help architects to make this introduction happen. Nassir and Faqeh (interviewed 2014) advise that to make their way towards programming, architects need to learn the basics and logic of programming, be able to combine two disciplines, architecture and computer science at the same time, do programming in a separate subject, and have an architect who is a specialist in programming to teach architecture students (because computer science specialists are not aware of architectural design principles). In brief, Nassir and Faqeh comment that once students have learned the basics of one programming language, they can learn other languages with ease. Architecture students need to keep in mind that they are indeed doing two disciplines at the same time. Therefore, it could be hard to do programming within design studios as the design studio time is not enough for both. They need also to keep in mind that programming is like a tree – programming is the main trunk and the branches are other disciplines. The core information is the same for all disciplines, but the branches are different. Thus, it is better to educate architects to teach architecture students to ensure they have sufficient knowledge in architecture and programming.
8.7 Conclusion

In current Saudi architectural education, traditional designing and teaching techniques are still in use and focus on manual skills. This is due to using old curricula and not having updated educators. Computers and technology are used only for drawing and montaging. Saudi architectural education uses computers in a modest way for the ten reasons mentioned in Section 8.2.2. In terms of the available infrastructure, students use modest computer laboratories and some commercial software such as AutoCAD, 3D MAX, Rivet and SketchUp. Advanced software and equipment are very limited or, sometimes, not available. This situation will not help improve students’ digital knowledge and skills. However, the plans are more promising and are developing a digital focus, through overseas scholarships, young administration and diversity of approaches.

There is no clear or direct relationship between Saudi architectural education and digital design techniques. Some educators think digital design techniques are positive and will improve Saudi architecture, and others contradict that. It appears there is a gap between digital design techniques and Saudi architectural education. This gap could be due to the current personal knowledge about digital design techniques; some educators know these techniques, while the majority do not know them. They are not aware of them because they are senior architects, there is no one tell them about digital design techniques, they are educated locally, and they are not fluent in English. As a general perception the gap is also caused by Saudi architectural education and computer use skills.

It is important to consider how Saudi architectural education will respond to digital design techniques. Overall, the young student generation are more keen and enthusiastic about technology. However, among the interviewees, there were some who just accept digital design techniques, whereas others reject them. Others are concerned about English and scripting languages. This drove the study to investigate the aspects that could prevent or contribute to introduction of digital design techniques including the current education situation, ignorance and old mindset, English and scripting languages, looking for old techniques through technology, infrastructure and facilities, and over-qualification. All could contribute to prevent, limit, slow or make the introduction difficult.
There are four ways to introduce digital design techniques to Saudi architectural education: through educators, architectural education, architecture students and computer science specialists’ assistance. The educators need to update themselves and be aware of these techniques, abilities and benefits. The more digital design information educators have, the more knowledge students will receive. Educators also need to motivate and encourage students to use these techniques. Saudi architectural education needs to set plans to follow (which may include attracting digital design specialists), add or change some curricula, encourage educators to improve their digital skills, change the educational techniques and patterns, and get help from other departments such as computer science and mathematics departments. Architecture students only need to receive help from their educators, or they could contribute in the introduction through self-learning and research. Students could also be more active and lobby their educators for change. From a different perspective, computer science specialists have advice that to learn these digital techniques architects need to learn programming logic, combine architecture and programming skills, do programming in a separate subject, and get the programming skills from an architect who is a digital design techniques specialist.
Chapter 9: Conclusion

9.1 Introduction

This concluding chapter discusses the future of digital design techniques in Saudi Arabia, including the expected use and outcomes of these techniques in Saudi architecture. This raises two questions: first, is a Saudi digital architecture style possible after introducing digital design techniques, and second, will Saudi architects only use digital design techniques or they will develop them as well. It investigates the potential influences of digital design techniques at all levels—Saudi architectural education, Saudi built environment, Saudi architecture practice and Saudi culture. Then it explores the available opportunities to introduce digital design techniques in Saudi Arabia. In addition, the chapter provides an overview and summary of the findings of the study, discusses the current implementation actions and identifies future research directions.

9.2 Expected future of digital design techniques in Saudi Arabia

As part of the future of digital design techniques in Saudi Arabia the study assumes that, by introducing these techniques, a Saudi digital style will appear and Saudi architecture will develop these techniques rather than just using them. The following is a detailed exploration of these two assumptions.

9.2.1 Saudi digital style

From the study perspective, the Saudi digital style is a style that presents the local Saudi architecture traits (including cultural and environmental requirements) in a new digital context, in other words, an architecture that is produced using digital design techniques and, at the same time, meets the Saudi cultural and environmental requirements to be acceptable. Among the interviewees there are two groups: a group which is optimistic and supports the emergence of a Saudi digital style, and a second group which is pessimistic and does not expect a Saudi style to emerge.
The Saudi digital style should be a combination of traditional Saudi architecture and the use of new digital design techniques to design. In this case, digital design techniques will be just a tool and Saudi architects should use them in a way that serves and respects local culture and architectural identity. This could result in the emergence of a Saudi digital style. Babsail (interviewed 2014) comments that this style would combine traditional Saudi architecture and the new digital design techniques. Famous architects have used these techniques as tools, so it is possible for Saudis to use the same tools as well. Saudi architects must learn who to respect for culture in design, and how to reflect Saudi architectural identity using these techniques. Almughariy (interviewed 2014) also says that a Saudi digital style is possible, as digital design techniques will allow the combining of technology and culture, and thus the outcome blend will suit Saudi culture, religion and environment. Saifuddin (interviewed 2014) adds that there will be a distinctive style. Those architects who are leading the introduction of digital design techniques in Saudi Arabia with new ideas stemming from merging local architecture and new techniques will constitute a powerful new generation who can present itself and become acceptable to society in terms of cost, forms and function. This study argues the need to introduce and use these techniques to move Saudi architecture forward and, within the framework of its characteristics and restrictions, to produce unique architecture.

In contrast, other interviewees believe that Saudi digital style will not happen. Their argument is that digital design techniques are international techniques and produce international architecture. Qawasmi and Ashmeel (interviewed 2014) argue that digital design techniques are against local identity, the outcomes are international, and will continue to be international. S. Bargawi (interviewed 2014) also adds that a Saudi digital style will not happen. There may be personal styles of architects who master these techniques, for example, Zaha Hadid has her style, but it is not a British or American style. This also applies to Frank Gehry and Rem Koolhaas. Therefore, architects could make their own styles, but not a Saudi digital style. Abu Ouf (interviewed 2014) asks “Are we going to make a new architecture and give it a name?” He claims that names are not important; it is more important to fulfil the users’ comfort and security through these techniques. There is nothing wrong with the point that digital design techniques will produce international architecture, but they can also produce other products that relate to
specific culture. Digital design techniques are a tool that could be used to make a variety of options and outcomes, and could be iconic buildings or merely an element on a normal building. There is no limitation on how to use digital design techniques and what the outcomes will be.

### 9.2.2 Saudi architects as users or developers

In general, Saudi culture is a consuming culture; most of the technologies in use now are imported. Indeed, there has been no effort at developing and inventing Saudi technologies. However, in the last few years, the Saudi government has funded some large projects to start developing and producing technologies such as Makkah Techno Valley, Dhahran Techno Valley, Riyadh Techno Valley and King Abdullah University of Science and Technology. This section shows the interviewees’ expectations of digital design use in Saudi Arabia. Some architects believe that Saudi architects will use and develop these techniques, whereas others are convinced that Saudi architects will only use digital design techniques but they will not develop them.

Some interviewees have a positive impression about using and developing digital design techniques in the near future. The current generation is obsessed with technology and will try to find new solutions through technology to achieve their goals and desires. Therefore, it is expected to have a generation that is able to use and develop technology including digital design techniques. Alkharoubi and Babsail (interviewed 2014) claim that Saudi architects will take this field further and will establish research centres and digital design schools. Abu Suleiman and Albazai (interviewed 2014) believe that, after introducing digital design techniques, there will be Saudi professionals who will adopt, study and research these techniques; nothing will prevent them from developing and competing. Baz (interviewed 2014) argues that Saudi architects will be pioneers in this field, and the West will look at them to see the new Islamic digital architecture. They will use and develop these techniques in a different way, which is more connected to local Saudi architecture. In contrast, Koshak (interviewed 2014) thinks that, at the beginning, Saudi architects will be only users, but under the university vision of scientific research and development there will be research and development in this field – but it needs time.
There are ambitions to master digital design techniques and then improve them through research centres and architecture schools.

On the other hand, different interviewees believe that Saudi architects are just technology users and will not develop or invent technology. Aldaaish (interviewed 2014) thinks that there will not be any research in this field and Saudis will not develop digital design techniques – only use them. Ahmad (interviewed 2014) states that once Saudi architects have started researching digital design techniques some new techniques and trends will emerge, and therefore their research will be too late or useless, hence research and studies will not happen. Sabri (interviewed 2014) also adds “we are users or consumers”. The situation is very similar to the pattern of introducing computer-aided design packages for some interviewees. For example, Mohamad Alamri, a final year student at King Saud University (interviewed 2014) believes that there will not be any research, as using AutoCAD has not changed for many years in Saudi Arabia: “We will use digital design techniques as they are, and then we will wait for the next new technology”. The other issue is that the research field is still not strong enough in Saudi Arabia therefore digital design techniques will be used as they are. S. Bargawi (interviewed 2014) highlights that digital design techniques will be used as they are, but says adopting them as a research field is not achievable. Saudi Arabia is weak in this area. This could have been the situation a few years ago, but now, it might be suggested, Saudi Arabia is about to move from being a consumer to innovation and manufacturing. The new national plans and the new Techno Valleys are good signs and promising.

9.3 Digital design techniques influence at all levels

By introducing digital design techniques, their influence will be manifested in four levels: Saudi architectural education, Saudi built environment, Saudi architecture practice and Saudi culture.

Significant improvement will occur in Saudi architectural education including curricula, infrastructure and educators. According to Karban (interviewed 2014), introducing digital
design architectural education will dramatically improve curricula, laboratories and staff to keep pace with the new trend. Even the way of architectural thinking will be more advanced. Amoudi (interviewed 2014) adds the introduction will change the entire Bachelor’s program structure or may lead to a separate new Bachelor or Master’s program in digital design. Koshak and Jabali (interviewed 2014) emphasise that introduction of digital design techniques will increase both the education and the students’ quality. As a result, Saudi architectural education will be a model to be followed by other Arab neighbour countries (Fuda, interviewed 2014), while Alsuweti (interviewed 2014) believes that Saudi architectural education will be linked to global architecture education. However, there will be some obstacles at the beginning, mostly because of the lack of qualified staff, software, hardware and curricula. This is normal and expected to happen when introducing new techniques to an old system. Normally there will be a period of decline, which may reduce productivity and quality. Nevertheless, patience and dedication are needed to overcome this decline, and then a quantum leap in the Saudi architectural education will take place (W. Bargawi, interviewed 2014).

As a consequence of digital design techniques, the Saudi built environment will be influenced and changed. According to the interviewees, a fundamental urban development is expected in all levels. Bin Yassin (interviewed 2014) assumes that the city image will change, thus high control is needed when digital design techniques are introduced and used. This control may stem from the sense of conserving local Saudi architecture. This means using digital design techniques in a way that will not change the local architecture identity, but in a way that could improve it. Saifuddin (interviewed 2014) argues:

When general technology was introduced about 15 years ago, a quantum leap happened in Saudi society, which makes technology an indispensable part of daily life. In my personal opinion, the same thing will happen; if digital design techniques were introduced to Saudi culture, another quantum leap will happen leading to development and change. However, this requires us to act in parallel to improve using technology and to develop local vocabulary to maintain them. This way we can produce new local zeitgeist vocabulary.

The focus is still on developing, reviving and maintaining old traditional architecture. This is indeed promising; digital design techniques will be used in a way that fulfils the
local cultural and architectural requirements, in a way that might be considered as a renovation of the Saudi architectural values in a new digital context. For example, Osrah (interviewed 2014) claims that “through plug-ins like Grasshopper we can revive these traditional architecture values easily”. At the same time, Koshak and Atwa (interviewed 2014) expect that these techniques will impose a new way of thinking and new solutions, therefore new, different and unique buildings will be built. From the study perspective these influences are indispensable. Indeed, they are healthy and should happen. Changes in the built environment are needed as well as maintaining and improving the local architecture.

Digital design techniques will take Saudi architectural practice to new levels to produce better architecture and access digital optimisation and fabrication. The use of these techniques will be exclusive only to Saudi architects knowledgeable in digital design techniques (Saqqaf, interviewed 2014). This is assumed to happen just at the beginning, but later these techniques will be common. Abu Suleiman (interviewed 2014) states that digital design techniques will take Saudi practice to a new extent where functions become more complex and buildings became more diverse. Thus, every architect will produce better and different outcomes. Alasker (interviewed 2014) points out that it is not necessary to see strange buildings if digital design techniques are used. The outcome could be better in all aspects – functional, environmental and cultural, with ease and beauty. As a result of this development Saudi practice will have the chance to compete internationally (Al Mahdi, interviewed 2014). Saudi architects will also be able to access digital optimisation, error detection, digital fabrication and 3D modelling (Amoudi and Ashor, interviewed 2014).

For Saudi culture, there may not be a significant or important change. Saudi culture will be more advanced in terms of awareness and will appreciate outcomes of digital design techniques. Shahrani (interviewed 2014) claims that digital design techniques will impose a hybrid style, which will move society’s architecture taste to a higher level; even the way people look at digital design outcomes will change. Hariri (interviewed 2014) comments that digital design techniques will contribute to improve Saudi culture, while Koshak
(interviewed 2014) declares that generally mixing Saudi culture with digital design techniques will produce something very special. These interviewees talk about the smooth and easy introduction and acceptance of digital design in Saudi, but some resistance in the first stages is expected. According to Osrah (interviewed 2014), there will be a rejection at the beginning. People think architecture must be simple forms, but by the time digital design techniques are accepted the drawbacks will turn to advantages. Overall, it is likely that Saudi culture will change to accept digital design outcomes eventually.

9.4 Opportunities to introduce digital design techniques

When commenting on the available opportunities to introduce digital design techniques to Saudi culture, architecture and architectural education, the interviewees’ responses were very positive and promising. Shehata (interviewed 2014) says:

Opportunities are available now. Compared to ten years ago, we are now in a development revolution. The Kingdom is witnessing a leap, especially investments in higher education and overseas scholarships, and the opening of new universities. In brief, the investments are not just targeting projects and constructions, but also developing people and education. Architectural education therefore, must benefit from this revolutionary wave, or it will be lagging behind. Now our university provides all possibilities and opportunities to start digital design techniques introduction or foundation. In a few years, these opportunities will be wider as all the decision-makers will be new and younger.

Most of the interviewees emphasised the role of the scholarship student in this introduction, such as Alkharoubi, Alsuweti, and Ashmeel (interviewed 2014). Students are the coming opportunity to introduce new techniques and technology, which will move Saudi architectural education forward. This relates to the current lack of teaching staff competent in digital design techniques. Otherwise, other circumstances such as cultural openness, funding and equipment are ready and available. Even though many interviewees criticised the Saudi education system and how it is hard and slow to make changes, Abu Suleiman (interviewed 2014) expresses the opposite. He confirms that:

We can introduce digital design techniques as a new program/degree in architecture departments. We do not have qualified staff, but we need to know that Saudi Arabia is constructing and will construct large distinctive projects, thus we need these techniques now. There are very excited young architects. I see all conditions and opportunities are available now.
This is not only limited to the potential flexibility of the educational system at Saudi universities, but also includes other changes at the Saudi education ministry. The new Ministry of Education is working to direct education towards creativity and innovation (W. Bargawi, interviewed 2014). Indeed, there is no problem with the available opportunities (say all opportunities are available now), but the problem is the shortage of digital design qualified academics. Most of the interviewees are waiting for overseas scholarship students to return to Saudi Arabia to establish the digital design trend. However, if this is the only problem, local architects and academics can gain digital design knowledge through online courses or by hosting seminars and workshops.

9.5 Overview and summary of findings

This study investigated Saudi cultural traits in relation to the potential use of digital design techniques including how digital design techniques could relate to Saudi culture, architecture and architectural education, influence ways of thinking and processes of designing, and potentially advance architecture in Saudi Arabia. The study also explored important aspects of Saudi culture and architectural education as they are the direct source of current Saudi architecture. It questioned the cultural, architectural and educational aspects that could affect, challenge or prevent introduction of digital design techniques in Saudi Arabia. This study has analysed the potential introduction of digital design techniques to Saudi culture, architecture and architectural education. It highlighted the potential influences and interactions. It also provided information about digital design techniques, their theories, the ways to use them and the requirements to implement them.

Saudi culture was very conservative due to very strict restrictions, traditions and customs. Unsurprisingly, oil development forced the culture to change. As a consequence, the culture started to change and lose some of its traditional aspects. Therefore, a preservation campaign has emerged to preserve Saudi traditional architecture, but the general trend is moving toward modernisation. Hence, Saudi culture has developed its characteristics to match the challenges of the new built environment and lifestyle.
Saudi architectural education was influenced by foreign countries in the early 1970s. The educational curricula were developed with the help of foreign universities. Unfortunately, these curricula were not directed to serve Saudi cultural, environmental and architectural requirements. In Saudi architecture schools there are few computer facilities available for students, and computer use and training is modest, focusing on specific skills and the traditional way of doing architecture, but not using digital design techniques.

Computer applications in architecture have become the current zeitgeist and, as a result, the design process has changed to produce unprecedented shapes, surfaces and configurations. Using these applications has changed the way architects think and design, increased complexity and novelty in architectural design, and opened new channels between architecture, mathematics and computation. As a result, architects need to (re)think design differently in all stages.

Architects are now able to produce and understand geometries that were previously impossible to achieve. In addition, architects are now capable of connecting design, computation and mathematics in ‘one logic’. Therefore, providing information about digital design techniques is vital, especially for young architects. It is important to understand that digital design techniques will allow new ways of thinking and designing, maximise complexity and novelty, and enhance the intimate relationship between architectural design, mathematics and computation. Digital design techniques will also enable architects to use computers to generate design rather than being mere drawing tools.

The introduction of digital techniques has inspired digital theories. Since 1990, theories such as folding in architecture and the blobs, performative architecture, parametricism, morphogenesis, nonlinear organisation, digital tectonics, topology in architecture and digital poetics indicate that architecture is entering a new stage of computation. These theories are implemented by using programming languages and algorithms. This allows architects to benefit from the computer’s power rather than just using commercial
architecture software. Therefore, it is significant for architects to understand and assimilate the era of digital design techniques through their theories and history.

Almost all these theories are oriented to add computation to the process of design, materialisation, production and construction. In addition, with digital theories and computation, architects can design the design – designing the design process rather than the product. Architects are designing a set of rules encoded using programming language to generate many iterations. Designers need to be flexible to find their way through these theories and digital skills, and to grasp the way they interact with computers and the expected outcome.

This study provides a base for Saudi architects who want to use digital design techniques, especially architects who do not know about these techniques. Digital design techniques can reveal the hidden calculation and functions, through coding or programming languages, which allow a shift in the design process. Due to this shift, architects in Saudi Arabia are now facing new frontiers. Knowledge in the field of algorithmic and geometric calculations is desirable. The conceptual understanding of geometries, mathematical formulae, how geometries are generated, and how they are fabricated and built, is fundamental. Architects also need to keep pace with the available fabrication machines and materials.

Coding or scripting is an important way to access the computation world in architectural design. This requires the exploration of generative mathematical concepts such as chaos, recursion, fractal, packing, tiling, flocks, schools, swarms and crowds in order to use these generative behaviours. As a result, it is crucial for architects to use coding languages, to know their benefits, how to access them, their techniques, the role of algorithms in coding, their relationship to computation, and why and how to use scripting.

As expected, the interview data showed the perception of digital design techniques among Saudi architecture staff and students was and is both positive and negative, both accepting
and rejecting. There are several groups of responses. First, there were some who already know digital design techniques, and they want to introduce them as soon as possible. This may potentially suggest that digital design techniques will not conflict with Saudi culture, and that digital design techniques will contribute to improving old architecture techniques. *Using digital design techniques in the Saudi cultural context may produce new styles and values.*

Second, some architects who know digital design techniques and accept them may wish to develop some other conditions and concerns. For example, digital design techniques should be used to serve the local culture and identity, they should be used in a way that respects the human sense of space, they should be introduced by Saudis, and they should suit the society requirements.

Third, architects who do not know digital design techniques, may, after a brief introduction, just accept them and want them. But, it is possible that they do not know because they are from the old architecture school generation, or because they have not received information about digital design techniques.

Fourth, the ones who do not know digital design techniques might, after a short introduction, accept and want them, but with some additional conditions. For instance, the value of manual sketching skills has priority, and the need to control the way of using digital design techniques.

Fifth, there are those who do not know digital design techniques and, after a short introduction, reject and do not want them because they are from the old generation school of architecture, and hold an antagonistic position.

Sixth, there are those who know these techniques and reject them because they are concerned about the architect’s role in the design process.
The view of digital design techniques from a cultural and architectural perspective is divided into four possible categories: Saudi culture will accept digital design techniques; digital design techniques may conflict with Saudi culture, and therefore will be rejected; Saudi architecture will accept digital design techniques; and Saudi architecture is not ready now to accept digital design techniques.

There are four reasons that Saudi culture may accept these techniques: (1) the desire to explore and use new technology; (2) the exposure of Saudi culture to digital design outcomes through travelling; (3) the ability of digital design techniques to improve local architecture; and (4) government initiatives to take a forward development step, which could include the new Saudi iconic buildings which are designed using digital design techniques by international offices.

In contrast, rejection of digital design techniques could relate to some cultural concerns, for instance, digital design techniques may conflict with Islamic principles and values; digital design techniques may be seen as irrelevant and threatening to Saudi culture and history; digital design techniques may impact on cultural and architectural values; and digital design techniques may not comply with society, religion and environmental needs.

A third view is that Saudi architecture will accept digital design techniques, but only for iconic buildings designed by international architects due to reputation; the admiration of and fascination with digital design outcomes; and because there are no qualified Saudi architects in this field.

The final view is that the Saudi architectural environment is not ready yet for the introduction of digital design techniques. This could be due to the lack of an overarching environment for digital design techniques; construction techniques are unknown in Saudi yet; reliance on foreign architects; Saudi practice is not ready; there is no political desire or plan to use and teach digital design techniques; and because of their high cost.
digital design techniques becomes exclusive to foreign architects and international architecture offices because Saudi architecture is not ready.

Saudi culture might suggest that digital design techniques rely on computation and technical skills considered as extra knowledge that architects need to gain. This includes knowledge of English, mathematics, programming languages and software, which are the main requirements to enter the world of digital design techniques. Unfortunately, Saudi architects are missing these skills because they are not taught them at Saudi universities. Although collaboration between architects and computer science specialists is needed, this is an ongoing problem for two reasons: Saudi architects do not know that computer programmers can help them, and Saudi computer programmers do not know they can help architects.

Digital design techniques are unlikely to pose any technical problems for Saudi architects. Technical difficulties are expected to happen in almost all disciplines and can be solved through developing missing knowledge. To overcome the current lack of technical knowledge, Saudi architects need to know and understand how computers think; have enough information about programming languages; have fluent English; and understand the structure and logic of the language itself. Solving problems using programming and mathematics is fundamental. Architects also need to know that programming for architecture is different, even using the same principles and logic, and will be difficult especially at the beginning. To understand programming, Saudi architects need to study separate subjects to learn the principles and logic, then they need to study another subject to link architectural requirements with programming.

There are four different aspects to the relationship between current Saudi architecture and digital design techniques. First, digital design outcomes are now in Saudi Arabia, but Saudi architects have not created them because there are no Saudi architects specialised in this field. Using international architects reduces opportunities for Saudi architects to enter this field and may produce irrelevant architecture as foreign architects are not from the Saudi culture and environment. By introducing digital design techniques to Saudi
architects this dilemma will be solved. Learning and using digital design techniques is the way to overcome these consequences and for Saudi Arabia to be self-sufficient.

Second, Saudi architects are not able to use these techniques now. The problem is that Saudi architects have no knowledge of digital design techniques now, and the ones who do know are few or not recognised.

Third, despite Saudi architects and architecture practices using computers, they use them for drawing, montaging, calculations and documentation only. Digital design techniques are not prevalent. Thus the introduction of digital design techniques will be a step forward and will maximise the opportunities.

Fourth, in Saudi architecture there is a clash point where the desire to move forward and conservatism collide. The clash is manifested in three points: some Saudi architects think that digital design techniques are irrelevant and threatening; others think that use of digital design techniques in Saudi Arabia should not harm Saudi traditional architecture; and the government approach to protecting the history of Saudi architecture is ongoing and significant. Nevertheless, it is possible to use digital design techniques in the context of traditional architecture to produce hybrid Saudi architecture.

Indeed, many aspects of Saudi culture have changed and using digital technologies can become a culture within Saudi culture itself, especially for youth. It is expected that the relationship between Saudi culture and digital design techniques will be more positive than negative, even though the existence of technology is opposed by some antagonists. The majority of youth will be more responsive to digital design techniques, and they will trust them. It is likely they will understand digital design techniques more quickly than older generations. There will be the open-minded who will welcome digital design techniques, and the antagonistic who are against digital design techniques. The second group will be more conservative and careful: they are most likely people from the older generations. There will also be a recognisable enthusiasm to use these new techniques.
This will be achieved by following the footsteps of other societies using digital design techniques, and by an easy and understandable introduction.

Within Saudi culture there are some aspects that could prevent introducing digital design techniques. The aspects are: being outside of interest, conflicting, irrelevance, ignorance, fear of the new, and not understanding architecture. Digital design techniques may be outside of interest because they do not have meaning to Saudi society. The majority care about the outcomes, but not the technology or techniques that have been used to produce the outcome. A conflict could happen if digital design techniques have influenced the culture itself or some important aspect of it, and if they cannot provide the cultural requirements. Being irrelevant is also a reason preventing introduction of digital design techniques: they are irrelevant to Saudi culture as they are unknown before, and may be ‘new’. There is ignorance of digital design techniques among Saudi society. This relates to the newness of digital design techniques in Saudi culture which leads to a fear of using them. The last aspect is that Saudi society does not understand architecture outside its culture, which may prevent introduction of digital design techniques. In reality most Saudis prefer to build something easy, affordable and practical, regardless of its relation to traditional architecture and environmental requirements. These six issues are expected, yet they will disappear as society recognises the importance of digital design techniques.

Being aware that Saudi culture and architecture have aspects which may prevent introduction of digital design techniques, it is appropriate to recommend some solutions at the Saudi cultural and architectural levels that may help introduce digital design techniques. At the Saudi cultural level, there are six suggested ways to introduce digital design techniques: raising public awareness; having an introductory period; having an easy and smooth introduction; convincing Saudi society; showing the outcomes of digital design techniques; and respecting local culture. There are also six suggested ways to introduce digital design techniques to the Saudi architectural level: support local Saudi architecture; develop qualified Saudi architects; provide information about digital design techniques through conferences and workshops to Saudi architects; establish research centres for digital design techniques; launch an overarching plan or strategy to introduce
digital design techniques to Saudi architecture; and gradually introduce digital design techniques through experiments and tests.

Current Saudi architectural education is still using old methods to deliver architectural design knowledge and skills, starting from basic manual skills including 2D, 3D, shade and shadow and then moving to use computers for drawing and montaging such as 2D using AutoCAD then 3D modelling, due to four reasons:

1. There are debates about whether to continue using manual techniques or computers in design.
2. The curricula are old and teaching staff are not up-to-date.
3. The focus is on teaching students the main basic traditional techniques before they can use computers.
4. It is uncommon to find teaching staff who use different techniques such as digital design techniques.

The technology used in Saudi architectural education is also an issue. Computers are a commonly used technology at Saudi architecture schools, but they are used only for drafting and montaging for many issues. First, using computers in this way is easier. Second, students and teaching staff are not yet knowledgeable about digital design techniques. Third, there is a difference between the old and the new generations of architects. Fourth, using computers this way is the best available at Saudi architectural schools. Fifth, using computers this way is considered as current cutting-edge available technology. Sixth, it is also considered as the maximum current level of the available technology. Seventh, it is hard to find Saudi architects who are digital design experts. Eighth, using computers for digital design is not common and usual in Saudi architectural education. Ninth, these are the techniques imposed by the teaching staff. And finally, using computers in other ways is difficult.
The available infrastructure at Saudi architecture schools consists of modest computer laboratories and printing machines, while the commonly used software includes AutoCAD, 3D MAX, Rivet and SketchUp. Other equipment, such as laser cutters, computer numerical control milling, 3D printing, and some software such as Rhino and Maya, are not always available, or students have very limited access to them. However, infrastructure should not be a major obstacle preventing introduction of digital design techniques in Saudi Arabia, especially as the current plans are directed to use advanced technology and techniques in Saudi architectural education.

The current relationship between digital design techniques and Saudi architectural education is very weak, even though some academics and students have some information about digital design techniques. Lack of knowledge of these techniques is common among teaching staff and students, and is a result of several factors: (1) the old generation of architects, (2) staff have not received any information or knowledge about digital design techniques, (3) staff did their degrees locally, and (4) staff do not use English fluently. Nonetheless, a few academics and students know these techniques because they completed their degrees overseas, through media, or because they are able to use English fluently. However, they do not use or teach digital design techniques. Therefore, there is a gap between digital design techniques and Saudi architectural education. Saudi architectural education contributes to the gap by emphasising the usual way of using computers for drawing and montaging and also through the negative attitude of some senior academics who think computers will decrease creativity and complexity, the lack of academics competent in digital design, and the lack of financial support to equip laboratories. But this gap is not large and will be overcome by self-confidence, knowledge and enthusiasm.

A related issue is perception of digital design techniques among Saudi architectural educators. Even though the general perception is positive, optimistic and forward-looking, there are some concerns that architects will be computer engineers; digital design techniques will produce a non-buildable futuristic architecture; digital design techniques should not take the architect’s role in the design process; computers are complementary
and only architects can develop ideas; digital design techniques will destroy the discipline (and will open the field to programmers); manual drawing is a very important expression tool for architects; and there may be communication problems if every architect has their own software. These concerns stem from not having enough information about digital design techniques. These techniques could have a positive impact on architectural design and digital design techniques could be the way to a new and better Saudi architecture.

The current intentions and plans reflect the response of Saudi architectural education, especially youth as they are keen and enthusiastic to understand technology. Response to digital design techniques in Saudi architectural education is shown in four parts: acceptance, difficulty, necessity, and proponent or opponent. The general theme was acceptance of the introduction of digital design techniques, especially among young staff and students, but not senior or older architects. In fact, it is expected that the introduction will not be very hard as Saudi architects are able to use computers and they only need to push this use a little further towards digital design techniques. However, there will be difficulty for three reasons: fear of the unknown, education system difficulties, and administration problems.

There is a need to introduce digital design techniques to Saudi architectural education for several reasons: (1) Saudi architectural development will not happen without digital design techniques, (2) Saudis are relying on foreign firms which necessitates introduction, (3) this introduction is a necessity to avoid being left behind, and (4) it is needed to keep pace with the global digital revolution. Despite these factors, there are still a few proponents who think digital design techniques will threaten architects’ free hand skills, and will transform architecture students into computer science engineers.

Some factors could prevent the introduction of digital design techniques in Saudi architectural education, and they are similar to the aspects above. The factors are: (1) the current education situation, (2) ignorance and old mindsets, (3) English and scripting languages, (4) looking for old techniques through technology, (5) infrastructure and facilities, and (6) overqualification. The present architectural educational system could
prevent use of digital design techniques due to the educational system, educators and conflicts of interest. Digital design techniques also seem to be ignored because the power and ability of computers in design are not appreciated. In addition, the technical skills for digital design techniques will not be easy for Saudi architectural education, especially English and scripting. There is also misunderstanding of the role of these techniques. For instance, in some cases digital design techniques are conceived as a tool to convert freehand drawing into AutoCAD lines. The existing infrastructure and facilities are incomplete and not promising, and equipment, laboratories, software, experts and qualified teachers are needed. Even more, Saudi architectural practices does not embrace digital design techniques yet. Therefore, Saudi architects with digital design technique skills will be overqualified or not needed.

Digital design techniques can be introduced to Saudi architectural education through the educators, the education system itself, the students and computer science specialists. Saudi architecture educators will transfer knowledge of digital design techniques to students. Therefore, they need to be aware of these techniques and to improve their computational skills. There is an urgent need to develop and adopt a strategy and plan including adding or changing some curricula; encouraging teaching staff to change their approach; improving staff digital skills and keeping pace with new digital techniques; changing the educational pattern of relying on spoon feeding; getting help from computer science and mathematics departments to use the latest teaching techniques; and providing the required infrastructure including hardware and software, and digital design qualified teaching staff. Saudi architecture students need to contribute to this introduction through self-learning and research through the internet and increasing their skills in mathematics, computer science and English. Saudi computer science specialists can also contribute to this introduction by helping architecture students find their way toward programming. It is recommended that architecture students learn scripting basics, be able to combine the two disciplines of architecture and computer science at the same time, do programming in a separate subject, and have an architect who is specialised in teaching architecture students.
When digital design techniques are introduced to Saudi culture it is expected that a Saudi digital style will appear, and Saudi architecture will develop these techniques rather than just using them. Digital design techniques are a mere tool that Saudi architects use in a way that serves and respects local culture and architectural identity. It is also expected that Saudi architects will develop digital design techniques and not only be users. In the last few years, the Saudi government has funded major projects to start researching, developing and producing technologies. Saudi architects expect to be pioneers and role models in this field. Introducing digital design techniques will influence Saudi architectural education, Saudi built environment, Saudi architectural practice and Saudi culture.

The opportunities to introduce digital design techniques are very positive and promising. Saudi Arabia is undergoing a development leap, especially in education with overseas scholarships and establishing new universities. Architectural education will benefit from this development. Other chances are also available, such as cultural openness, funding, and ready and available equipment. Overseas scholarships, while important, are not the only opportunities to introduce digital design techniques. Local architects and academics can obtain knowledge of digital design techniques through online courses or by hosting seminars and workshops.

9.6 Current implementation actions

Saudi universities have plans to enter the world of digital design techniques. For instance, in 2016-2017 a Saudi university will introduce a new subject called ‘Advanced Applications of Computer Skills for Architects’ including scripting to teach these techniques. This subject will target architecture students in their third or fourth year to use these techniques. Students must have completed the previous computing subjects which are ‘Computer Skills for Architects One and Two’. The subject aims to deepen the concept of using the computer to the student through presenting the capabilities of these techniques to increase creativity and quality. It will also show the ability of computers in analysis, optimisation and repetitive tasks. The subject aims to reveal the background
operations which happen when using the interfaces of commercial architecture software. It will also introduce visual coding and hard coding techniques, such as using a plug-in such as Grasshopper and coding language such as Rhino Python. The subject will clarify the role of these techniques in linking design, fabrication and materialisation. This will expose students to the new fabrication techniques and machines. This subject may be considered as an unprecedented introductory step from the university, and it could be the starting point to spread digital design to other Saudi universities. It will be important to evaluate the subject and seek feedback from students after the first year.

9.7 Future research directions

This research studied the introduction of digital design techniques to Saudi Arabia including potential interactions and influences on Saudi culture, Saudi architecture and Saudi architectural education. There are several future research directions to extend the study as follows:

- This research could be extended by establishing a study about education in digital design techniques in Saudi Arabia.
- This research could be a starting point for further research to develop a comprehensive framework or strategy to use digital design techniques in Saudi Arabia.
- This research could be extended to study the use and implementation of digital design techniques in Saudi architectural practice.
- This research could be extended to study a similar situation of introducing new digital technologies in other regions such as the Middle East or South East Asia and potentially other countries who have not developed digital technology in architecture.
Appendices

Appendix 1: Human Research Ethics Committee approval

HREC Approval

1 message.

Research.Ethics@uts.edu.au <Research.Ethics@uts.edu.au> 6 November 2013 at 10:06

Dear Applicant,

The UTS Human Research Ethics Committee reviewed your application titled, "Sydney Culture and the Introduction of Digital Architecture: Influences and Interactions", and agreed that the application meets the requirements of the NHMRC National Statement on Ethical Conduct in Human Research (2007). I am pleased to inform you that ethics approval is now granted.

Your approval number is UTS HREC REF NO. 201300500
Your approval is valid five years from the date of this email.

Please note that the ethical conduct of research is an on-going process. The National Statement on Ethical Conduct in Research Involving Humans requires us to obtain a report about the progress of the research, and in particular about any changes to the research which may have ethical implications. This report form must be completed at least annually, and at the end of the project (if it takes more than a year). The Ethics Secretariat will contact you when it is time to complete your first report.

I also refer to you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

You should consider this your official letter of approval. If you require a hardcopy please contact Research.Ethics@uts.edu.au.

To access this application, please follow the URLs below:
* If accessing within the UTS network: http://imp/produ/uts.edu.au/RMENet/HOM01TN.aspx
* If accessing outside of UTS network: https://remote.uts.edu.au/, and click on "RMENet - ResearchMaster Enterprise" after logging in.

We value your feedback on the online ethics process. If you would like to provide feedback please go to:

If you have any queries about your ethics approval, or require any amendments to your research in the future, please do not hesitate to contact Research.Ethics@uts.edu.au.

Yours sincerely,

Professor Marion Haefeli
Chairperson
UTS Human Research Ethics Committee
C/O: Research & Innovation Office
University of Technology, Sydney
T: 02 9514 9645
F: 02 9514 1244
E: Research.Ethics@uts.edu.au
P: PO Box 123, SYDNEY NSW 2007
[Level 14, Building 1, Broadway Campus]
CB01.14.00.04

Ref: E13.
Appendix 2: Interview transcript (example – transcribed from Arabic to English)

Today I am interviewing Dr. Mohammad Babsail, Head of the Architecture Department at King Fahad University of Petroleum and Minerals.

After introducing my study, its goals and significance in summary, let us start the questions.

Level 1:

Qattan: In general, what do you know about digital-design techniques DDTs?

Babsail: It is using computers to develop, improve ideas or translating ideas that developed manually into 3D computer models. The first part is taking sketches to draw and montage them using computers. The second part is developing the full design using computers. The advance part is developing design digitally using mathematical and physics equations, such as Generative Design. I have this information about DDTs because I did my master and Ph.D. overseas.

Qattan: How would you describe its relationship to Saudi culture?

Babsail: I think our culture began to become open now, and this is positive. We become excited to use every new thing. There is no doubt that Saudis architects are very excited to see real DDTs and Generative Design outcome after they heard about them. To introduce a new idea, you should deliver it in an easy way like public seminars. Or, our students could go to shopping malls to present simple introductory things. Public likes to see new things, and I expect these techniques will be accepted. There is no doubt that there will be positive acceptance, if these techniques are introduced in an easy way.

Qattan: What are the possibilities of using DDTs in Saudi architectural education?

Babsail: Now, we are planning to enter digital design world through fabrication. Recently we have a new lecturer specialized in this field. He did his master degree in the US in 2014. His teaching duty is to focus on how to design and at the same time how to produce this design even if it is very complex using devices such as laser cutters & CNC milling.

Qattan: Does the university have these devices?

Babsail: Currently, we have a laser cutter in our department. CNC & 3D printers exist in the FAB Lab, and we can use them through coordination with the administration.

Qattan: Do you know any other DDTs techniques?

Babsail: I know generative design and algorithmic design, parametric design and Data Mining.

Qattan: Do you support introducing DDTs to Saudi culture and architectural education?

Babsail: Absolutely.

Qattan: What are the possibilities of using DDTs in Saudi architectural education?

Babsail: Now, we are planning to enter digital design world through fabrication. Recently we have a new lecturer specialized in this field. He did his master degree in the US in 2014. His teaching duty is to focus on how to design and at the same time how to produce this design even if it is very complex using devices such as laser cutters & CNC milling.

Qattan: Does the university have these devices?

Babsail: Currently, we have a laser cutter in our department. CNC & 3D printers exist in the FAB Lab, and we can use them through coordination with the administration.

Qattan: Do you know any other DDTs techniques?

Babsail: I know generative design and algorithmic design, parametric design and Data Mining.

Qattan: Do you support introducing DDTs to Saudi culture and architectural education?

Babsail: Absolutely.

Qattan: What are the reasons that make you support? Are we in urgent need?

Babsail: The main reason is the rapid technological development in the architecture field. The whole world will be linked digitally shortly, thus, there is no doubt introducing and using DDTs is fundamental now to Saudi society. Currently, students avoid using pens, but that does not mean neglect manual skills. The Department panel is always discussing whether to be fully digitalised or to balance between teaching basic manual skills (very valuable) then expose students to the digital world. We often start teaching manual skills in the first two years after that we start using computers. Design carries the sense that does not come by using the computers’ mouse and screen. I think hand drawings is a primary thing, you can teach a child how to walk, but you cannot teach him how to jump suddenly.

Qattan: If we talk about using computers to develop new skills set that, allow students to convert what is on the screen to 1:1 models. Therefore, they can make models, test them and develop very complex forms that depend on repetition and divergence. Do you think this a new stage of architecture design that we need it? Or we will keep focusing on manual skills in the first years, which is prevalent in Saudi universities?

Babsail: In our university, we are focusing on manual skills in the first year. In the second year, we start introducing computers through AutoCAD course.

Qattan: Your bachelor degree program lasts five years?

Babsail: Yes, five years, including a foundation year. There is pressure on us as a department and students.

Qattan: Do you think DDTs are a necessity to Saudi Architecture and architectural education now?
Babsail: I prefer to balance, I do not see DDTs as an absolute necessity. I think DDTs should be introduced to students in the last year. Before they move to practice, which may not be ready to accommodate these digital skills in design and construction. Our discipline is practical and must balance between the market deeds and what we are teaching at universities.

Qattan: Is using DDTs a necessity to architectural education and practice?

Babsail: Practice will not change unless generations are changed.

Qattan: Or architecture practice will reflect what education provide. So, after graduation, students in practice will start changing.

Babsail: True.

Qattan: Do you think using these techniques shows future, modernity, and improve the environmental and construction qualities?

Babsail: Yes. From your question, I understood that DDTs would help you to create or have a new sense.

Qattan: True.

Babsail: Digital architecture produced forms, geometries, structure and new construction materials. The new building materials will not be efficient unless they are used in digitally designed projects.

Qattan: Do you think DDTs are used in Saudi architectural education?

Babsail: As you have mentioned “Generative Systems,” no. But, we use computers.

Qattan: Have you heard that any Saudi university has adopted DDTs?

Babsail: No.

Qattan: Do you think Saudi architectural education plans’ include DDTs?

Babsail: As I mentioned earlier, we have new Saudi lecturer specialised in digital fabrication. We aspire to introduce DDTs in the coming years. Even as an introduction.

Qattan: As a department, have you planned to deliver some lectures about DDTs?

Babsail: No, but it will be a great idea to conduct seminars and then use them later in design studios.

Qattan: Why DDTs are not used in Saudi until now?

Babsail: I think this is due to lacking training, but not lacking awareness. For lecturers, they do not have enough time to learn and practise using these new techniques.

Qattan: Are we suffering a shortage in qualified lecturers?

Babsail: Yes, there is no Saudis specialises in this area, or very few.

Qattan: You have mentioned there is new Saudi specialised in digital fabrication working in your department, is he the first one specialised in technology in the department?

Babsail: Yes, he is the first person.

Qattan: Do you think DDTs are conflicting with Islam?

Babsail: No, there is no conflict with religion. DDTs are a tool or a way of design.

Qattan: Do you think we do not use DDTs until now because we do not trust its outcome?

Babsail: No, I think because we do not have specialists. Students will accept new technology, but they need qualified teaching staff and fabrication machines, as they are very important. In my view, if you introduce DDTs on screens, sense will be missing. It is necessary for students to make, see and feel the power and importance of these techniques.

Level 2:

Qattan: Currently, what design techniques are used in Saudi architectural education? Or in KFUPM?

Babsail: You will be surprised if I tell you that drawing desks are neglected. In our last studios’ renovation, we do not focus on providing drawing desks, as they are not often needed now. This is by virtue to design teachers. Now we have
fewer teachers using classic design techniques. Students can now present their work on the projector instead of print it out.

**Qattan:** Is Saudi architectural design still using computers as a drafting and montaging tool only?

**Babsail:** Currently, yes.

**Qattan:** Why?

**Babsail:** In short, there are no specialised teachers and curriculums.

**Qattan:** There is qualified cadre shortage?

**Babsail:** Yes.

**Qattan:** There is also curriculums shortage?

**Babsail:** Yes, basic courses do not exist.

**Qattan:** Do you think Saudi culture encourages or limits the use of DDTs?

**Babsail:** Saudi culture encourages and there will be great acceptance, particularly at the architectural schools’ level.

**Qattan:** How Saudi culture responds to new technology?

**Babsail:** It is an active and dynamic relationship. I do not see any responding problem. Using DDTs helps to discover new solutions and new architectural trends. Bad design can be made digitally or manually, in the end, DDTs is a tool that can be used positively or negatively.

**Qattan:** Good and strong point. Do you think any technical issues limit the use of DDTs? Such as programming languages and English language?

**Babsail:** Yes course, both of them need training. I will go back to what I have said technical problems stems from a lack of assisting courses and qualified cadre.

**Qattan:** Is the Saudi architectural environment ready to embrace these techniques?

**Babsail:** If there is a clear strategy, we are as a department ready to follow it.

**Qattan:** Is this limitation to courses only or including cadre and fabrication machines?

**Babsail:** None of them is existing now.

**Qattan:** Is Saudi architectural practice ready?

**Babsail:** Currently not ready. There are class (A) contractors how can build anything, but they are few.

**Qattan:** Currently there are 3-4 iconic buildings in Saudi designed by international architecture offices such as Zaha Hadid.

**Babsail:** King Abdulaziz Center for World Culture designed by Snøhetta and constructed by Saudi Binladen group.

**Level 3:**

**Qattan:** Why Saudi use foreign experts to design their projects digitally?

**Babsail:** We are not lagging behind, but the architectural environment is not ready.

**Qattan:** Do you think using foreign architects with DDTs skills is positive or negative to Saudi architecture, or positive, but we need to reconsider its cultural dimensions?

**Babsail:** I see that positively and not interfere with culture. In other words, culturally DDTs have no effect.

**Level 4:**

**Qattan:** We have a talk about the gap between Saudi architectural education and DDTs usage, you admit that culture does not have a role in this gap. We have also spoken of the architectural education role there is cadre and courses shortage.

**Babsail:** In terms of course, we can add a new course and call it Digital Design, but is there any qualified teacher?

**Qattan:** We have also talked about technical skills. The skills of using technology.
Babsail: Yes, that is part of the problem.

Qattan: Is there any other reason cause the gap? Some architects described it as a massive gap to the extent that you cannot see the second end i.e. DDTs. In other words, the gap is not exist.

Babsail: We are knowledgeable and confess there is a gap. However, there is a strong desire to use technology. The problem as I mentioned, there is no correlation between the issues’ ends i.e. teachers, computers and fabrication machines. But, financial support is the gap that might be the most difficult fill.

Qattan: Are decision-makers a reason?

Babsail: They might be a reason. There are obstacles such as space. Currently, the department is planning to renovate all software and hardware. However, our labs do not accommodate the new hardware. As mentioned, the gap exists because of teachers, computers, and fabrication machines shortage. Unfortunately, the only Saudi specialist in digital fabrication will leave us to do his PhD soon.

Level 5:

Qattan: What is the relationship between Saudi culture, Saudi architecture and architectural education?

Babsail: Each one of work alone. Unfortunately, this topic is very big and needs a long time to talk. Saudi architecture is losing its identity now.

Qattan: Is Saudi architecture losing its identity, because of the oil boom?

Babsail: Yes, at the same time, public does not understand what architecture is. I mean the vast majority think architecture is a box shape building where they can live, work or pray.

Qattan: You have mentioned that your students went to shopping malls to present their works, and this is a good step, Australian universities do the same.

Babsail: This is part of our department message, we want to get out to Saudi society and teach them what architecture means. Unfortunately, public architectural awareness is very simple, limited to spaces distribution and a good facade. While architecture is deeper than that, it is a culture, which reflects the community thinking.

Qattan: What is the relationship between Saudi architectural education and the use of DDTs?

Babsail: We are thinking to introduce them now, but we have a shortage in qualified staff.

Qattan: Do you think DDT is irrelevant and culturally threatening?

Babsail: I see the opposite side. By using these techniques, forms will become better. Designing buildings digitally does not mean you are abandoning your culture or values. There will be construction structure and spaces, which are very similar to any traditional building. Using DDTs could be beneficial and improve the old traditional techniques. We could discover that building with bricks and mud may have wider possibilities. I see that these techniques may add to traditional local architecture new style and value.

Level 6:

Qattan: What are the consequences of introducing DDTs to Saudi culture and Saudi architectural education?

Babsail: The introduction will be a step forward and affect positively. I do not think DDTs will conflict with Saudi culture.

Qattan: Do you think DDTs will encourage studies and research in this area in Saudi? Or we will be just users?

Babsail: We will take this field further. There will be a creative generation of architects and researchers in the near future.

Qattan: Do you think DDTs introduction will happen easily, with difficulty or will not happen?

Babsail: It would be easy if there were a desire. At the same time, we will face resistance, which makes the introducing difficult. That depends on the department or the college vision and objectives. We need time to change our teachers’ culture.

Qattan: How long will it take to change?

Babsail: To be realistic, we need five years. If we start from now, DDTs would be something normal.

Level 7:

Qattan: What are the opportunities to introduce DDTs to Saudi architectural education now?
Babsail: Opportunities are limited. In other words, opportunities exist, but they are not activated.

Qattan: What is the way or criteria to introduce DDTs?

Babsail: We need to work gradually by raising awareness and provide information, thus they will be accepted faster. We also need to provide qualified lecturers for students.

Qattan: What is the academics’ role?

Babsail: Their role is manifested in encouragement and not criticism. Initially, it would be normal to produce funny outcomes. Our role – as administration – is to support and develop courses teachers and to introduce assisting courses.

Qattan: What are the obstacles that will face us?

Babsail: Mainly, the qualified cadre. Honestly, the qualified teaching staff is the core. If you found specialists Professor, students and the whole department will be interested. The qualified teachers are the missing link.

Qattan: Are we suffering an infrastructure problem?

Babsail: Our infrastructure has not improved for a long time. Despite all universities in Saudi do not face a problem with providing computers, the problem remains in the qualified cadre.

Qattan: After introducing DDTs, is Saudi Digital Architectural Style possible?

Babsail: I wish. This style would combine traditional Saudi architecture and the new DDTs. Famous architects such as Zaha Hadid, Frank Gehry, Norman Foster and others have used these techniques as a tool, so it is possible for us to use the same tool as well. We must learn who to respect culture in design and how to reflect our architectural identity.

Qattan: Thank you, questions finished. Do you have any questions?

Babsail: After you finish your research, are you going to do seminars? Do you think to put the basis/foundation of this trend in your university?

Qattan: Yes, I will go back to the architecture department at Umm Al-Qura University with new approach and way of thinking. I am planning to introduce a new studio focuses on using DDTs. I also suggest focusing on strengthening programming and mathematical skills among architecture students.

Babsail: Thanks for having me.

Qattan: Thank you for your time.
Appendix 3: Interview with computer science students (example)

Today I am interviewing Saud Nassir, a Ph.D. candidate in Computer Science at University of Technology, Sydney. He did his Bachelor degree in 2012 and Masters in 2014 at University of Technology, Sydney.

After introducing my study, its goals and significance, in summary, let us start the questions.

Group 1:

Qattan: How did you study programming?

Nassir: To study programming you need a guide whether it is a lecturer, tutor or online course. Someone to guide you because you cannot start programming on your own, you may learn the basics but may miss on industry practice and even how to design your code and write it in an efficient, reusable way. In other words, programming requires styles and things that you may not be able to find in textbooks.

Qattan: How long does it take to be a good programmer?

Nassir: To learn programming it does not take much time, but to be a good programmer you need to work on a lot of projects. To be fully able to program you need from six to eight months to find you way around. You will not necessarily know everything, but you will know how to find help if you require any.

Qattan: During your study, how many programming courses you had?

Nassir: I did Visual Basic first, and I studied it for about three months. I did Java 1 (Programming Fundamentals) for a semester. Then I did Java 2 (Application Programming) for another three months. There are also some other programming courses related to network and internet programming such as C++, PHP, Java script, HTML, and CSS. They are about eight to nine courses. These courses pretty much allow you to do what you want.

Qattan: What you need in terms of other knowledge?

Nassir: English is a very important in programming, for example, if you made a spelling mistake the program would not run. If you want to work with a formula that goes beyond normal calculation, this will require you some mathematical skills. In one of the courses I have done, I did the Opera House using scripting in OpenGL. That required a lot of maths, and my maths foundation was not very good at that time. It took me about two months to get my head around and get the script working. In terms of programming languages, you need basic English and knowing the structure/logic of the language itself.

Qattan: Do you learn at university just one programming language and then you self-learn whatever you want?

Nassir: At university, I have learned about six languages, but once you learned the basics you will learn everything else if you want to. You need to learn the basics and how and where to get help. If you get the basics, you can learn other languages with ease.

Qattan: What are the difficulties that you found as a Saudi student?

Nassir: I have faced some difficulties such as understanding the terminology that the lecturer was talking about. He used a lot of terms that I would not understand, or take me a long time to understand, for example, I have not understood some terms until the next module of the course which is the following semester. The other thing was spelling, but some languages like Java has a debugger to fix spelling mistakes.

Qattan: Do you think learning programming is something should be done in high schools?

Nassir: Yes, in Saudi they do at high schools, but roughly. They do only Visual Basic.

Group 2:

Qattan: Because you have done your Bachelor and Master degrees here in Australia, I cannot ask you about Saudi computer science faculties. Therefore, we will skip this section.

Group 3:

Qattan: Have you ever thought that architects are using programming languages in architecture design?

Nassir: Yes, I know that architects are using programming to design.

Qattan: What you think the difficulties that will face architecture students to program to design?
Nassir: May be learning programming skills itself. It requires different knowledge compare to what they do. What you want to do is moving them form architecture design environment to a programming environment is very hard. It is like doing two disciplines at the same time.

Qattan: What you think the reasons that prevent using programming in architecture?

Nassir: I think because of the variety of architectural software; architects need to learn how to master using these software plus using their programming languages. For example, you need to learn how to use Rhino and Python or Maya and Maya Scripting.

Qattan: Do you think teaching scripting within design studio is a good idea?

Nassir: It could, but within the design studio, there is not enough time to teach architects a scripting language. They will struggle a lot. The best way is teaching scripting in a separate subject running at the same time with design studio; especially if you have IT staff teaching. That means that you have access to different set of resources when needed, and also, it allows you to think of how to apply knowledge from both subjects into a project that may take in the following semester.

Group 4:

Qattan: Do you think there is cultural aspect that would prevent programming or make it difficult?

Nassir: As Saudis, we are good at outsourcing (using foreign workers or companies) rather than doing the work ourselves. The thing is about using foreign workers than investing in local talents which minimise the enthusiasm among Saudis.

Qattan: Is there any cultural reasons to make Saudi students avoid studying programming?

Nassir: I think there are no cultural reasons that make students avoid doing programming. I think it is for educational reasons. We have an issue with the English language even we do English in high schools. The other thing is difficulties and confusion in terms of learning many languages.

Group 5:

Qattan: Is it possible to use computer science departments to teach programming to architecture students at Saudi universities?

Nassir: Yes, and no, the computer science departments’ lecturers can teach architects students, but they need to aware of architecture design principles. The need also to how to use certain software like Rhino and Maya. It is different to use Python in computer science from using it in architecture design.

Qattan: Is programming in architecture different?

Nassir: Yes, although the basics of programming languages are the same, they are different.

Qattan: What are the potential difficulties that will face programming languages lecturers when they teach architecture students?

Nassir: They will face difficulties with programming languages first. Second, the will face a problem with time because you have only four years to learn two different disciplines. It could be a double major degree architecture plus IT for an extra year. There is a gap between IT tutors and architecture students. The gap is about applying the same knowledge in different disciplines. The IT lecturer can tell architecture student how to use programming languages, but he might not able to know how architects will make benefit of it. They are both using different terminology and references. I think it is better to have an architect who is a specialist in programming to teach architecture students.

Qattan: Questions finished, thank you for your time.

Nassir: Thank you, all the best.
Appendix 4: Permission to conduct interviews at Saudi university (email example)

Permission to Conduct Interviews at your department.

Wajdy Qattan <wajdyqattan@gmail.com> 14 August 2013 12:44
To: mbabasail@kmitl.edu.sa

Hi Dr. Mohammad,

My name is Wajdy Qattan, I'm a Saudi student doing my PhD research at University of Technology Sydney in Australia. I'm about to start my PhD thesis under the title "Architectural Creativity and the Role of New Design Technology (Case Study Saudi Arabia)". As a part of my data collection, I need to conduct some interviews with some people (staff & students) from your department. What I need is your permission to do those interviews to get the ethics approval from my university here in Sydney. Here is some information about my research:

The study Summary:
The argument in this Study is how new Digital techniques impact creativity in architecture in relation to specific culture (the Saudi Arabian culture), especially in the way it affect staff and student in Saudi universities. And introduce this idea to the Saudi universities as a new way of thinking and designing in architecture. Then test its implications in relation to the restrictions of the traditions and conventions of this culture. Also, what are the ethical and requirements to apply this idea in certain culture in specific time?

Why the study is important?
The current tendency is to produce new, novel and different architecture using the digital techniques, which are developed to change the way of thinking and designing. However, cultures are one of the main factors that have a profound impact when introducing new technological designing techniques. If we looked at different cultures we need to know what is appropriate, to how far and what are the benefits of the outcomes to these cultures.

The purpose of the interview:
Firstly, it's an important part of the study methodologies. Secondly, is to collect data based on how staff and students in Australia and Saudi Arabia perceive, use and develop technological design techniques. Finally, what is the cultural role in embracing these techniques?

It is easy to give the permission, just reply to this email with either the permission or any further questions and concerns.

Kind Regards,

Wajdy Qattan
Master of Islamic Architecture
Master of Advance Architecture in Design Technology
Saudi Arabia
P.O.Box:12004 Makkah, zip code: 21965
mob: +966 5 009 700 70
Australia-Sydney
230/66-60 small street,
Unikre NSW 207
mob: +61433291816

Mohammad Babasail <mbabasail@kmitl.edu.sa> 18 August 2013 06:04
To: Wajdy Qattan <wajdyqattan@gmail.com>

Dear Mr. Qattan,

Thank you for your email and explanations.
I think this study is wonderful as the debate always goes whether digital tool can really promote creativity in design.

Therefore, permission is granted and I do hope to meet with you once you are around in Dhahran to undertake your exercise.

Best Regards,

Mohammad O. Babsail | Ph.D.
Chairman, Architecture Department
College of Environmental Design

KFUPM
Dhahran, Saudi Arabia

t: +966 (3) 860-3591
f: +966 (3) 860-3210
e: c-arcd@kfupm.edu.sa
mmbbsai@kfupm.edu.sa
Appendix 5: Information sheet for interviewees

**PRINTED ON UTS (and/or joint) LETTERHEAD**

INFORMATION SHEET

Saudi Culture and the Introduction of Digital-design techniques (DDTs): Influences and Interactions.

WHO IS DOING THE RESEARCH?

My name is Wajdy Qattan and I am a student at UTS. (My supervisor is A/Prof Stephen Harfield)

WHAT IS THIS RESEARCH ABOUT?

The study will investigate Saudi cultural constructs in relation to using DDT, and how the latter (i) relates to certain cultural and educational aspects, (ii) influences ways of thinking and processes of designing, and (iii) potentially moves architecture forward within Saudi. The study then moves to analyse the particularities of Saudi culture and architectural education as the direct source of contemporary Saudi architecture. In order to achieve that, the study will focus on the important factors that led to the current Saudi cultural system, observing its background since the unification of the Kingdom of Saudi Arabia in 1932. It also questions the relationship between the cultural background and current Saudi architecture and architectural education, as well as the cultural and educational aspects that prevent or challenge the use of DDT.

IF I SAY YES, WHAT WILL IT INVOLVE?

I will ask you to do an interview which will take approximately 45-60 mins.

ARE THERE ANY RISKS/INCONVENIENCE?

There are very few if any risks because the research has been carefully designed. However, it is possible that there might be inconvenience, such as your time.

WHY HAVE I BEEN ASKED?

You are able to give me the information I need to find out about the Saudi cultures and the potential DDTs’ introduction, and the possible influence and intercations.

DO I HAVE TO SAY YES?

You don’t have to say yes.

WHAT WILL HAPPEN IF I SAY NO?

Nothing. I will thank you for your time so far and won’t contact you about this research again.

IF I SAY YES, CAN I CHANGE MY MIND LATER?

You can change your mind at any time and you don’t have to say why. I will thank you for your time so far and won’t contact you about this research again.

WHAT IF I HAVE CONCERNS OR A COMPLAINT?

If you have concerns about the research that you think I or my supervisor can help you with, please feel free to contact us on wajdy.s.qattan@student.uts.edu.au and Steve.Harfield@uts.edu.au or by phone on +61 2 9514 8848 and +966 2 527 00 12, or you can contact Jameel Alsalafi at the Architecture faculty at Umm Al-Qura University at +966 2 527 00 12 or arc_jms@msn.com

If you would like to talk to someone who is not connected with the research, you may contact the Research Ethics Officer on 02 9514 9772, and quote this number 2013000500
Appendix 6: Consent form

CONSENT FORM

I __________________________________ agree to participate in the research project Saudi Culture and the Introduction of Digital-design techniques (DDTs): Influences and Interactions, (UTS HREC approval reference number 2013000500) being conducted by Wajdy Qattan a Phd Student at the University of Technology, Sydney __ supervised by A/Prof Stephen Harfield, Steve.Harfield@uts.edu.au and wajdy.s.qattan@student.uts.edu.au or by phone on +61 2 9514 8848 and +966 2 527 00 12 __ for his degree, Doctorate of Philosophy.

I understand that the purpose of this study is to find out the relationships between DDTs, Saudi culture, architecture, and architectural education, and the potential influence and interactions.

I understand that I have been asked to participate in this research because I’m able to give information that help to find out the aforementioned relationships, and that my participation in this research will involve an interview that may take about 45-60 mins.

I am aware that I can contact Wajdy Qattan or his supervisor A/Prof Stephen Harfield if I have any concerns about the research or I can contact Jameel Alsalafi at the Architecture faculty at Umm Al-Qura University at +966 2 527 00 12 or arc_jms@msn.com. I also understand that I am free to withdraw my participation from this research project at any time I wish, without consequences, and without giving a reason.

I agree that Wajdy Qattan has answered all my questions fully and clearly.

I agree that the research data gathered from this project may be published in a form that may identify me.

I agree to be identified for this project Yes / No

________________________________________  ____/____/____
Signature (participant)

________________________________________  ____/____/____
Signature (researcher or delegate)

NOTE:

This study has been approved by the University of Technology, Sydney Human Research Ethics Committee. If you have any complaints or reservations about any aspect of your participation in this research which you cannot resolve with the researcher, you may contact the Ethics Committee through the Research Ethics Officer (ph: +61 2 9514 9772 Research.Ethics@uts.edu.au) and quote the UTS HREC reference number. Any complaint you make will be treated in confidence and investigated fully and you will be informed of the outcome.
Appendix 7: Seminar and workshop outline

Digital Designing Techniques (DDTs) & Saudi Architecture
INTRODUCING & UNDERSTANDING

Today’s Schedule is:

1. Seminar:
   1.1 DDTs Background.
   1.2 DDTs’ Theories.
   1.3 DDTs’ Frontiers.
   1.4 DDTs as multidisciplinary trend.
   1.5 Common design and fabrication methods.
   1.6 Using DDTs.
   1.7 Scripting (Rhino Python).
   1.8 Recent examples.
2. DDTs introductory Workshop.
3. Your feedback.

2. The workshop outline:

1. Introducing Python as scripting language.
2. Some basic and simple examples of using Python.
3. Design project (TV, Radio, and Internet Building).
4. Introducing Grasshopper as Scripting alternative.
5. Important Scripting books and references.
Appendix 8: Seminar and workshop transcript

Hi everyone,

My name is Wajdy Qattan (WQ); I am a Ph.D. candidate at University of Technology, Sydney.

Today we have seminar and workshop titled “Digital-design techniques (DDTs) and Saudi Architecture: introducing and understanding”. Directed to you as Saudi architects studying at Sydney’s universities (overseas). This seminar and workshop are part of a research project to investigate DDTs’ implications on Saudi culture, architecture, and architectural education through your feedback. As any research procedure, I need to get your consent to use all the information that has been delivered during today’s event.

Today we have:
Mohamad Qattan, master student at the University of Sydney. (MQ)
Saaed Bargawi, a Ph.D. candidate at the University of Sydney. (SB)
Sabri Khibari, Master student at University of Technology, Sydney. (SK)
Salah Gamdi, master student at the University of Sydney. (SG)
Trad Benabood, Master student at University of Technology, Sydney. (TB)
Wajdy Atwa, Master student at University of Technology, Sydney. (WA)

The seminar and workshop schedule:

1. **Seminar:**
   1.1 DDTs Background.
   1.2 DDTs’ Theories
   1.3 DDTs’ Frontiers.
   1.4 DDTs as a multidisciplinary trend.
   1.5 Common design and fabrication methods.
   1.6 Using DDTs.
   1.7 Scripting (Rhino Python).
   1.8 Recent examples.

2. **DDTs Introductory Workshop.**

3. **Your feedback.**

After we have finished the seminar and workshop, I need your feedback and reflection upon the discussed topic.

TB: it is very interesting and fundamental topic. It is needed in Saudi universities; Saudi architecture students need to be exposed to these techniques right from the start. Exactly like what is happening here at UTS.

*WQ: I would like to start with: What we know about DDTs in Saudi?*

TB: Not too much.

WA: Nothing, in Saudi we know how to use AutoCAD, 3D MAX, and Rivet.

SB: I think the software exists there in Saudi, but the problem is utilising them correctly. For example, AutoCAD 13 was entirely script.

*WQ: But, there were no other options, AutoCAD 13 was the only available technique.*

SB: Exactly, I’m talking about the way Saudi students using this software. Besides, Saudi universities do not provide advanced and licensed software to its students.

*WQ: Using computers to design, I think is the missing point in Saudi architecture.*
SB: Recruiting the software to serve your design is the point.

TB: I think the Saudi practice needs is the problem, most of the Saudi projects focus on rectangular forms, not curvy ones. Compare to Western countries, they are open minded and having a future vision. That is why they invent this kind of software; they have this kind of architects who can write a script and use it to serve architecture goals.

SK: For me, the relationship between the form and the function is fundamental. For sure, using digital techniques offer wider possibilities.

WQ: Using DDTs can serve form and functions at the same time. You can control this relation.

SB: Why to use DDTs?

WQ: As I have mentioned in the seminar, some scholars assert the importance of using DDTs.

SG: I think to use these techniques you need to conceive the final building form.

WQ: Using these techniques in architecture design is the same as using any other techniques. You start by placing your ideas on paper and then develop them using computers.

TB: I think computers in architecture are used for drawing and montaging, only to do the final product.

WQ: With DDTs the difference is, you can use the computer to think with you and to do tasks that you cannot do or consume time and effort.

SG: For example, Rivet offers you some suggestions to help you in the design process.

TB: Yes, SG is right.

WQ: Rivet is different that DDTs, Rivet is Building Information Modelling (BIM), is a different school.

TB: What about Rhino?

WQ: Rhino is design software.

TB: Can we combine the two software?

WQ: Of course, you can, if you know how to do that. Indeed, you need to be skillful in using this software.

SG: From a private sector view, why I need to use these techniques? How much it will cost me to use these techniques and do I need to train my architects to use them?

WQ: We will discuss this later.

MQ: It is my first time to hear about DDTs.

SG: Me too.

TB: I do not know anything about DDTs until I came to here (UTS).

SB: are you asking about the software or the technology? In Saudi, we are using technology in architecture, but not in design.

WQ: How we would know about DDTs in Saudi?

TB: As an initiative, we need to import experts to teach us; also, we need to insert new subjects in Saudi architectural education.

SK: I do remember when Rivet is first introduced at King Abdulaziz University there was a cooperation between the Rivet representative in Saudi and the University.

WA: We need to introduce DDTs through universities’ workshops.

WQ: We can say that Saudi architectural education is the best to initiate this introduction.

MQ: In Saudi, I think we need to start with individual initiatives. The reason is that private sector does not trust these techniques from the start, if its revenues will not reach 90% or the risk is very high, we will not use them.

SB: The same story happened with introducing GIS software. GIS first introduced in Saudi in 2000 but do not become prevalent until 2004 when it finds a good marketing and advertisement.

SG: I would like to ask, is there any comparison studies between these techniques?
WQ: There are a huge number of studies show the benefits and the power of using these techniques. Moreover, how these techniques will help us to optimise buildings performance and forms to be more environmental friendly.

SB: Are all the presented examples are designed digitally?

WQ: Referring to the designers’ websites, they mentioned these designs are made using digital techniques. They do not specify the exact techniques that been used in the design processes.

SG: I think you cannot enforce Saudi universities to introduce these techniques. Unless initiative comes from the faculty dean side or the head of the architectural department. That also apply to privet sector, unless the client asks to use them.

WQ: This is true, most if not all the present examples are designed by international architecture offices under a request from Saudi government or private sector to be designed digitally. However, in what level we need to introduce DDTs? Low, mid, high?

WA: We need to introduce them gradually until we reach a higher level.

MQ: We need to start from the end, which means we need to show our students the outcome of DDTs and then start teaching them to reach the outcome’s level. That will push the student to learn and boost their motivations.

TB: This could negatively affect students especially if they have been told how hard is to use computers this way. They will be disappointed and less motivated.

MQ: If we started from top to bottom, the percentage of enthusiasm would be greater than disappointment and more students will learn. We are going to make a radical change, and this will be difficult.

WA: In terms of education, DDTs will be fine, but in terms of practice and constructing real buildings, nobody will accept them. Because, reality requires basic forms, which can be built.

WQ: We need to rethink that DDTs can produce highly sophisticated forms and primary forms as well. As I mentioned in the seminar, Kolarevic (2004) claims that using DDTs could produce curvilinear ‘blobby’ or rectilinear ‘boxy’ forms.

SG: If I want to make a simple design, I will use AutoCAD much easier for me. I do not need to use DDTs in this case; also, the cost will be much higher.

WQ: Yes, true, but you cannot optimise your design to reach its optimum level. Using these techniques allow architects to achieve the optimum levels of form and cost.

SB: If you are talking about Rhino and how many years we need to introduce it? I would like to ask to what extent there is a demand for it in Saudi.

WQ: I am not talking about introducing Rhino, I am talking about introducing any digital design techniques will move us from A to B. However, how many years we need to introduce DDTs?

TB: If we have a plan to follow, this will not take more than one year.

SK: I think we need five years.

WA: We need more than five years; I guess we need from 5 to 8 years.

MQ: We need more than eight years, no less than ten years.

SB: Ten years are too much, we need 5-7 years, and then DDTs will become something normal.

SG: I do not think we need time (years), but we need to see a reasonable number of constructed buildings – designed digitally.

WQ: introducing DDTs compulsory vs optional

WA: I think compulsory is better.

TB: Compulsory to improve and optimise the educational outcome.

SK: I prefer optional.

MQ: Compulsory is the best way to go, and this will force Saudi practice to change.

SB: If we are talking about creativity, we need to make DDTs introduction something optional.

SG: DDTs are just a tool, so everyone can choose the tool he likes.
**Q:** It is hard for all of us to agree with the same point. We do not know about the private sector if they are using DDTs or not, but if make the introduction compulsory through universities, will that affect the private sector?

**MQ:** Yes, 90% private practice will be affected, because universities will produce this kind of architects who can use DDTs.

**TB:** This will change Saudi practice as all Saudi graduates are DDTs skilled.

**WA:** If it is optional, this will not change the practice. For example, here in Sydney, you will not find a job if you do not master Rivet. At the same time, Rivet is not a compulsory subject at the University.

**SG:** At the end of the day, the client is the only one how can control practice. What the client want is what the practice need to meet and use.

**Q:** Universities vs private teaching? Because DDTs is hard for the student for their first time, are they going to use private teaching, university academics or do it themselves?

**SG:** This will make no difference, the most important thing is learning these techniques.

**SB:** Most of the computer skills teaching classes do not offer more than 20%, and the rest is the student duty.

**MQ:** This acutely relate to the students themselves, it is not the university responsibility. There are students who want to improve themselves and learn whatever the circumstances are, and there are others who want just to pass the course whatever the way is.

**WA:** Students can decide that if they have the desire, they will learn. I totally agree with SG.

**TB:** Still academics must have a role in teaching process, if they are not good in DDTs, they will not deliver useful knowledge to students.

**SK:** I think combining private and university teaching is the best way to introduce DDTs. That is what happened when Rivet was first introduced at King Abdulaziz University.

**TB:** Yes, a collaboration between private and university teaching is the best way.

**Q:** What about Self-Learning it will work in Saudi?

**MQ:** Totally will not work.

**TB:** As Bachelor students’ establishment, self-learning will not work.

**SK:** Saudi students need someone to follow-up them.

**WA:** Yes, I agree with SK, the teaching theme is spoon-feeding. Self-learning will not work.

**SB:** This not fair, there are some students who are willing to self-learning, although the prevalent teaching style is feeding.

**SG:** If the self-learning is the standard method used in Saudi university education, yes it will work.

**Q:** If self-learning will not work, what should universities and government do?

**TB:** In that case, we need a plan/framework to follow to make this introduction happen. We also need to send students overseas to gain this knowledge.

**SK:** We need also marketing to make sure that the idea of DDTs reaches every architect in the country. We need some architects who are in a power position, those who can make an impact on all levels (education, government, and practice). The individual approach is very effective.

**WA:** We need a framework to follow. It could include seminars and workshops.

**MQ:** I think education and government need to work together to achieve smooth introduction.

**SB:** This depends on the decision-maker power and personality. Each architect who is in this position will make a change. If his approach is using DDTs, he will change and make a plan to change. Why? Because he wants to make this change happen.

**SG:** If DDTs are imposed as SB said (agree with that), it should go gradually and smoothly. DDTs should be introduced in workshops at the beginning and then become part of design studios.

**Q:** What about architects and public perception (understanding), as we see DDTs require math and scripting skills.
SK: This will be encountered with difficulty.

WA: For the first time, it will be difficult as any new thing. The smooth introduction is recommended, and I assert on avoiding difficulty shock.

SB: Architects will understand DDTs importance, but public will face a confusion. According to a study was done by Urban Development Architecture Office owned by Abdulaziz Kamel, in terms of introducing a new style of housing style Saudi society is divided into three section 60% will as to get their houses’ design exactly like someone else – usually a friend. 20% prefer to wait for anybody to try and then ask them about their experience. The other 20% are willing to take the risk of trying something new. You need to find those who are willing to take the risk to introduce DDTs to public successfully.

SG: Architects and public are different. As an architect, I need to understand DDTs software and in what aspects they will help me. Of course, they will help in designing complex forms, but in basic forms, there is no need to take the headache of learning sophisticated programming languages. Public usually ask for simple and easy to build forms, if it happens it will be with mega projects and landmarks buildings.

WQ: What about cultural restriction and trusting DDTs outcome

TB: If we see DDTs outcomes in a way we saw them in KAFD buildings, there will be absolute acceptance and less cultural restriction.

WQ: We have some fundamental cultural restrictions such as separating male and female. We can see that in KAFD Men’s and Women’s Portal Spas by WORKSBUREAU.

TB: DDTs will not change our cultural condition, but will change our way of doing architecture, and to keep pace with what is happening in the other world.

SK: I feel there will not be cultural restrictions. DDTs will succeed to meet our cultural needs.

MQ: I think cultural restriction will control DDTs’ outcome and the way of using them.

WA: DDTs are merely a tool; thus designers can use them to match their local requirements.

TB: We need to use DDTs to preserve our architectural heritage or to modernise this heritage.

SB: DDTs will not affect our culture. They will be used to serve Saudi society’s desires.

SG: DDTs will have no impact on culture, but the culture will form DDTs to suit its conditions.

WQ: Do expect a cutting-off restriction?

MQ: Possible, if DDTs are conflicting with decision-makers interest.

SK: Possible in one case, if DDTs interfere with some religious affairs, and that will not happen at all.

SB: Possible if DDTs conflict with the decision-makers’ approach. In other words, “conflict of interest”. For some students, designing complex or curvy forms is something undoable, because they do not know how to draw them using computers.

WA: The current cutting-off restriction is our ignorance of DDTs. If we introduce them, we can modify them to fit our needs and restrictions.

SG: Cutting-off rejection is not a disadvantage this will promote diversity. For academics and students, they do what they know. They avoid complex forms because they do not know how to do them using Rivet.

TB: The only restriction will be the conflict of interest.

WQ: What about difficulties and opportunities of introducing DDTs?

SK: All opportunities are available, and the evidence is the examples you have showed us.

TB: Yes, this is true, but we need to invest in educating Saudi architects to be able to use these techniques.

MQ: Difficulties are manifested in the rejection of DDTs from a decision-maker who do not understand DDTs, its importance and the way they work.

WA: I think changing to something new and unknown is a significant difficulty.

SB: There will be no difficulties at all. Introducing DDTs is like any techniques that have been introduced before. Possible to continue or disappear.
SG: Difficulties will be three folds (1) is the qualified trainer, (2) financial difficulty to buy licensed software, (3) marketing difficulty.

WQ: Antagonists and conflict of interests? Academics, students and universities OR culture, practice and universities?

SB: In practice, there is no conflict, as many the client pay as much the architecture office will work, no matter what techniques are used or the client asks for.

SG: Conflict is something positive, it will promote competition and diversity.

WA: Yes, this is true and will increase productivity.

MQ: This will offer more options as well.

TB: It is difficult to force someone to use a particular technique. The conflict you are talking about is something normal.

SK: The only fear is if the conflict happens with decision-makers. I am afraid if this conflict causes DDTs rejection.

WQ: What about local and international architects?

SG: Are talking about introducing DDTs to Saudi society or Saudi architectural education?

WQ: I am talking about introducing DDTs to Saudi culture, architecture, and architectural education.

SG: If DDTs introduction will happen on the national scale, there is no difference if the building is designed by a local or international architect.

WQ: Is local architects can produce better/suitable buildings that international architects?

MQ: I think using local architects is better, as they are part of the culture and know its restrictions and requirements.

WQ: What about providing equipment and infrastructure.

TB: We will not face any difficulty in offering equipment and infrastructure.

WA: Yes, totally agree.

MQ: Maybe in the beginning and until architects and decision-makers convinced.

WQ: How much did the seminar and workshop add to you?

SK: It adds to my knowledge, my information about DDTs were not clear.

WA: I was wondering, how they made these complex forms. I do not know about scripting in architecture design; I know only about Grasshopper.

MQ: Today’s seminar and workshop 100% add to my information, I do not know anything about DDTs before today.

SB: To be honest it adds to my information, but not that much.

SG: For me I only know how to use AutoCAD, Rivet, and some popular software. DDTs are new knowledge for me, and I wish to see them at Saudi universities.

TB: I know about Grasshopper, but not using scripting to produce forms.

WQ: Thank you very much this is all for today. If you have any question, please ask?

SG: What you mean by fabrication and tectonic?

WQ: I mean, when material, structure and architecture form work together in the design process.

WQ: Again thank you for attending.
Appendix 9: Interview transcript validation email (example)

[Image of a Gmail inbox]

**Interview Validation**
2 messages

Wajdy Gattan <wajdygattan@gmail.com> 17 August 2015 at 22:23 To: Saud Nassir
<alhaa27@hotmail.com>

Hi Saud,

This is an inquiry email regarding your interview. As a research validation process, the researcher needs to contact the interviewee to check their interview’s transcript after being typed. Thus, could you please read your interview transcript, and reply to this email your opinion and view regarding the information i.e. do you agree or disagree? Is the information correct?

The interview’s transcript file is attached.

Kind Regards,

Wajdy Gattan
PhD Candidate @ University of Technology Sydney, Saudi Arabia
Po Box 12004 Mail, 21955, mob: 4614085, 461432389016

Saud Nassir <alhaa27@hotmail.com> 26 August 2015 at 18:30 To: Wajdy Gattan <wajdygattan@gmail.com>

Hi Wajdy,

Sorry for the late prompt.

Please find attached interview transcript. I’ve made few changes but as far validity I’m happy with it. The information provided reflects my own opinion :)

Regards, Saud

Date: Mon, 17 Aug 2015 22:23:52 +0300
Subject: Interview Validation From: wajdygattan@gmail.com To: alhaa27@hotmail.com

[Attachement: Saud Nassir_01.docx]
Bibliography


Bentley, P. 1999, Evolutionary design by computers, Morgan Kaufmann, San Francisco.


296
Dar Al Hekma University 2015, School of Architecture, viewed 21/06/2015,

Dar Al Uloom University 2015, School of Architecture, viewed 21/06/2015,


DeRose, K. 2005, 'What is epistemology', A Brief Introduction to the Topic. Yale University, Department of Philosophy.


Dunn, N. 2012, Digital fabrication in architecture, Laurence King.


Effat University 2015, School of Architecture, viewed 21/06/2015,
<http://www.effatuniversity.edu.sa/Pages/Homepage.aspx>.


Actar-D, Barcelona ; New York, pp. 211-239.


Leach, N. 2004, 'Swarm tectonics', in N. Leach, D. Turnbull & C.J. Williams (eds), Digital tectonics, Wiley-Academy, Britain, pp. 70-77.


Leach, N., Turnbull, D. & Williams, C.J. 2004, Digital tectonics, Wiley-Academy, Britain.


Lynn, G. 2004b, Folding in architecture, Rev. edn, Wiley-Academy, Chichester, West Sussex; Hoboken, NJ.


Menassa, C. & Kulby, D. 2012, 'To blob or not to blob that is not the question', in A. Agkathidis (ed.), Computational architecture, BIS Publishers, Amsterdam, pp. 70-73.


Umm Al-Qura University 2015, School of Architecture, viewed 07/07/2015, <https://uqu.edu.sa/engineering-architecture-en>.


Arch. Wajdy Sadagh A. Qattan

Doctorate of Philosophy, Digital Design Techniques.

Master of advanced architecture in design technology.

The University of Technology Sydney, Australia, Sydney.

Master of Islamic architecture.

Bachelor of Islamic Architecture.

Umm Al Qura University, Kingdom of Saudi Arabia, Makkah.

wsqattan@uqu.edu.sa

wajdyqattan@gmail.com