Active BIM with Artificial Intelligence for Energy Optimisation in Buildings

by

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Certificate of Original Authorship

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 part of the collaborative doctoral degree and/or 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.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

2D CAD	2 Dimensional Computer Aided Drawing
3D	3 Dimensional
AC	Air Conditioning
AI	Artificial Intelligence
API	Application Program Interface
ANN	Artificial Neural Network
ASCE	American Society of Civil Engineering
BIM	Building Information Modelling
CDA	Conditional Demand Analysis
CDE	Common Data Environment
CFD	Computational Fluid Dynamic
DBLink	Database Link
DT	Decision Tree
EED	Energy Efficient Design
EU	European Union
GA	Genetic Algorithm
GB	Green Building
GBS	Green Building Studio
GHG	Greenhouse Gas
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and Communication Technology
IES	Integrated Environmental Solution
IFC	Industry Foundation Class
IFP	Implication for Practice
IT	Information Technology
IS	Information System
LEED	Leadership in Energy and Environmental Design
LoD	Level of Development
MLP	Multilayer Perceptron
MSE	Mean Square Error
ODBC	Open Database Connectivity
POS	Particle Swarm Optimisation
RC	Reinforced Concrete
SVM	Support Vector Machine
TMY	Typical Metrological Year

PhD Publications

S. Banihashemi, G. Ding and J. Wang. 2017. BIM and Energy Efficient Design: 10 Years of Review and Analysis. Journal of Renewable and Sustainable Energy Reviews, Elsevier (under review).

S. Banihashemi, G. Ding and J. Wang. 2016. Developing a Hybrid Model of Prediction and Classification Algorithms for Building Energy Consumption Optimisation. Energy Procedia, Elsevier, Volume 110, pages 371-376.

S. Banihashemi, G. Ding and J. Wang. 2016. Identification of BIM-Compatible Variables for Energy Optimization of Residential Buildings: A Delphi Study. 40th AUBEA, Cairns, Australia. July 6-8, 2016.

G. Ding and S. Banihashemi. 2016. Carbon and Ecological Foot Printing of Cities. Sustainable Energy Technologies, Encyclopaedia of Sustainable Technologies, Elsevier, Volume 2, pages 43-51.

S. Banihashemi, G. Ding and J. Wang. 2015. Developing a Framework of Artificial Intelligence Application for Delivering Energy Efficient Buildings through Active BIM. COBRA, Sydney, Australia. July 8-10, RICS 2015.

Abstract

Using Building Information Modelling (BIM) can expedite the Energy Efficient Design (EED) process and provide the opportunity of testing and assessing different design alternatives and materials selection that may impact on energy performance of buildings. However, the lacks of; intelligent decision making platforms, ideal interoperability and inbuilt practices of optimisation methods in BIM hinder the full diffusion of BIM into EED. This premise triggered a new research direction known as the integration of Artificial Intelligence (AI) into BIM-EED. AI can develop and optimise EED in an integrated platform of BIM to represent an alternative solution for building design. But, very little is known about achieving it. Hence, an exhaustive literature review was conducted on BIM, EED and AI and the relevant gaps, potentials and challenges were identified. Accordingly, the main goal for this study was set to optimise the energy efficiency at an early design stage through developing an AI-based active BIM in order to obtain an initial estimate of energy consumption of residential buildings and optimise the estimated value through recommending changes in design elements and variables.

Therefore, a sequential mixed method approach was designated in which it entailed conducting a preliminary qualitative method to serve the subsequent quantitative phase. This approach was started with a comprehensive literature review to identify variables applicable to EED and the application of a three-round Delphi to further identify and prioritise the significant variables in the energy consumption of residential buildings. A total of 13 significant variables was achieved and factualised with simulation method to first; generate the building energy datasets and second; simulate AI algorithms to investigate their functionality for energy optimisation. The research was followed with developing the integration framework of AI and BIM; namely AI-enabled BIM-inherited EED to optimise the interdisciplinary data of EED in the integration of BIM with AI algorithm packages. Finally, the functionality of the developed framework was verified using a real residential building and via running comparative energy simulation pre and post-framework application (baseline and optimized case). The outcomes indicated around 50% reduction in the electricity energy consumption and 66% saving in the annual fuel consumption of the case study.

Enhancing BIM applicability in terms of EED optimisation, shifting the current practice of post-design energy analysis, mitigating the less integrated platform and lower levels of interoperability are the main significant outcomes of this research. Ultimately, this research heads

toward the higher diffusion levels of BIM and AI into EED which contributes significantly to the current body of knowledge and its research and development effects on the industry.