UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Application of a Deep Learning Approach to Map and Predict the Age-friendliness of the Built Environment

by Fereshteh Moradi

Thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

under the supervision of
Dr Nimish Biloria
Dr Mukesh Prasad

University of Technology Sydney
Faculty of Design, Architecture and Building

September 2022

CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Fereshteh Moradi declare that this thesis, is submitted in fulfilment of the requirements for the award of the degree of Doctor of Philosophy, in the Faculty of Architecture at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

Signature: Production Note:
Signature removed prior to publication.

Date: 18/03/2022

ACKNOWLEDGEMENT

My first and foremost appreciation goes to my supervisor, Associate Professor Nimish Biloria, for his marvellous supervision, guidance, and encouragement. Nimish has been an ideal teacher, mentor, and thesis supervisor, offering advice and encouragement with a perfect blend of insight and humour. I am proud of and grateful for my time working with him. Thank you very much Nimish.

Also, I appreciate my second supervisor, Dr.Mukesh Prasad, for his feedback and guidance. Also, I want to thank Rhonda Daniels for her help with proofreading my thesis.

I am incredibly grateful to my friends Dimitra Dritsa and Chrysostomos Tsaprailis, who always shared their knowledge, fun stories, and unsuccessful bread recipes with me. I was so lucky to meet them in the first days of my PhD journey; they were always there for me. I am also thankful to my friends Biyanka, Caroline, Enya, Fiona, Kerl, Mukesh, Tazy and other members of the "UTS PhD Girls et al." group, who are the kindest, funniest, and most supportive friends from around the world.

My most profound appreciation goes to my lovely partner, Pezhman Pakdel. Thank you, Pezhman, for constantly listening to me rant and talk things out about my thesis chapters, your cracking jokes when things became too serious, and the sacrifices you have made for me to pursue a PhD degree.

And finally, I am particularly indebted to my lovely daughter, Audrey. She motivated me to finish this thesis with her tiny kicks during the last months of my pregnancy.

THESIS FORMAT STATEMENT

This thesis is formatted following the requirements of a conventional thesis. So far, two papers have been extracted from this thesis. An article entitled **"Analyzing the age-friendliness of the urban environment using computer vision methods"** has been accepted by the journal "Environment and Planning B: Urban Analytics and City Science" to be published. Another paper entitled "**Implications of Artificial Intelligence for assessing the built environment"** has been submitted to the "Journal of Urban Technology" and is under review.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Population aging is one of the most significant phenomena worldwide. The concept of age-friendly cities is gaining attention globally, considering the increase in the aging rate. Research into age-inclusive built environments is a relatively evolving area. However, there is a lack of extensive research on urban data acquisition on cities' age-friendly features using modern technologies. Considering the size of modern cities, it is beyond the capacity of traditional audit tools to develop a comprehensive analysis concerning spatial issues. Therefore, this research's core objective is to predict the built environment's age-friendliness using modern computer vision tools to overcome traditional auditing's limitations. Urban computing and deep neural networks are employed to map, analyze, and predict the urban environment's age-friendliness utilizing street-level images. The model is built using a transfer learning technique based on a pre-trained architecture (VGG-16), enabling a more rapid and precise analysis of the Google Street View images from three Sydney neighbourhoods. The proposed model is scalable to more neighbourhoods, and urban planners can apply it to evaluate neighbourhood conditions. The proposed model can achieve adequate accuracy in generating human-like assessments. Ultimately, some mitigation measures for developing age-friendly urban places will be offered based on the study's findings.

ABBREVIATIONS

ACM	Association for Computing Machinery
AFC	Age-Friendly Cities
AI	Artificial Intelligence
API	Application Programming Interface
ANN	Artificial Neural Networks
BGR	Blue, Green, Red
BPNN	Backpropagational Neural Network
BRISQUE	Blind/Referenceless Image Spatial Quality Evaluator
CANVAS	Computer Assisted Neighbourhood Visual Assessment System
CASIL	California Spatial Information Library
CBD	Central Business District
CCAHS	Chicago Community Adult Health Study
CCTV	Closed-Circuit Television
CGI	Computer Gateway Interface
CNN	Convolutional Neural Network
COPD	Collection Of Part Detectors
CSV	Comma-Separated Values
CT	Computerised Tomography
CV	Computer vision
DHHS	Department of Health and Human Services
DNN	Deep Neural Network
DT	Decision Tree
FC	Fully-connected
FCN	Fully Convolutional Neural network
Fov	field of view
FV	Fisher Vector

GD	Gradient Descent
GIS	Geographic Information System
GMCP	Generalized Minimum Clique Graphs
GPS	Global Positioning System
GPU	Graphics processing unit
GRU	Gated Recurrent Unit
GS	Google Scholar
GSV	Google Street View
GVI	Green View Index
IEEE	Institute of Electrical and Electronics Engineers
IQA	Image Quality Assessment
LASSO	Least Absolute Shrinkage and Selection Operator
LSTM	Long-Short Term Memory (Network)
MA	Microsoft Academic
ME	Mean Error
ML	Machine Learning
MRI	Magnetic resonance imaging
MSE	Mean Squared Error
NGO	Non-Governmental Organisation
NLP	Natural Language Processing
NSS	Natural Scene Statistics
NSW	New South Wales
OD	Object Detection
OSM	OpenStreetMap
R-CNN	Region-based Convolutional Neural Networks
ReLU	Rectified Linear Unit
RGB	Blue, Green, Red
RNN	Recurrent Neural Network
SD	ScienceDirect

SGD	Stochastic Gradient Descent
SS-CNN	Streetscore-CNN
SSO	Systematic Social Observation
SVM	Support Vector Machine
SVR	Support Vector Regression
RNN	Recurrent Neural Networks
MAE	Mean Absolute Error
RMSE	Root Mean Square Error
UN	United Nations
WoS	Web of Science
WHO	World Health Organisation
XOR	eXclusive OR
YOLO	You Only Look Once