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Spatiotemporal dynamics of urban health: Physiological data driven strategies for enhancing urban health and wellbeing

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Doctor of Philosophy

under the supervision of
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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Dimitra Dritsa 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.

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THESIS FORMAT STATEMENT

This thesis is formatted following the requirements of a conventional thesis. Two papers submitted for publication are also presented in Appendix A and B. References to the two papers have been included in the main work whenever appropriate.

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ABSTRACT

The starting point for this research was the emergence of physiological data as a source of information that can help us understand how our interactions with the urban environment affect the human body. There is significant potential in extending existing methods for physiological data analysis in the urban domain in a way that maximises the benefits at the individual and the city scale. Physiological data could be used to identify the least stressful route, but there is currently a lack of research on their incorporation in pathfinding studies. The area of prediction of physiological responses during outdoor walking has also been understudied.

This study aims to address these issues by designing a methodology for collection and analysis of physiological data in the urban space. The methodology incorporates three components: (1) the collection and analysis of physiological data at an individual level, (2) the hotspot analysis of physiological responses at a city scale, and (3) the utilisation of the collected data in models for prediction of physiological responses, and pathfinding methods for the identification of the least stressful route. The methods and algorithms for each component of the methodology are calibrated using data collected in Sydney from experiments organised by the author, and publicly available data from a previous study conducted in Zürich.

The study acts as a pilot project that will pave the way towards large-scale experiments in this area. Its main contribution is that it supports the construction of tools for individuals who want to understand how different routes might affect their physiological responses, and have a calm experience while walking in the urban environment. It can also help researchers identify which parts of the city are associated with an increased intensity of physiological responses, possibly indicating increased stress levels. The construction of a theoretical and conceptual framework supporting the construction of the methodology also enriches current research on the links between urban environment, activity and physiological responses. Other methodological and practical contributions include the development of methods for analysing how movement may influence physiological responses as a physical stressor, and their incorporation in the designed methodology; also, the development of

methods for identifying physical and psychological stressors from contextual data, based on freely available OpenStreetMap and Point of Interest data, as an alternative to image-based analysis which was used in previous studies.

ABBREVIATIONS

ADAM	Adaptive Moment Estimation
AHR	Additional Heart Rate
ANS	Autonomic Nervous System
API	Application Programming Interface
CNN	Convolutional Neural Network
DBSCAN	Density-Based Spatial Clustering of Application with Noise
DNN	Deep Neural Network
DT	Decision Tree
ECG	Electrocardiogram
EDA	Electrodermal Activity
EDR	Electrodermal Response
EEG	Electroencephalography
FFT	Fast Fourier Transform
GIS	Geographic Information System
GPS	Global Positioning System
GSR	Galvanic Skin Response
HMM	Hidden Markov Model
HR	Heart Rate
HRV	Heart Rate Variability
KDE	Kernel Density Estimation
k-NN	k-Nearest Neighbors

LISA	Local Indicators of Spatial Association
LSTM	Long-Short Term Memory (Network)
MAE	Mean Absolute Error
ML	Machine Learning
MSE	Mean Squared Error
NS.SCR	Non-Specific Skin Conductance Response
OSM	OpenStreetMap
PANAS	Positive And Negative Affect Schedule
POI	Point Of Interest
STD	Standard Deviation
SVM	Support Vector Machine
RNN	Recurrent Neural Networks
RF	Random Forests
RMSE	Root Mean Square Error
PPG	Photoplethysmography
ST	Skin Temperature

PUBLICATIONS

Materials presented in chapter 1 have generated the following research output:

Dritsa, D. & Biloria, N. 2021, 'Mapping the urban environment using real-time physiological monitoring', *Archnet-IJAR*, Vol. ahead-of-print No. ahead-of-print, doi: https://doi.org/10.1108/ARCH-02-2021-0041.

Materials presented in Appendix A have generated the following research output:

Dritsa, D. & Biloria, N. 2021, 'Analysing the relationship between POI density and stimulus complexity in the urban environment', *Journal of Urban Design*, Vol. ahead-of-print No. ahead-of-print, doi: 10.1080/13574809.2021.1903306.

Materials presented in chapter 1 are based on findings from the following research output:

Dritsa, D. & Biloria, N. 2018, 'Towards a Multi-Scalar Framework for Smart Healthcare', *Smart and Sustainable Built Environment,* vol.7, no.1, pp.33-52, doi: https://doi.org/10.1108/SASBE-10-2017-0057.