RGC Ref. No.:
UGC/FDS16/E12/20
(please insert ref. above)

RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines:
1. *Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.*
2. *Completion report: within **12** months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. Project Title

Modelling the Social Aspects of Interactive Objects for Pedestrian Trajectory Prediction in Urban Areas

2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Dr Kevin HUNG King-fai / Associate Professor	School of Science and Technology / Hong Kong Metropolitan University
Co-Investigator(s)	Prof Andrew LUI Kwok-fai / Honorary Professor	School of Science and Technology / Hong Kong Metropolitan University
Others	--	--

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval *(must be quoted)*
Project Start Date	1 Jan 2021	--	--
Project Completion Date	31 Dec 2022	30 Jun 2023	13 Oct 2022
Duration *(in month)*	24	30	13 Oct 2022
Deadline for Submission of Completion Report	31 Dec 2023	30 Jun 2024	13 Oct 2022

4.4 Please attach photo(s) of acknowledgement of RGC-funded facilities / equipment.

There was no RGC-funded facilities / equipment in this project.

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. To model reactions of pedestrians as the social influence of interactive objects and to formulate functions accordingly based on trajectory data

2. To design and implement a deep learning architecture for pedestrian trajectory prediction tasks in areas crowded with pedestrians and interactive objects

3. To develop and evaluate embeddings for classes of interactive objects for model reusability

5.2 Revised objectives

Date of approval from the RGC:	N/A
Reasons for the change:	N/A

5.3 Realisation of the objectives

(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

In this reporting period, the project team investigated the modelling of pedestrian movement in the presence of social objects represented as facilities and services found in public buildings. The features associated with the attraction aspect of social objects, or social objects as destinations, were studied and a two-stage destination-based deep neural network was designed to build specific models. Two datasets suitable for data-driven model building were prepared, and one with long trajectories required significant registration and annotation work (Objective #2). The problem of pedestrian trajectory tracking was divided into three modelling problems, namely, the to-social-object, in-social-object, leave-social-object, of which several formulations of the first model were developed and evaluated comprehensively (Objective #1). A paper was written on the findings, and it was accepted for presentation at a top conference. Zonal neighborhood models for social interactions of pedestrians were investigated and some variants had been developed for testing. The understanding enabled the drafting of formulations for the in-social-object modelling, which is currently ongoing (Objective #2). The next reporting period will continue develop models for pedestrians moving in location designated as in-social-object (Objective #1). The selection and preparation of datasets for model training will soon be finished and ready for the designed deep network architecture (Objective #2). The datasets selected are for the modelling of information kiosks and notice board around where there are specific features of pedestrian movements such as queuing. After a thorough treatment on the in-social-object modeling, the focus will switch to the leave-social-object model, which

should explain the pedestrian movement away from a social object (Objective #1 and. Objective #2). Other commonly found social objects have been studied and modelled. The common features and the reusability and transferability of the models have been identified (Objective #3).

Although original PI and Co-I have resigned from HKMU during the project period, the project team (with the new PI) have overcome the difficulty and have successfully achieved all 3 objectives, delivering 2 conference papers and 3 SCI-indexed journal papers (2 under review).

5.4 Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	**Addressed** *(please tick)*	**Percentage Achieved** *(please estimate)*
1. To model reactions of pedestrians as the social influence of interactive objects and to formulate functions accordingly based on trajectory data	✓	100%
2. To design and implement a deep learning architecture for pedestrian trajectory prediction tasks in areas crowded with pedestrians and interactive objects	✓	100%
3. To develop and evaluate embeddings for classes of interactive objects for model reusability	✓	100%

6. Research Outcome

6.1 Major findings and research outcome *(Maximum 1 page; please make reference to Part C where necessary)*

The project team has successfully developed a dual-level architecture designed to model individual pedestrian movement. This model takes into account of the relationship between pedestrians and functional objects. Performance evaluations have demonstrated the significant role functional objects play in pedestrian movement modelling. Furthermore, the accuracy of trajectory prediction for users of functional objects has shown marked improvement over models that do not consider these objects. The method was trained and evaluated using three functional objects selected from a multi-functional center in an indoor urban complex in Osaka, Japan, as per the Osaka ATC Dataset. Please refer to [Attachments 1, 4 & 5] for more details.

Additionally, a sophisticated deep circadian-informed probability refinement network (CIPRNet) for pedestrian intent classification in areas crowded with pedestrians and interactive objects has been designed and implemented. Using the same Osaka ATC dataset, the proposed network has proven to outperform existing state-of-the-art approaches, particularly under varying weather-time (WT) conditions. This presents a compelling alternative for enhancing the performance of various deep learning-based trajectory prediction models under different weather-time conditions. For more information, please refer to [Attachment 2]. Lastly, a novel deep weather-time-trajectory fusion network (WTTFNet) has been developed. This innovative framework can be applied to other baseline models to enhance their performance using new WT embedding for classes of interactive objects under fluctuating weather-time conditions. For further details, please refer to [Attachment 3].

6.2 Potential for further development of the research and the proposed course of action *(Maximum half a page)*

The deep learning frameworks developed in this project were based on the open data (Osaka ATC datasets). Based on this experience and insights gained from the project. the project team is ready to apply perform similar studies on datasets obtained from other urban complexes. The team will continue to explore the possibility of similar research based on datasets that have a Hong Kong or greater bay area (GBA) focus. This will deepen the understanding of how pedestrians interact with functional objects, and how these insights be applied to facilitate public space development, evacuation planning, and technology-driven retail in smart cities with distinct 'Chinese characteristics'. The future research with GBA focus will generate insights contributing the smart city development initiatives in this strategically important economic hub.

7. Layman's Summary *(Describe in layman's language the nature, significance and value of the research project, in no more than 200 words)*

Technologies for smart city make our lives safer and more comfortable. For example, real-time data can be used to predict activities like traffic flow and business trends. One of the key research areas for smart city is to understand how people move around in urban areas. This is important for development of self-driving cars, smart shopping experiences, and crowd control strategies. However, predicting how people move around is complicated, especially in busy indoor areas like shopping malls or train stations. As social beings, people follow certain unwritten rules while commuting. For example, we might keep our distance from strangers or move closer to friends. Researchers can use artificial intelligence to learn these social rules and predict how people move. There are objects in cities, like escalators or benches, that people interact with. These objects have physical properties, like where they are located, and functional properties, like how people use them. They also have social properties, like how people react to them and to others near them. This project has developed a new way to understand these social properties using deep learning. The findings could help us better predict how people move around cities, and therefore develop technologies for smart city.

Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project

(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				Author(s) *(denote the corresponding author with an asterisk*)*	Title and Journal / Book *(with the volume, pages and other necessary publishing details specified)*	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this Report *(Yes or No)*	Acknowl-edged the Support of RGC *(Yes or No)*	Accessible from the Institutional Repository *(Yes or No)*
Year of Publication	**Year of Acceptance** *(For paper accepted but not yet published)*	**Under Review**	**Under Preparation** *(optional)*						
2023	--	--	--	Andrew Kwok-fai Lui *, Yin-hei Chan, Kevin Hung	Functional Objects in Urban Walking Environments and Pedestrian Trajectory Modelling / Sensors, Vol. 23, Iss. 10, 4882, 2023.	No	Yes [Attachment 1]	Yes	Yes
TBC	TBC	Yes	--	Ho Chun Wu, Paul Yuen, Esther Hoi Shan Lau, Kevin Hung*, John Kwok Tai Chui, Andrew Kwok Fai Lui	Deep Circadian-Informed Probability Refinement Network for Pedestrian Intent Classification in Urban Complex / IET Electronics Letters	No	Yes [Attachment 2]	Yes	Yes
TBC	TBC	Yes	--	Ho Chun Wu, Esther Hoi Shan Lau, Paul Chun Ho Yuen, Kevin Hung*, John Kwok Tai Chui, Andrew Kwok Fai Lui	WTTFNet: A Weather-Time-Trajectory Fusion Network for Pedestrian Trajectory Prediction in Urban Complex / IEEE Access	No	Yes [Attachment 3]	Yes	Yes

9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered *(Please attach a copy of each conference abstract)*

Month / Year / Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this Report *(Yes or No)*	Acknowl-edged the Support of RGC *(Yes or No)*	Accessible from the Institutional Repository *(Yes or No)*
Dec / 2021 / Orlando (Virtual)	Modelling of Destinations for Data-driven Pedestrian Trajectory Prediction in Public Buildings	IEEE International Conference on Big Data 2021	Yes (2021)	Yes [Attachment 4]	Yes	Yes

Apr / 2022 / (Virtual)	Modelling of Pedestrian Movements near an Amenity in Walkways of Public Buildings	The 8th International Conference on Control, Automation and Robotics (sponsored by IEEE Robotics & Automation Society)	No	Yes [Attachment 5]	Yes	Yes

10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning *(Please elaborate)*

This research project has been used as a case study for teaching senior-year students in the *B.Sc. (Hons) in Data Science and Artificial Intelligence* and *B.Sc. (Hons) in Computer Science* programmes. Specifically, the project was used as a reference for teaching in the courses: *COMP S461F Data Science Project*, *COMP S492F Machine* Learning, , *COMP S493F Deep Learning*, and *STAT S311F Time Series Analysis and Forecasting*.

11. Student(s) Trained
(Please attach a copy of the title page of the thesis)

Name	Degree Registered for	Date of Registration	Date of Thesis Submission / Graduation
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12. Other Impact *(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)*

N/A

13. Statistics on Research Outputs

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Research Outputs (please specify)	
					Type	No.
No. of outputs arising directly from this research project	3	2	0	0	-	-

14. Public Access Of Completion Report
(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons
N/A	N/A