PEDESTRIAN DYNAMIC BEHAVIOUR MODELING

An application to commercial environment using RNN framework

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Abstract. The research of developing and improving pedestrian simulation model is essential in the process of analysing, evaluating and generating the architectural spaces that can not only satisfy circulation design condition but also promote sales by attracting customers. In terms of programming the simulation for commercial environment, current study attempts to use shortest-path algorithm generally and these results suggested that the model can reproduce approximate real trajectory within given environment. However, these studies also mentioned about necessity of considering shopper internal state and visual field. In this paper, in order to further incorporate the dynamic internal state (memory) into simulation model, we propose using iterative algorithm based on recurrent neural network (RNN) framework which allow it to exhibit temporal dynamic behaviour for a time sequence. Finally, we demonstrate the effectiveness of these algorithms we introduce and assess the combination of multiple algorithms and calibration of probability by comparing with trajectories of the experiment.

Keywords. Pedestrian simulation; Algorithm; RNN; Commercial environment.

1. Introduction

Agent-based simulation of pedestrian movement has been developed in years over the fields of urban planning, transportation planning, evacuation studies, and evaluation of building. These approaches are categorized into two broad groups: large-scale urban simulation and low-level building micro-simulation (Penn & Turner 2001).

In recent urban research, multi-agent simulation and Space Syntax Theory tend to be combined in order to investigate field observation (Asriana & Indraprastha
In addition, one of the study of this topic revealed the Space Syntax Theory in particular using VGA can help model to be functional solving the problems in sophisticated real-life environment. (Hu et al. 2017).

In terms of micro-simulation, Alasdair Turner who contribute to development of Space Syntax Theory also introduced a dynamic agent model that derives aggregate spatial analysis from the visual affordances of the built environment (Penn & Turner 2002). Based on the principle of Turner’s theory on embodied space, his agent model proves to correlate well with natural movement behaviour in architectural and urban environment. Regarding case of adopting statistical method, Kawaguchi’s research adopted the Markov chain model by defining the number of visitors as variable parameter for the purpose of analysing criteria at early phase of design (Kawaguchi 2003). With the development of pedestrian simulation in real space, Shen-guan’s research proposed to integrate the Markov chain model with spatial information such as location, direction, walkable point, destination, shortest path and avoiding mutual collision of agents. It is expected that the representational model can be used to assist designers in analysing the relation between building plan and circulation (shen-guan et al. 2009). However, they mentioned that the model is not able to compare the result of the simulation to realistic data of pedestrian movement. In other words, there is a problem in accuracy of virtual simulation results in comparison to real data.

According to above-mentioned situation of the field, the majority of existing research about pedestrian simulation models are classified as fundamental research and practical research. For instance, Penn and Turner’s research that aim for developing tool is classified as fundamental research. Another one for analysis of evacuation by means of multi agent simulation which can be used to analyse a given design within a given scenario is classified as practical research.

Actually, the most of research in this topic are classified into practical research and these models are driven by analysis rather than design. There are two main reasons for this. One, the majority of existing crowd flow simulation models have evolved from building evacuation needs. The second reason is the complexity of the models. People movement models tend to be inherently complex, as they need to account for a combination of factors such as spatial configuration, population behaviour, and agent interaction. The ability to account for design variable within the model often adds to the complexity and processing time and is as such avoided (Sharma & Tabak 2008).

However, from the background that the performance of computers in particular, calculating speed improves day by day, a momentum of fundamental research on pedestrian simulation aiming at improvement of accuracy and reproducibility is increasing lately. Specifically, that is to enhance feasibility of developing a simulation model which reproduces realistic human walking that identifies and calculates complex spatial configuration and makes its own decision dynamically. Therefore, taking into account recent developments in the study of machine learning and deep learning, simulation reproducibility in fundamental research becomes more critical issues.

In this paper, we define a subject of study as commercial environment where it is necessary to take into consider both psychological state and visibility when
constructing a pedestrian simulation model.

2. Objective
The objective of this research is to develop humanistic or realistic algorithm that involve dynamic internal state of customer who can be applied to commercial building, in order to improve pedestrian simulation model. The model allows not only iterative design optimization of circulation space but also iterative design study of detail such as size of signboard, location of poster and aperture ratio.

3. State of Art
In the current state of art related researches which referred to development of pedestrian simulation in commercial environment has suggested a significant results and issues regardless of fields. A model of Kitazawa and Batty’s research that have been applied to modelling microscopic behaviour, uses the shortest-path model as one of evaluation criteria of Genetic Algorithms to computationally emulate retail movements of shoppers. The study concludes that reproducing the actual behaviour need to consider several influential factors on pedestrian movement besides the shortest-path through comparison between the results of the simulation and observed data. (Kitazawa & Batty 2004).

Another research of this topic, Penn and Turner’s model which based on Space Syntax Theory of VGA mentioned these influential factors. Taken together, the feedback effects of stopping and congestion as the influential factors on agent movement flows will further improve the correlation with observed shopper movement patterns (Penn & Turner 2001).

In the field of science technology, there is a research by Sehnaz Cenani that referred to basic concepts and rules of simulation models in shopping mall. As main issue indicated by this research is to construct memory system and the learning ability (Sehnaz & Gulen 2008).

4. Problem Statement
In such situation, though there are several theories about realistic pedestrian behaviour model with a commercial environment in micro-scale. Furthermore, there are few descriptions about its details of psychological factors, in other words, dynamic internal state such as memory system and the learning ability. Of course, incorporating them into the algorithm of the model will result in considering effects of stopping and congestion.

5. Hypothesis and Research question
Regarding incorporating dynamic route-choice in model, our hypothesis is that if recurrent neural network (RNN) framework is adopted, it is possible to dynamically change the psychological internal state from visual information and develop an algorithm reflected in route-choice. The author expects that it can be implemented in any commercial environment as a versatile simulation model that accurately reproduces consumer purchasing behaviour. In this paper, we followed
the following procedure for its development.

First, we classify and describe behaviour from the record of the experiment that executed in commercial environment (shinkiba station) to represent walking by multiple algorithms.

Secondly, In the following section, we discuss algorithm to implement the model based on RNN by taking knowledge acquired from experiment into account.

Finally, we assess combination of multiple algorithms and calibration of probability by comparing with trajectories of the experiment.

Figure 1. Concept of walking process found from experiment (left) and RNN framework.

6. Case study - Shinkiba Station

In this paper, we have selected Shinkiba Station as a model case to conduct experiment and development of simulation model as a typical example having commercial shops with the train station. The reason for choosing this case is described as the following.

Needs for adopting simulation: Shinkiba is located in coastal area of Tokyo which is expected to be converted from industrial area to commercial area. Shinkiba consortium that has been discussed to develop this area is focusing on potential of train users and several commercial shops in order to attract and guide people towards outside.

Scale: If walkable points is made up of 1m grid in the target area, the total is 733 points. Turning simulation 200 times is also appropriate in terms of calculation load.

7. Experiment

In the experiment, 16 subjects, graduate students who are in their twenties, were asked to shop around in lunch time and the routes they took were tracked and recorded by examiner. For the purpose of finding several criteria that assists in creation of the algorithm, we observed what they thought and what kind of behaviour they did.
7.1 EXPERIMENT METHOD

The methodology of the experiment is following these rules.

- The walkable points of experiment is defined by 1 meter grid points which is same as virtual model described above. The subjects walk at these points in 360 degrees and 8 directions around by selecting a point every two steps.
- The termination of the experiment is determined by whether the subject enters shop, enters ticket gate or reaches exit.
- All subjects were asked to think aloud, which is to talk to a voice recorder what they were thinking and trying to do.
- I asked subjects to walk on assumption that is looking for a shop to enter in lunch time.

7.2 EXPERIMENT DATA

The table shows a part of result from recorded data. The result suggests that subjects without mental map tend to find information of store list. In common with all subjects, there was a process of making decision by means of gazing at the details of multiple shops such as poster, banner and atmosphere of inside. Their behaviour indicate that the decision is made based on the internal state of the pedestrian and the information he/she perceives from surroundings and it is important to express the memory of recognition with algorithms. In addition, that also showed necessity to incorporate dynamically changing visibility that influences on recognition as one of criteria in model. The next chapter shows its algorithms of framework we create, and finally the combination of that are shown as a result.

8 Programming

When creating an algorithm based on experimental results, our framework consists of a global algorithm for whole process and a local algorithm under specific conditions. In this paper, we attempt to adopt the RNN (recurrent neural network) framework instead of hidden Markov models that could be used for state transitions in past years. That is possible to reproduce behaviour in terms of dynamic decision and allow agent to memorize states based on recognition and to include them in
consideration of making decision.

8.1. METHOD OF VISIBILITY MEASUREMENT

In digital media field, there are several researches on agent-based interface by Chiung-hui Chen who is one of the expert on programming model of pedestrian movement. His research suggested that future studies may incorporate three-dimensional space to examine the effect on visible area of attention (Chen et al, 2004). In order to extract the view object which is clues for making decision to walk with a micro-scale, in this research, we adopt 3d-isovist for quantitative calculation of the view object.

Figure 3 shows the view object we defined based on a group of Watanabe’s researches and the other (Watanabe et al. 2001; Watanabe et al. 2003; Arima et al. 2008). According to their research, the view objects are classified into multiple categories: hanging sign-board, poster, shop-window, exposure, banner, and shop billboard and also demonstrates that the number of viewing times of the view objects depends on the distance in commercial street. We speculated that this result is influenced by size of characters that can be read. This paper assumed that it is important to calculate whether character of the view objects is readable or not, as one of the significant spatial factor that affects human recognition.

Therefore, we set 160 degrees visual field, calculation distance to 30 meters and a focus to 12 meters based on the research results of Watanabe et al as shown in Figure 3. Regarding calculation method, we prepared 144 rays which is an appropriate resolution for the size of target. The score of evaluation visibility (EVa..b..c..) is defined as the ratio of the number of rays hitting the view objects as a reference to following research (Hwang & Lee 2017).

Figure 3. The view object and the calculation method.
8.2. GLOBAL ALGORITHM

Two ideas were gained on devising a global algorithm. One is a ranking format that decide to destination by highest score of EV among each store. Idea of this format is similar to method of shortest-path walking (Kitazawa & Batty 2004), but it differs from precedent in terms of adding measured numerical values of the view objects to process. Considering knowledge acquired from many of the subjects, the state of recognition based on human visibility is composed of two stages: it looks somewhat visible and becomes recognizable, and these recognition states are significant items that affect memory, judgment and behaviour.

Another idea that we propose is a threshold format that determines the destination when EV reaches the threshold value. In this format, the threshold is set as boundary as to whether or not the characters can be read. This means that the recognition state is reproduced on algorithm and we define the stages of recognition associated with this threshold as internal condition (ICa..b..c..).

8.3. LOCAL ALGORITHM

The local algorithm under specific conditions as follows:

Adaptation to configuration: when agent reaches a specific point such as along the wall or entrance of the shop to adapt to the space, an algorithm for correcting the traveling direction is executed.

Dynamic visibility: when EV exceeds the threshold, the calculation of EV is doubled at moment. This algorithm reproduces the gaze of the view objects suddenly appeared in the field of view. For instance, if people are looking for something and when they find clue of it most people gaze them at moment. It is described in detail as follows. IC = 0: EV = 0 (nothing is visible); IC = 1: 0 <EV <threshold (they can check the store but they cannot read the letters on the signboard); IC = 2: the moment the EV exceeds the threshold (to be appealed to gaze at the store strongly); IC = 3: EV >= threshold (state in which the store can be well recognized).

Making a judgment: an algorithm express to judging whether to enter the shop and it is executed when agent reaches entrance of the shop.

Changing a destination: an algorithm that express to behaviour such as returning to a shop that go way once by considering selection of entering the stores, it is executed as following condition. When an agent located at the point in front of the store, if they have other stores that reaches the threshold value (IC = 2 or 3), agent return to the store closest to the distance according to probability.

Checking surroundings: the store is invisible in visual field from the current heading, but an algorithm adapted to behaviour to predict direction of destination by looking at the surroundings such as flocks of people.

9. Application

In this section we describe application of model to the Shinkiba station. The purpose of this process is to assess combination of both algorithms and the setting of random variables by comparing the results of experiment on trajectories and the
simulation results. At this time, trajectories are disclosed by destination.

Figure 4 shows the result of the experiment and simulation which entered the store B as destination. Case A using algorithm of ranking format fits relatively well to the outline of real trajectories but cannot assimilate to its details. Case B and G that consist of algorithm of threshold format, from case B, it is observed that the trajectories changes direction from the store C to the store B, and the accuracy of reproducibility is improved more than the ranking format. At last in case G, the features returning to the store B that go way once are reproduced clearly.

Figure 4. The result of the experiment and simulation which entered the store B as destination.

Figure 5 shows the result which reached the exit as destination. In comparison with result of experiment, case A adopted ranking format reproducing the route of shortest-path. The trajectory of the agent attracted to the store C is not expressed. Case C and G consisting of algorithm of threshold format reproduce well feature of longest route by approaching all the stores. Especially, in case C, the difference of average of the distance between agent trajectory and subject was only 0.77 meter.

Figure 5. The result of the experiment and simulation which reached the exit as destination.
At last, Figure 6 shows the result of the experiment and simulation which reached the ticket gate 2 as destination. In terms of the ticket gate 1 as destination, trajectories of experiment were shown in each case, and there was little deviation in the simulation. In another one, the algorithm of ranking format clearly shows the trajectory reaching the ticket gate 2 by the shortest-path in case A. case E and G adopting the threshold format well reproduce the detour route towards the store, but case E lacks a detour route towards store C in details and the longest detour route in experiment is well reproduced by case G rather than the others.

Finally, we evaluate the reproducibility with respect to the ratio of destination. This repeatability guarantees visual field setting and calculation accuracy of the model. By comparing the cases for each destination, we can see that case F reproduces them most accurately as shown in Figure 7.
The fact that the simulation result is similar to the real trajectory suggests that the evaluation functions and parameters used in this model are valid to reconstruct design of shop.

10. Conclusion

The important result revealed in this study is that the shortest-path algorithm cannot accurately reproduce the pedestrian simulation in a commercial environment and we found that threshold algorithm using RNN we propose can reproduce them by combining multiple local algorithms. Of course, there is assumption we apply only elementary guidance rules. These rules were that destinations may only be chosen from 160 degrees visual field from the current heading, and that the destination is reassessed under specific condition. Whether or not this result is reproducible for other building types has not been resolved.

References