Computer Graphics and Visualization (5B)

A PROTOTYPE USING MULTI-AGENT BASED SIMULATION IN SPATIAL ANALYSIS AND PLANNING

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Abstract. Pedestrian's movements and spatial cognition in urban environments are main issues for urban designers in urban spatial planning and analysis. This paper aims to study interactions between a behavioural model of pedestrians and urban spaces. The pedestrians can be represented by an agent program, and behavioural reactions of walking agents under different stimulus can be further simulated. Thus, this study suggests that, a correlation study on pedestrian behaviours and spatial environments become the criterion for urban designers in order to help them create better flows.

Keywords. Spatial analysis, multi-agent, behaviour, simulation.

1. Introduction

An innovative trend in supporting architects in their activities is represented by virtual environments in which alternative architectural designs can be visualized and compared by involved actors, in a collaborative decision scheme. This kind of approach could be improved by the possibility to include in the virtual environments also an envisioning of pedestrian dynamics in the related architectural structures, given the fact that human movement behaviour has deep implications on the design of effective pedestrian facilities (Willis et al., 2004). Particularly in architectural and urban design, the user behaviours are unknown to the designers. The gap between the assumption and the actual behaviour is wide. Several continuum models for pedestrian dynamics are based on an analytical approach (Borgers, 1987). A relevant example is represented by social force models (Helbing, 1995), in which individuals are treated as particles subject to forces. Other analytical models take inspiration from fluiddynamic (Helbing, 2000). Accordingly, Multi-Agent Based Simulation is based on the idea that it is possible to represent the global behaviour of a dynamic system as the result of interactions occurring among an assembly of agents with their own operational autonomy (Wooldridge, 2002). Therefore, this paper attempts to explore the human activity scheduling behaviour and movement patterns on streets for urban design purposes. On the other hand, the "what if" becomes a typical approach for environmental designers to better understand user needs and actual behaviours. Moreover, active attention is essential to manipulate an enormous amount of information in the environment. Therefore, we have developed a prototype model, which was drawn from the point of view of the attention theory and agent technology.

At every moment we pay attention to only one or a few objects. Paying attention to something makes us to see these objects more clearly, accurately, and remember better. We can turn the head, or eyes, or even take a step toward an interesting object in an environment (Berlyne, 1960). Indeed, when we walk along a street and enjoy a sequence of scenes, we may perceive a physically continuous street as a series of separated spaces of different atmosphere. Furthermore, an important recent development in the agent technology is the changes in the mode of presentation: from passive mode to active one. This active mode of visual perception is essential to environmental perception, because active attention is necessary to manipulate the enormous amount of information in the environment. Thus, the present study attempts to make clear some physical features which are influential for changing atmosphere based on the experiments conducted in existing and simulated spaces. The research methodologies undertaken include: observation, analysis, prototype, and simulation.

2. Spatial Visibility as Selection Range during Pedestrian Movements

This paper defines spatial visibility selection range to be the activity area that pedestrians are able to reach in open space; spatial visibility range is dependent on viewpoint (Berlyne, 1976). For this reason, in urban space, establishing viewpoints that pedestrians are unable to pay attention is meaningless. In theory, visual vanishing points can be formed when pedestrians' attention distances increase; in the theory of perspective drawing, the standing side of buildings on the street would gradually be compressed to a small point toward the visual vanishing point. Therefore, spatial exteriors can not be easily noticed at the end of the vision. If considering the perspective fundamentals, vision end should be seen as the shape of a funnel; however, since the paper focuses more on visible attention than the reality spatial visual effects, the visual vanishing point factor is not further considered. In addition, the visible attention range varies from two-dimensional (2-D) real buildings, roadside furniture, and obstructions; even though the paper neglects the height variations in three-dimensional (3-D) space, the research subjects are basically moving on the given ground surface that includes little altitude variations. In other words, since the 3-D space does not significantly affect the surface visible attention, the paper discusses only the 2-D plane.

Moreover, the difference between each movement is related not only to the speed, but also to the selection of activity point in space; the change of activity point in space is a result of reactions to the environment. In many possible reactions, ones that are provided to the pedestrians need to be decided before they can be systematized. This process needs to follow a basic principle that allows agents to differentiate the difference between each selection. For this reason, the study has defined the following three reactions for agents' selection: simple reaction, selective reaction, and differentiation reaction; see Figure 1.

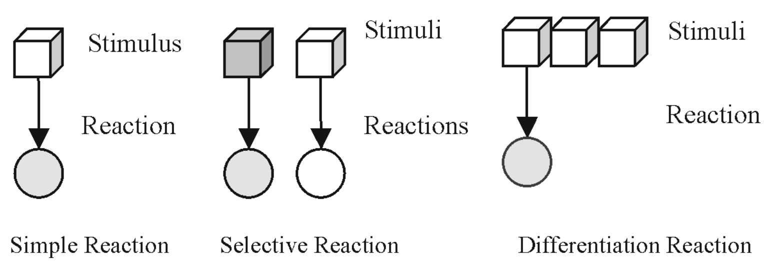


Figure 1. Street Environment and Agent Reaction Mode

3. Spatial Design Factors of Urban Streets

The various stimulating factors in the street environment can be analyzed and divided into two types: the reality visual factors that include implications, characteristics, and relative relation with pedestrians, and the non-reality visual factors that include street environment and other pedestrians (Figure 2). These visual factors can lead pedestrians to pay attention to environment elements; implications that are novel and unique can either fulfill pedestrians' mental need of curiosity pursuit or suggest pedestrians the possibility of other activities. For example, an assembled crowd on the street may imply the occurrence of certain activities. These visual factors may stimulate pedestrians to be involved in secondary activities during the process of the purpose-driven activities; they may even affect pedestrians to discontinue the purpose-driven activities or to change locations.

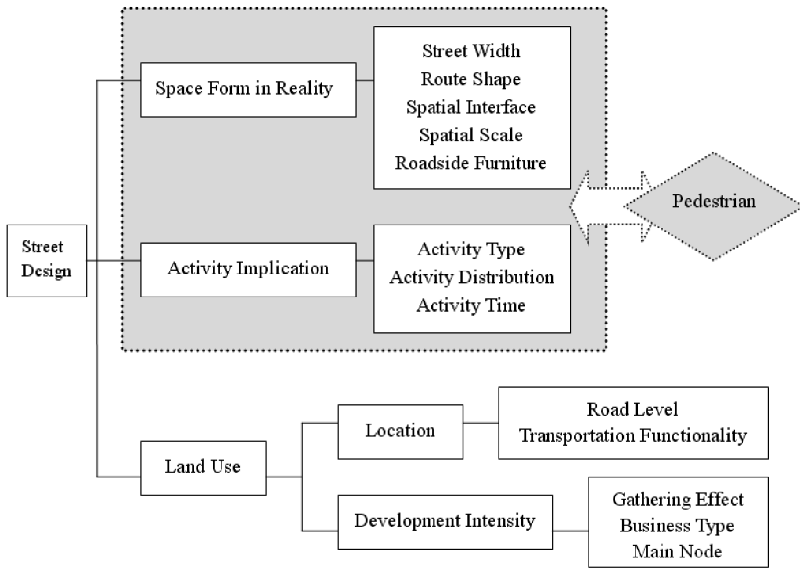


Figure2. Major Factors in Street Design: Grey Area Highlights the Scope of this Study

Speaking as a whole, the more perceptible stimuli good streets can provide for pedestrians, the more they can satisfy pedestrian needs. The messages with which the elements in street design present have an important role in the meaning of environment communication and behavioural rules. This study has divided the messages in the environment into three categories:

(1) Fixed-feature elements: these elements, such as architectural shops, roadside furniture, street lights, etc., are basically more stable; the organization of this type of elements not only defines the physical size or scale, but may also conceal another meaning; in Taiwanese street space, the columns of arcades under buildings may have the function of advertisement to attract pedestrians' attention.

(2) Semifixed-feature elements: these elements include many types such as any moveable objects; in Taiwanese street space, many semifixed-feature elements, including clothing displays, commercial boards, plants, display windows, outdoor café, street vendors, etc., not only expresses personalities, but also presents hidden functions; the use of these elements in the classification system of cultural meanings represents not only apparent function, but also hidden environment implication with complicated messages that attract pedestrians' attention.

(3) Nonfixed-feature elements: these elements indicate the pedestrians with different poses, facial expressions, incidental eye contacts, and other non-verbal behaviours in the street space.

3.1 OBSERVATION AND ANALYSIS OF PEDESTRIAN BEHAVIOUR MODE

This paper concentrates on famous Taiwanese commercial-recreational street (see Figure 3) as the subject of observation and simulation. The environment is observed through realistically monitors pedestrians' behaviour modes; the recording and analyzing means include diagram and note making, photo shooting, videotaping, and others that are indirect. The main observation techniques are two folds: (1) follow and photograph the subjects for important stop points (tracking observation); (2) videotape subjects within a certain space on streets (fixed-point observation). The chief purpose for these two techniques is to observe interactions between pedestrians and street environment and to ask them what they were thinking when perceiving messages signal by the environment.

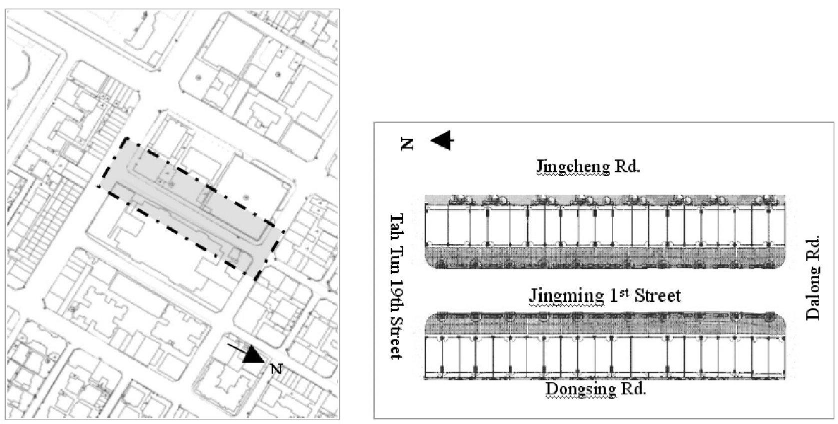


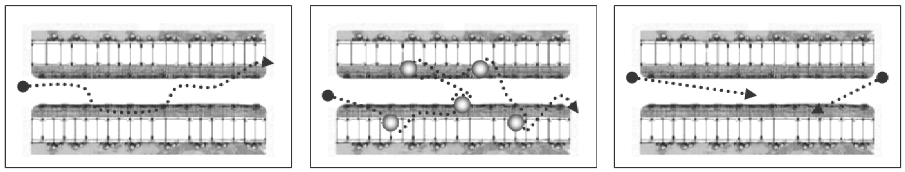
Figure 3 Jingming 1st Street

Three movement modes can be inferred based on observation of pedestrians' moving traits and destinations:

(1) Motivation and destination are unclear with random moving trait and indecisive direction and route; see Figure 4 (a).

(2) Destinations are distributed as pedestrians make selections and decisions upon receive of attractive activities and can change destinations during the movement process; see Figure 4 (b).

(3) Motivation is simple and straight so that pedestrians' behaviours reflect direct movement mode to destination; see Figure 4(c).



(a) Random Movement (b) Scattered Destinations (c) Single Destination
Figure 4. Pedestrian Movement Modes on Streets

3.2 AGENT BEHAVIOUR

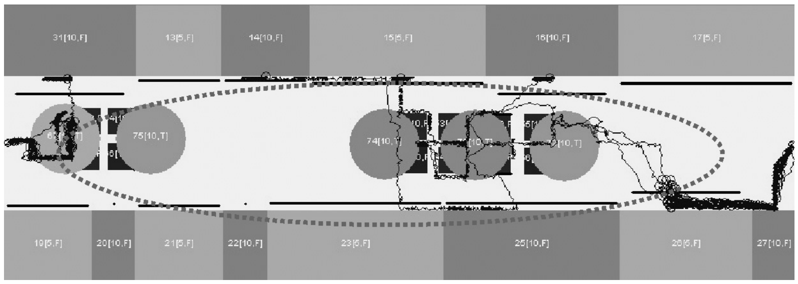
Based on the analyses, this research considers pedestrians on streets as computer agents that follow three movement modes in the system model. For the first mode, the reactive-agent wanders randomly without stops. For the second mode, the proactive-agent presents its destination selecting abilities of stopping and moving that avoids collisions with objects in the environment regardless of whether the agent is heading in some direction or approaching certain objects. For the third mode, the motivate-agent searches the environment with a set destination and heads for distant yet interesting matters with a higher speed. The study embeds agent based rules and attributes into the model just described and forms a so-called Agent-Based Street Simulator that mainly discusses how design factors in urban street space can influence pedestrians' behaviours. The following sections verify the feasibility of this model by simulation.

4. Simulation Experiments

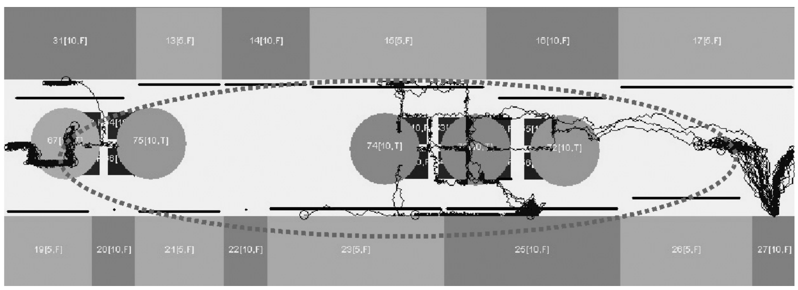
To validate the suitability of simulating pedestrian activities such as window shopping and movement modes by the system model that have been developed in this study, the following case studies that test the effects of different space activity factors and their associated positions on pedestrian behaviours are mainly focused on activities generated in street space.

4.1. OUTDOOR CAFÉ SEATS AND WOODED RECREATIONAL AREAS ON PEDESTRIAN SIDEWALK

The simulation time is set to be 30 minutes with 50 proactive-agents that have a step distance of 30 centimeters and a comfortable radius of 100 centimeters in respect to other agents during movements. Two entrances are located at left and right, respectively. The simulation results are shown in Figure 5.



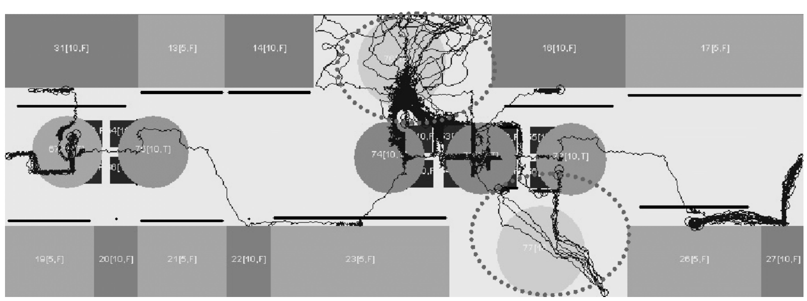
(a) Setting of a 10 m Horizontal Distance of Visibility and a 90 Degree Visibility Angle



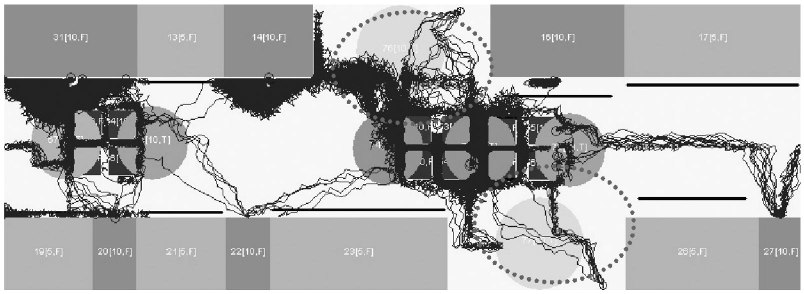
(b) Setting of a 30 m Horizontal Distance of Visibility and a120 Degree Visibility Angle
Figure 5. Outdoor Café Seats and Wooded Recreational Areas on Sidewalk

4.2. OUTDOOR CAFÉ SEATS AND WOODED RECREATIONAL AREAS ON PEDESTRIAN SIDEWALK WITH TWO SECONDARY ENTRANCES

The simulation is set to be 50 proactive-agents that have a step distance of 30 centimeters, a horizontal distance of visibility of 30 meters, a visible angle of 120 degrees, and a comfortable radius of 100 centimeters in respect to other agents during movements. The simulation results are shown in Figure 6.



(a) Time: 30 minutes



(b) Time: 60 minutes

Figure 6. Two Secondary Entrances

5. Discussions and Conclusions

Comparing the simulation results in Figure 5 (a) and (b), agents are found to have different levels of attention due to different destinations and motivations and a larger visibility angle and horizontal distance of visibility. Because of these factors, agents would in principle, choose the primary activity locations in advance and decide for the secondary activity locations during the course of primary activities.

By examining the simulation results in Figure 6, business types, space forms, and crowd gathering locations are found to be the affecting factors for the agent distribution. The line-like distribution indicates that agents are likely to generate activities of shopping or passing through the street. The area-like distribution suggests that the streets provides for crowd gathering space. Furthermore, when shop display areas contain setbacks to allow for small plazas or when major business activities take place, agents are more likely to be attracted. In other words, visible attentions in the environment can be seen as indirect guides to attributes of space structures; the more attractions are given, pedestrians are relatively more purposeful in space usage.

We adopt an empiricism approach for generating reactive path following based on the pedestrian examples of the desired behaviour. The examples are used to build the agent of the desired reactive behaviour. Although, there are important issues to be considered as to what people want to do and what information is keep on them. However, the exploration through our empirical studies of agent behaviour in real environment is undertaken and some limitations were pointed out. We implement scenario founded in the pilot studies as computer scripts in the agent-based interfaces. In such attempts, the work will contribute to the further understanding of the effects of specific interventions and their potential to achieve desired changes in user mobility, behaviour and perception.

Acknowledgements

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