THE DESIGN OF AN INTERACTIVE SCENARIO-BASED AGENT SIMULATOR FOR SUPPORTING THE EARLY STAGES OF URBAN DESIGN

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Abstract. Recently, urban planning has largely placed the user at street as the centre of infrastructural design, with significant implications for the perceived attractiveness of user environments. The urban designers faced with the task of designing such spaces, needs a tool that will allow different designs to be compared in terms of their attractiveness as well as their effectiveness. Therefore, this paper applies the selective attention theory and establishes a pedestrian behavior model that embeds the behavior-based rules and attributes of an agent. We call this simulation platform to be an agent-based street simulator (ABSS). Through experiments and verifications on cases of real-life urban streets, the system and its applications, and major findings are reported.

Keywords. attention theory; street design; agent; behavior; pedestrian

1. Introduction

The movements of pedestrians in urban settings and their space cognition behaviors are important study topics when urban designers are involved in urban planning and analysis. Generally speaking, pedestrians' activities and space selections are affected by their understanding of the environment information and past space experiences. Therefore, how do pedestrians proceed in space selections in a complex urban environment? During space selection, how do pedestrians' understandings on the environment affect their decisions on space selection? These are interesting issues that merit special attention. Space cognition researches are concerned about the ways that individuals acquire, organize, store, and recall information, which include locations, distances, and the space arrangement of the physical environment. Through insights on individual space cognition, designers are able to identify the unique mechanism that an individual reflects on the environment. This identification helps designers understand what factors within the urban space have critical effects on individuals' space selections.

Through overviews on past documents that discuss urban pedestrian movement space selection, most discussions are under the field of individual continuity space selection. This type of researches mostly utilizes the gravity model with the embedment of Markov chains to predict pedestrian movements (Borgers and Timmermans, 1986, 1987). Nevertheless, this type of model mainly elaborates on the positions between regions, but not individual space selection. In addition, this type of model usually assumes that the individual has complete information regarding the surrounding environment. In reality, however, people's different understanding of the environment, based on each person's level of cognition, would cause great differences between research results and real-life circumstances. This inadequacy has led to an alternative research approach that employs cognition to understand the processes of how individuals make decisions. These model development concepts are to base the behavioral

selections in the environment as foundations and to make decisions through perception consideration and preference forming. The above points have encouraged the research inspiration that studies the effects of pedestrian space cognition on space selection. From the perspective of individual pedestrians, the paper refers to the attention theory and integrates both the urban street design knowledge and the agent-based simulation model; see Figure 1. The theory model of this paper consists of three parts: the urban street design, the agents, and the attention theory. The focus of this model is on individuals' space cognition and selection processes that can later be transferred to individual differences in environment space cognition. It sees each pedestrian as a computer agent that can react to the surroundings based on its environment cognition. With assigned unique attributes and parameter values for all agents, the model can then be simulated by affecting each agent's individual movement.

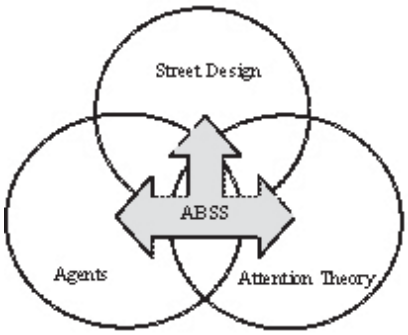


Figure 1. Theory Model

2. Related Studies

2.1. SELECTIVE ATTENTION THEORY

Among many stimulating factors in the environment near us, only a few would enter the brain through our sensory organs for more exquisite processes. Attention is the main mechanism during this selective process for that filters out most stimuli and only concentrates on the few related ones for high-level cognitive processes or reactions. British psychologist Broadbent (1958) proposed the filter model of attention to explain an individual's message filtering process, including a selective filter, a limited-capacity channel, and a detection device. He thinks that attention is a selective filter and considers the human mind to be a message processing and communicating system that uses attention as a filter to shut out unwanted stimuli and perturbation. For the sense of sight, attention is a very important message processing mechanism; psychologist Berlyne(1965) have once pointed out that humans and animals are mostly interested by matters that are not too simple yet also not overly complicated. Only subjects that are slightly more difficult or complicated than an individual's experiential capabilities can they attract a person's attention. In other words, if attention is to be increased, the motivation associated to the attention needs to be enhanced. In addition, human cognition to the external environment is conveyed through sight for about 80% of the time (Merrill, Hammons, Vincent, Reynold, & Christensen, 1996). The sense of sight allows us to know the environment distances and human activities. Even though some sight messages have characteristics that are easier to be received by the sight system, not all messages are received at the same level since the perception of the external environment is not static.

Consequently, this paper considers that the movement of pedestrian in an urban area is a model of perception and reaction. During spatial movements, pedestrians will constantly search the surroundings by senses and perception and change their positions. During this constant process, the two phases of sensing and perception are dissimilar: sensing is of a lower level

phase that relies on sensory organs such as sight, hearing, taste, smell, etc to receive external messages while perception is of a sense-based phase that does not rely solely on real-life stimuli. Thus, perception is most likely an integration of many senses. Studies on how pedestrians understand and integrate the stimuli in the environment and their consequent perception during the process of perception have mostly been focusing on senses of sight, hearing, and movement detection. In other words, when conducting researches and observations on searching behaviors, the stimulating factors in space can affect the accuracy of the results. As a result, this paper defines the term, selective attention, to be information after the receiving of stimulating messages and selective recognition. More specifically speaking, selective attention causes pedestrians process partial information after the perception. This dimension is more important than other dimensions for that they have different weights in significance. Explicitly saying, the movement perception in the sight space is the base of this paper, which discusses pedestrians' curiosity and their consequent movements upon the receiving of urban stimuli by selective attention. The method that the system detects pedestrians' stop points during their movements will also be in accordance with this movement perception.

2.2. AGENT TECHNOLOGY

Pedestrian simulation is included in the city simulation part of architecture and is the reference for certain objectives or projects that build a complex yet accurate virtual environment in a computer program. Earlier researches of crowd simulation have mostly focused on the maximization of real-time system efficiency; recent researches have begun to discuss the problem of inadequate in-depth studies on individual behaviors. For example, when agents can be completely alike humans, large-scale movement simulations are likely to have decreased chances of uncertainties and more reliable results. In crowd simulation, a single agent represents the basic unit of the whole system; the behavioral capability of this single unit in turn determines the realism and complexity of the system. With vivid external body functions, agents have an internal decision making process that forms the basis for the external behaviors. Thus, the agent in this study can perceive street environment and select an action to counter-affect the environment. Figure 2 explains the perception and evaluation process of an agent before the initiation of its actions. In the figure, perceiving is performed through receive of environment stimuli whereas actions are the agent's ability to counter-affect the environment. The agent at one hand is reactive to stimuli and at the other is proactively moving toward destination based on the different degrees of stimulation.

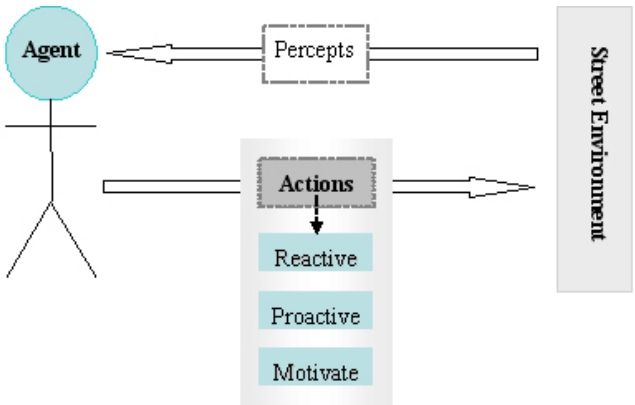
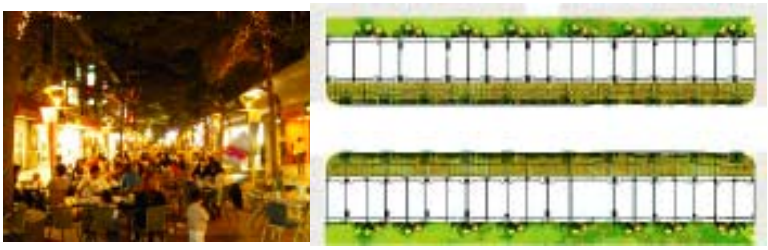


Figure 2. Agent Actions and its Perception and Evaluation Process

3. Research cases on streets

A popular shopping street, Jing-Ming Street in Taiwan was chosen as an experimental environment for the research. The site is about 50m by 130m large, and 40 shops are located, mainly offering fashion products (12x foods, 5x drinks, 6x shoes, 14x clothing, 1x electronics, 2x small department stores), see Figure 3. The attraction of the street is strongly related to the people movement and street activities. There are various kinds' activities namely, walking, people-watching, eating, relaxing, chatting, gathering, and performing along the street.



(a) street plan (b) Human in the shopping street

Figure 3 Jing-Ming Street in Taiwan

3.1. SPATIAL DESIGN FACTORS OF URBAN STREETS

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 behavioral 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 less variable; 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 ass any moveable objects; in Taiwanese street space, many semifixed-feature elements, including clothing displays, commercial boards, plants, display windows, outdoor caf , street vendors, ect.

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

3.2 OBSERVATION AND ANALYSIS OF PEDESTRIAN BEHAVIOR MODEL

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.

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

(3) Motivation is simple and straight so that pedestrians' behaviors reflect direct movement mode to destination.

Based on the above analyses, this paper 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 either 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 (ABSS) that mainly discusses how design factors in urban street space can influence pedestrians' behaviors.

4. Agent-based street simulator (ABSS)

The simulation interface in this paper is developed with Java programming language; for simplicity of presentation, we have used the mechanism of Applet for that only the webpage is required for the program usage. The entire system design organization is as the following five models: Basic Settings, Time, Scene Settings, Agent Settings, and Simulate; see Figure 4. For function mode, E, in the figure, users can configure street scenes and perform simulations.

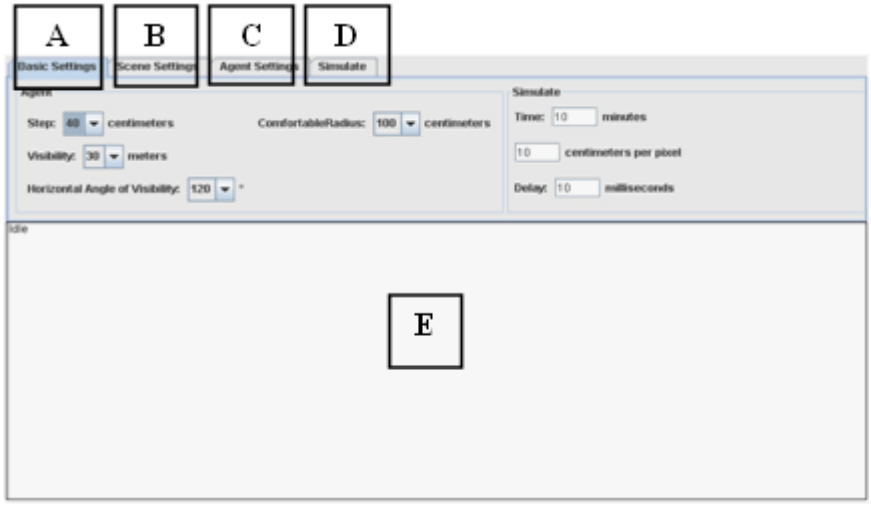


Figure4. ABSS System Interface
http://hk.geocities.com/chiunghuichen/AgentApplet.html

The following describes the functions of each function mode:

- **A:** Basic Settings mode allows configuration of agents' pace, horizontal visible sight distance, visible angle, movement courses, and comfortable radius between other agents.
- **B:** Scene Settings mode allows construction of activity incidents, stimulate, and primary and secondary entrances for multiple streets in the street environment that includes mainly two categories of real and virtual factors. For positions or locations of shops, roadside furniture, wooded recreational areas, fountains, plazas, food vendors, and crowd activities, the configurations of sizes, shapes, and whether or not they can be passed through can all be separately handled.
- **C:** Agent Settings mode permits three types of agent, namely, the reactive-agent that displays green movement traits, the proactive-agent blue, and the motivate-agent red. The numbers and the value of movement speed per minute for each type of agent can be separately configured.
- **D:** Simulate and Time modes allow the system simulation time to be equivalent of real-life time.

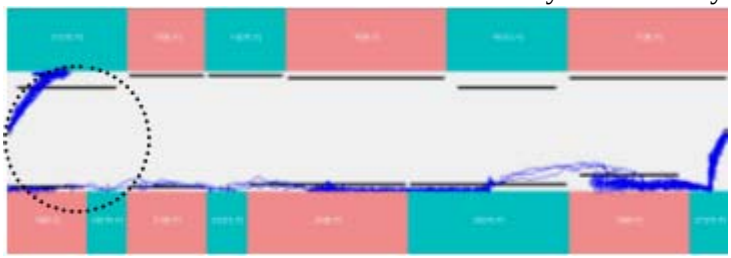
5. Results and discussions

To validate the suitability of simulating pedestrian activities, the following case studies that test the effects of different space activity factors and their associated positions on pedestrian

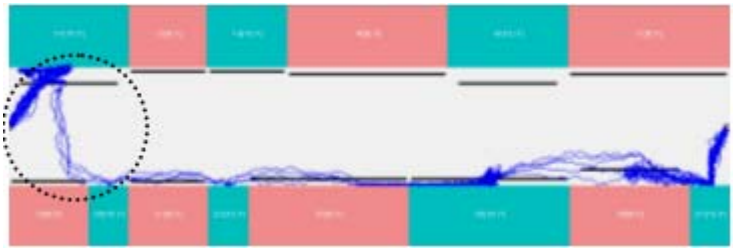
behaviors are mainly focused on activities generated in street space. The simulation time is set to be 30 minutes with 50 proactive-agents that have a step distance of 30 centimeters and a comfortable radius of 100 centimeters in respect to other agents during movements. Two entrances are located at left and right, respectively.

- NO FACILITIES ON OUTDOOR PEDESTRIAN SIDEWALK

Comparing the simulation results in Figure 5 (a) and (b), agents are found to change their course of directions when their horizontal distance of visibility and visibility angle increase.



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

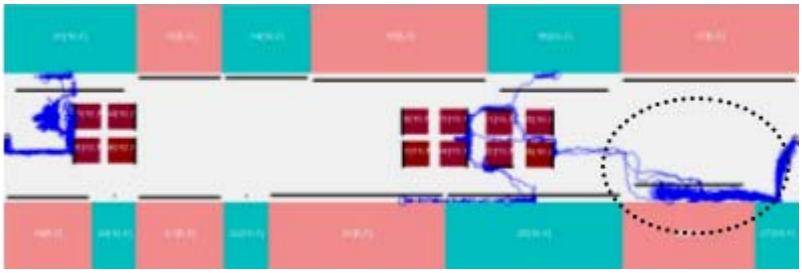


(b) Setting of a 30 m Horizontal Distance of Visibility and a120 Degree Visibility Angle

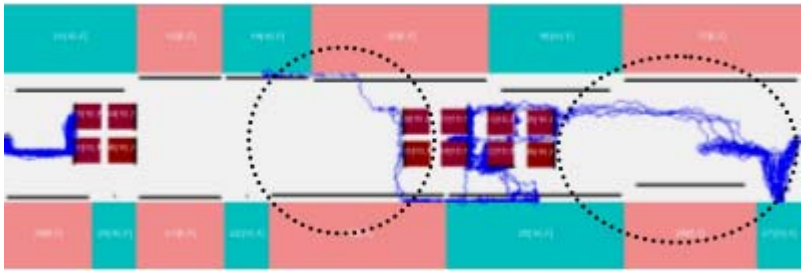
Figure 5. No Facilities on Outdoor Pedestrian Sidewalk

- OUTDOOR CAF SEATS ON VIRTUAL PEDESTRIAN SIDEWALK

Comparing the simulation results in Figure 6 (a) and (b), agents are found to have a larger visibility angle, a longer horizontal distance of visibility, a consequently higher change of arriving at the destination, and consequently less used time. As a result, their stopping time spent with activities at the destinations is increased, too.



(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 6. Outdoor Café Seats on Virtual Pedestrian Sidewalk

Simulation results have shown that agents have a decision sequence when they walk on streets; agents' previous decisions are thought to also affect later decisions. When sectioned by activity type, agents' activities are divided into three categories of shopping, stopping, and passing through. Shopping behaviors are likely to be line-like distributions or partly point-like and partly area-like distributions that are easy to generate activities. Stopping includes behaviors of shopping, waiting, or resting, and it can be variable with respect to time. Comprehensively speaking, when pedestrians select locations for activities, they would evaluate beforehand between factors of activities' spatial connectivity, activity positions, and movement effort. The method of evaluation is firstly use the knowledge and experience of space, in combination with identifiable objects in the environment, to recognize directions and secondly refer to facility and activity attraction levels in the street environment. Afterwards, agents would then form shopping activities based on shop attraction levels and select for other activity locations based on these shopping activities. That is to say, pedestrians' stop points and stop period in the street space are affected by each location's level of attraction.

The behavioral simulation model that has been developed in this study can be applied in other fields of study; designers can adjust the relative attributes of the parameter controlling agents through system interface. However, the settings of behavior types and parameters are still not fully objective. Further developments on the value testing of certain objectives are considered to be worthwhile. Furthermore, each agent's behaviors can be parameterized to adjust different modes that are targeting at different subjects. The interaction between multiple agents in the scenes is something worthwhile for more development and discussion; multiple layers of interaction would create more research details of system structure that not only include the completion of agents' self tasks, but also the decision makings of communications between other similar entities nearby.

Acknowledgements

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