ORGANISATION OF PEDESTRIAN MOVEMENTS: An Agent-based Approach

ANANDAN KARUNAKARAN
Architect & Urban Designer
Singapore.

Abstract: Cities are becoming more complex in this digital era due to technological changes. Thinking of cities without such technological changes is equivalent to an embryonic state in the morphology of city growth, that is, the growth seems less advanced. So it is appropriate to think of the non digital city digitally.

Urban design is one state which establishes the perfect relationship between the street, people and building. The relationship of the people with the building and street is becoming one of the key factors in architecture. It has been observed that the design of a city has been influenced by the pedestrian movement. Many cities prior to the industrial era were largely determined by the social interactions based on walking. Thus the pedestrians play a key role in the formation of the city. They are a very important component in any representation of transport movements. They generally terminate or initiate a chain of linked activities, and if observed carefully, a single pedestrian movement is meant to include various sub journeys from one location to another. In order to organize pedestrians, we need to understand the pedestrian movement system. Though there is a lot of development of urban models in this aspect, it is still in a nascent state in comparison with the digital advancement. Thus much research work is carried out which can be applied to any given environmental setting, and as a result urban designers can respond to the changing socio-cultural technologies.

1. Introduction

The New Urbanism which is focusing on contemporary engineering and architectural designs is now effective in incorporating the daily traveller into a non-automobile centred transportation scheme. Thus interest in pedestrian facilities has been renewed.

In this context there is a need to provide fervent transportation professionals and urban designers with standards and guidelines by which pedestrian-oriented facilities can be evaluated in an undemanding manner.

With the advent of digitalization, there is an increasing research going on to upgrade methods of urban design analysis. There has been a progressive analysis about the random series of road traffic since 1934. The first classic publication by two British scientists, Light hill and Witham in 1955, entitled *“A theory of traffic flow on long crowded roads; on kinematics waves”* describes that there exists a shock waves and density waves in the road traffic in a relatively easy way. Primarily there have been five distinctive approaches to pedestrian modelling, *like the Simple statistical regression, spatial interaction theory, accessibility approach, space syntax approach and Fluid-flow analysis*. Although there were several distinct attempts at such modelling prior to the mid-1990s, in actuality these attempts were sporadic and there was never enough momentum for the field of pedestrian modelling to takeoff.

All these modelling styles were more theoretical and were unable to provide stable, single predictions that are relevant to an appropriate scale & environment. Thus there was a need for a balanced pedestrian modelling that was both theoretically developed and practically valid.

1.1. HYPOTHESIS

(i) How do urban designers respond to the cultural values of the people with the “Change in technology for the analysis”?
(ii) What are all the advantages of digital methods?
(iii) How can the behaviours in a given environmental setting be represented?
(iv) What are the measurement criteria for the behavioural patterns of humans?

1.2. OBJECTIVE

The aim of this paper is to investigate and analyse the **self-organization phenomena of pedestrian movements using the digital approach.**

2. Organization of Pedestrians Using the Digital Approach

2.1. AGENT-BASED PEDESTRIAN SYSTEMS

The earlier research methods developed for pedestrian movement never reached the scale at which detailed predictions of walk trips might be made. In recent years, a new modelling approach has been adopted by researchers in social sciences—*agent-based modelling* (Batty, 1983). Although the origins of this technique can be traced back to the 1970s, only recently it has become sufficiently mature to have potential as a tool for practical applications. *An agent-based model is one in which* *the basic unit of activity is the agent.* Typically, a model will contain many agents (at least tens, perhaps many thousands) and their outcomes are determined by the interactions of the agents. Habitually, agents explicitly represent actors in the situation being modelled, often at the individual level. Broadly speaking, "*an agent is an identifiable unit of computer program code which is autonomous and goal-directed*" (Hayes, 1999). Agents are autonomous in that they are capable of effective independent action, and their activity is directed towards the achievement of defined tasks or goals. According to the heterogeneity of the field there is no common agreement about a definition of the term '*agent*'. We regard an agent as "*anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors*" (Frank et al.). *Agents are situated in some environment and capable of autonomous action. Thus the property of 'Autonomy' and 'the embedding of the agent into the environment' are the two key properties of agents.*

2.1.1. Generic Model

In this digital approach the agents are not necessarily spatially located or aware about their modelling environment. All the agents act as a generic model. Once the simulation modelling is completed the implications of such outcomes are broadly considered. The main concern of the researcher is only to understand the global outcomes in a generic sense, rather than in the real modelling.

Primarily four generic features that direct the pedestrian movement have been identified. One, geometric obstacles need to be negotiated to induce movement as given in Figure 2. Two, agents repel each other when congestion and crowding builds up, and three, agents are attracted to each other as seen in the flocking given in Figure 3. The fourth element relates to the desired direction in which the walker wishes to travel. A useful formulation of these ideas has been developed over several years by Helbing and his group. These four features are associated with a force that pushes the walker in a particular direction. Thus the social repulsion and attractions are all the interaction effects with other agents that are within the neighbourhood or within the relevant fields of movement. This movement technique is used where the respective components perform their function and are synchronized with the computational data that are to be made digitally operational.

Figure 1: At sufficiently high densities, pedestrians form lanes of uniform walking direction. *(Source: Environment and Planning B: Planning and Design 2001, 'Self-organizing pedestrian movement'.)*

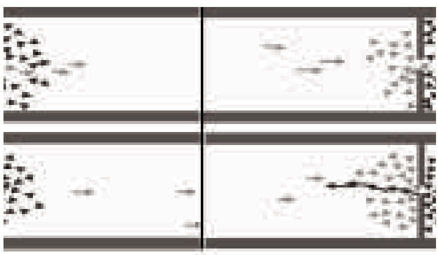

Figure 2: At narrow passages one finds an oscillation of the passing direction. When a pedestrian is able to pass through the door, normally another pedestrian can follow him or her easily (above). *However, the pedestrian stream arising in this way will stop after some time owing to the pressure from the other side of the passage. Some time later, a pedestrian will pass through the door in the opposite direction, and the process continues as outlined. (Source: Environment and Planning B: Planning and Design 2001, 'Self-organizing pedestrian movement'.)*

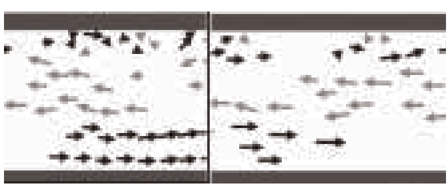

Figure 3: In crowds of oppositely moving pedestrians, one can observe the formation of varying lanes consisting of pedestrians with the same desired direction of motion. *This is also the case if interacting pedestrians avoid each other with the same probability on the right-hand side and on the left-hand side. The reason for lane formation is the related decrease in the frequency of necessary deceleration and avoidance maneuvers, which increases the efficiency of the pedestrian flow. (The positions, directions, and lengths of the arrows represent the places, walking directions, and speeds of pedestrians.) (Source: Environment and Planning B: Planning and Design 2001, 'Self-organizing pedestrian movement'.*

2.1.2. Multi Agent-based Models

Agent-based models are essentially structures in which the behaviour of a single agent or object is always a function in the system. Gradually, as this system acquire cogent data on fine-scale spatial locations and flows, it leads to new classes of models where every individual walker in the system is simulated. These are the ostensible ***multi agent-based models***.

Multi-agent systems are an emerging conceptual paradigm to simulate the interaction of multiple autonomous agents in an environment. Multi-agent systems have many applications and they can be used for computational models of independent cognizing agents in a spatial environment. In general, a system is called multi-agent if it contains at least one agent that perceives a simulated environment through some sensors, and its actions are influenced by the perceived situation in the environment. The agent should be able to act autonomously in its environment. Autonomous agents have control over their actions and internal state, i.e., the agent can act based on its own knowledge and perception. A system lacks autonomy if its behaviour is completely determined by its built-in knowledge so that it does not need to perceive its environment to decide about its activities.

3. Agents & Environments

3.1. THE ENVIRONMENT

All environments provide percepts to the agent and the agent performs actions in them. Multi-agent theory regards the environment as an integral part of the framework. In general, two classes of environments can be distinguished: artificial and real environments. Agents that are computer programs and exist in artificial software environments are called *software agents*. The general rules governing the behaviour of the environment are determined and represented by the laws of the universe. Objects in the environment are located at some position in space. In the simplest case the environment consists of at least one agent in the set of objects. The environment changes in time from one state to another depending on the modelling system and its functional program.

3.2. AGENT ARCHITECTURES

An agent constructed after the reactive approach reacts purely to its current percepts following condition-action rules. Deliberative architectures follow the classical AI (Artificial Intelligence) approach (the Sense-Plan-Act paradigm) that decomposes the control system of an agent into three elements: the sensing system, the planning system, and the execution system. The agent plans its actions based on its percepts and knowledge. The control flow between the three components is unidirectional from the sensor to the effectors.

4. Digital Simulation Technologies

4.1. SELF-ORGANIZATION AND STARLOGO

There have been many efforts in providing software platform for multi-agent simulations. Swarm (Minar et al.) is such a software platform, produced by Santa Fe Institute, for the simulation of complex adaptive systems. This software facilitates scientists to focus on research rather than on tool building. Star logo is developed from Logo as a programming language for children (Papert). The idea behind StarLogo is so-called self-organisation, i.e. organised without an organiser, and coordinated without a coordinator. StarLogo has developed this idea, and incorporated three main types of characters in the virtual world: patches, turtles, and observer as in Figure 4. Turtles are the main inhabitants of the StarLogo world. Patches are the world in which the turtles live. Patches are arranged in a grid with the original co-ordinate in the centre. One can specify the size of patches and size of the environment according to the size of the turtles. If one likes the agents to look relatively realistic, then large patches are desirable. StarLogo as depicted in Figure 4, can be regarded as a cellular-automata world with turtles roaming around on top. Both the patches and the turtles have a certain look, while the observer is invisible. The observer is responsible for creating the turtles and patches and to monitor the activities of the turtles and patches.

StarLogo is a programmable environment, which it provides a lot of procedures of patches / turtles / observer to build up various applications, for instance, for creating turtles and defining the behaviour of turtles such as heading, movement and so on; for statistical analysis involving arithmetic functions; for visualisation like colour, data input/ output and animation, etc. It also allows users to develop their own procedures.

4.2. SIMPED: SIMULATING PEDESTRIAN FLOWS IN A VIRTUAL URBAN ENVIRONMENT

The basic hypothesis is to test whether morphological structure has some impact on pedestrian movement in urban environments. To achieve this goal, a virtual urban environment with virtual humans is constructed using multi-agent simulation. Such virtual worlds offer many advantages (Resnick). In virtual worlds it is easy to create a large number of virtual humans, new sensory capabilities to the humans, and to set up and control precise experimental conditions.

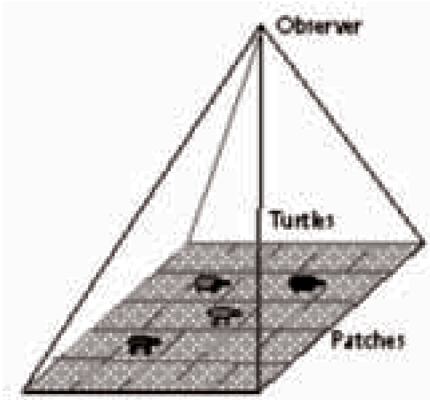

Figure 4: StarLogo – observer, turtle and patches *(Source Bin Jiang, Division of Geomatics,Institutionen för Teknik, University of Gävle, 'SimPed: Simulating Pedestrian Flows in a Virtual Urban Environment'.)*

TABLE 1. A set of instances in Sem Ped. *Source Bin Jiang, Division of Geomatics, Institutionen för Teknik, University of Gävle, 'SimPed: Simulating Pedestrian Flows in a Virtual Urban Environment'.*

Elements of Multi agent Simulations	Instances
Agents	Pedestrian behaviour speed (up / down) heading (0 - 360) movement (forward / backward)
Objects	Church, Hotel, Monument, Post office, School, Library, Park etc.,
Environments	Urban Space
Communications	Between people Between people and urban environment

Figure 5: Simulation done by the author. *It illustrates the self organization phenomenon of the pedestrian (agents) along the boundaries or the edge of the streets.*

5. Conclusion

It was pointed out that pedestrian dynamics shows various collective phenomena, for example, lane formation and oscillatory flows through bottlenecks. These and other empirical findings can be described realistically by microscopic simulations of pedestrian streams which are based on a behavioural force model. The collective patterns of motion can be interpreted as self-organization phenomena, arising from the nonlinear interactions among pedestrians.

Self-organizing flow patterns can significantly change the capacities of pedestrian facilities. They often lead to undesirable obstructions, but they can also be utilized to obtain more efficient pedestrian flows with less space. Applications in the optimization of pedestrian facilities are therefore quite natural. Eventually we should move from simulation to reality to constantly validate the results and observations and exert on further research.

Acknowledgements

I would like to express my sincere gratitude to my supervisor Dr Perry Pei-ju Yang, for his assistance and guidance throughout my paper.

References

Batty, Michael. c1983, Environment and planning B: planning and Design, London: Pion Ltd.

N.Bjorn-Andersen, M.Earl, O.Holst & E. Mumford. 1982, 'Information Society' – For Richer, For Poorer, Amsterdam; New York: North-Holland Pub. Co.; New York, N.Y.: Sole distributors for the U.S.A. and Canada, Elsevier Science Pub. Co.

Hutchinson, Bruce, Batty M. 1986, 'Advances in Urban Systems Modelling', Amsterdam; New York: North-Holland; New York, N.Y., U.S.A.: Sole distributors for the U.S.A. and Canada, Elsevier Science Pub. Co.

Castells Manuel. 1989, 'The informational city: information technology, economic restructuring, and the urban-regional process' Oxford, UK; Cambridge, Mass., USA: B. Blackwell.

Horan, Thomas A. c2000, 'Digital places: building our city of bits', Washington, D.C.: ULI-the Urban Land Institute.

Philip, Thiel. 1996, 'People, Paths, Purposes, Notions for a Participatory Envirotecture, Seattle, Wa: University of Washington Press.

Rubenstein Harvey M. c1992, 'Pedestrian malls, streetscapes, and urban spaces', New York: Wiley.

William J. Mitchell. c1995, 'City of Bits' – Space, Place and the Infobahn, Cambridge, Mass.: MIT Press.

William J. Mitchell. 2002, E-bodies, E-Building, E-Cities. Wiley-Academy produced in association with RIBA.

Tarik, A. Fathy. 1991, 'Telecity' – Information Technology and its Impact on city Form, New York: Praeger.

U. Frank, Andrew, Bittner, Steffen & Raubal, Martin. Dept. of Geoinformation, Technical University Vienna, Spatial and Cognitive Simulation with Multi-agent Systems.