Simulating Pedestrian Evacuation Using Geographic Information Technologies

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Abstract: Pedestrian assemblage is now a normal phenomenon in modern cities. To maintain an unblocked traffic situation, protect the pedestrians' safety and make preparedness for any emergencies is an important task for police department. Modeling pedestrian dynamics and simulating evacuation process can provide useful information for make accurate decisions. In this paper, by virtue of geographic information technologies, the authors proposed a conceptual framework to simulate pedestrian dynamics and evacuation in an open urban environment.
Keywords: Pedestrian, Evacuation, Simulation

1. Introduction

Pedestrian assemblage is a normal phenomenon in modern urban environment. People celebrate for victories and festivals, citizens oppose certain unfair decisions, even people go out to same destination just for relaxation, all of which will cause the large assembling of population and may result in congestions. Usually these large gatherings of people occur without serious problems. Occasionally the combination of inadequate facilities and deficient crowd management results in injury and death [4]. At the same time, the heinous terrorist attacks of September 11, 2001 has remind and attracted both researchers and officials make preparations for terrorism response, more broadly emergency response. Geography especially the new geographic information technologies will play a crucial role to policy makers in the coming year [3].

There have lot of individuals and institutes dedicated to the research of pedestrian dynamics, and their research results have been applied in the large building evacuation, fire or emergency evacuation, city-wide evacuation and parades [1][2][5][6][10]. Accordingly, there are now a few of pedestrian models or systems used for pedestrian evacuations both in buildings or open environment, such as PedGo, Egress, Pedroute, Exodus, Rampage and etc. This challenging topic attracts views from many field, psychology, architecture, transportation engineering, and also the geographic information technologies and sciences, especially the GIS (Geographic Information System), RS (Remote Sensing) and GPS (Global Positioning System). In this paper, a conceptual framework is proposed to model and simulate this behavior of pedestrian evacuation, which will provide useful information for make decisions by government departments.

2. Basic Theories

1) Pedestrian Level of Service

Often, the department of Transportation Engineering and Planning has guidelines for pedestrian planning. They define these as pedestrian level of service (LOS) that has become the standard for many subsequent building design and planning operations.

Table 1. Pedestrian Levels of Service [11]

LOS A: Pedestrian Space >=130 sq ft/ped Flow Rate: <= 2 ped/min/ft. Pedestrian move in desired paths and freely selected speed, and have little conflicts.
LOS B: Pedestrian Space >=40 sq ft/ped Flow Rate: <= 7 ped/min/ft. Pedestrian begin to be aware of other pedestrians, and to respond to their presence in the selection of walking path.
LOS C: Pedestrian Space >=24 sq ft/ped Flow Rate: <= 10 ped/min/ft. Minor conflicts will happen, and speeds and volume will be lower.
LOS D: Pedestrian Space >=15 sq ft/ped Flow Rate: <= 15 ped/min/ft. Fluid flow, considerable friction and interaction is likely to occur.
LOS E: Pedestrian Space >=6 sq ft/ped Flow Rate: <= 25 ped/min/ft. Restricted walking speed and bypass.
LOS F: Pedestrian Space >=15 sq ft/ped Flow Rate: <= 15 ped/min/ft. Flow is sporadic and unstable. Space is more characteristic of queued pedestrians.

2) Pedestrian Interaction

When pedestrians move, there are inevitably interactions or conflicts between them. While at the same

time, especially during large number of pedestrian evacuation, their behaviors are severely restricted by the whole pedestrian flow. Fig 1 has showed the basic law of pedestrian interactions.

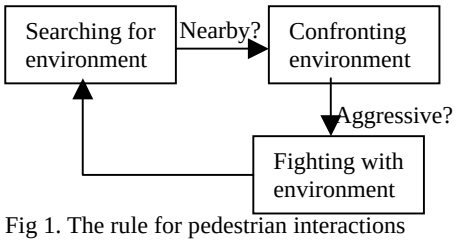

Fig 1. The rule for pedestrian interactions

The algorithm is as follows:

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if there is a pedestrian ahead
    if there is a pedestrian right or if at the right edge of road
        if there is a pedestrian left
            set speed equal to pedestrian ahead
        take over left and accelerate
    take right and accelerate
move forward
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3. Pedestrian Models and Simulating System

The basic theories of pedestrian movement are vital for modeling pedestrian evacuation, and provide guidelines for accurate decisions made by government departments. During the whole modeling and simulating process, new geographic information technologies will exert great functions. They are GIS, RS, GPS, VR technologies and other geographic analysis methodologies.

1) Research Area

Fig 2. Research Area – Tsim Sha Tsui

Tsim Sha Tsui region is a multifunctional site in Hong Kong attracting people there for shopping, sightseeing, relaxation and etc. Especially on the Seashore Pathway, many activities will be held in each holiday and large number of people will assemble there, which also bring headache to the traffic department for the traffic jams in surrounding roads or crowd safety. Recently, for recovering the Hong Kong economy shocked highly in the campaign of SARS, the Hong Kong Government has proposed a series of projects there, and the management of pedestrian crowds will be more important.

2) Data Acquisition and Management

Pedestrian movement is a kind of complex behavior. Each person has his own choice of direction, has no conversation of momentum and can stop and start at will. This walking dynamics do not follow completely the law of physics or any others. But in certain circumstance, pedestrian cannot walk by his own will, and they must form some rules. Often, the evaluation methods applied in the data collection of pedestrian behavior were based on direct observation, photographs, time-lapse films and questionaries [6]. While with the development of geographic information technologies, more methods can be used and the data is more precise. Using the remote sensing images, we can calculate the number of pedestrians precisely, and GPS can now achieve accuracies well within one centimeter and get the attribute of one person, such as speed, location, direction, and etc. Combined these new technologies with traditional ways of data collection makes more data available with higher quality.

At the same time, GIS provides a platform to collect, manage and retrieve these metadata. All the features of geographic entities will be stored in the database as points, lines and polygons. Also, different layers with different themes will be overlayed, displayed and manipulated more easily. What's more, the real-time data of pedestrian movement will be stored and retrieved in the database. All of these data are important for make analysis and decisions.

3) Pedestrian Evacuation Modeling

Multi-agent based modeling is one of the popular ways of modeling social complex phenomenon in recent researches [1][2]. An agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives.

Pedestrian evacuation is very complex and also a kind of self-organized phenomenon [6]. Using agent-based modeling, researchers have found that the complex phenomenon is emerged from simple interaction and communications (between individual pedestrians and between pedestrians and the environments they are acting on). Based on the observation result of pedestrian's movement and the pedestrian levels of service, models of pedestrian movement in the normal and emergent evacuation are created to find the law of this complex behavior. To make modeling and predicting more efficient and effective, we will make a typology on the different pedestrian crowds in terms of modeling complexity. To focus on a rapid modeling rather than programming, we will adopt existing software and programming platforms such as StarLogo and SWARM. Finally the models will be validated with observation datasets.

4) Visualization and Integrated System

We will use GIS as a basic platform and attempt to

integrate agent-based pedestrian simulation together. Fig 3 is the overall framework of this system.

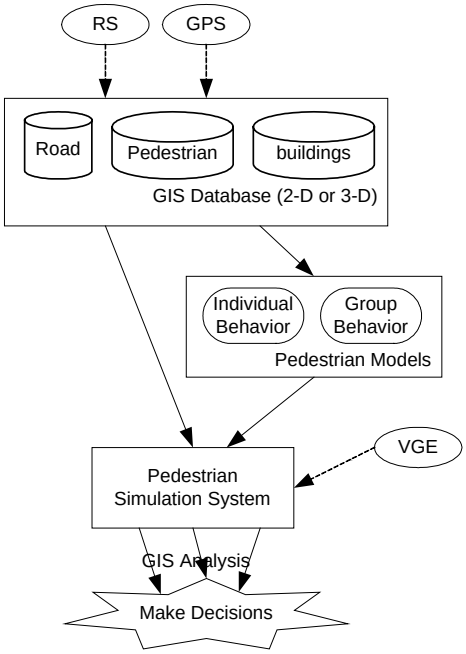

Fig 3. the framework of pedestrian evacuation

Such a system will provide an exploratory interface with which end users are able to conduct what-if modeling. Users can set the different parameters that will affect the pedestrian movement. According to the set parameters, the graphic window will show the simulated pedestrian movement or evacuation. At the same time, the analysis window will count the average speed, time, or other result of the pedestrian moving. Users also can set an activity in certain place and then observe the pedestrian activities or set one place that will ask all to evacuate as soon as possible. Through all of these simulated results, this system will provide useful information for decision makers.

As the greater need for more immersive and realistic environment, and with the rapid development of VR technologies, this system will also have 2-D and 3-D interfaces. VGE will fully engage all the users truly senses and provides full interactivity and that also, in real time. Virtual environments provide greater immersion into the world or environment of scientific data, thereby enhancing the users' perception of its features and forms, enhancing the interactivity between users and geographical environment.

5) Analysis Modules

1. **Congestion Analysis.**

One of the normal phenomena during pedestrian evacuation is the congestion. When the pedestrian density reaches the road maximum capacity, it will easily happen, which may result in worse situations. Through the real-time calculation of pedestrian evacuation, the density will be observed. At the same time, analyzing individual pedestrian walking speed also get the crowd information. When the minimum walking speed of the overall pedestrian crowds reaches 0, it also means that congestions occur likely. All of the information will suggest decision makers to take some evacuation measures.

2. **Evacuation Route Choice.**

Accurate evacuation route is vital for urban transportation and pedestrian safety. According to the real-time display of road condition, decision-makers can choose the best evacuate route or take temporary traffic control to evacuate pedestrian crowds in a short time.

4. Conclusions

This system will be useful in the management of pedestrian crowds and evacuation. Geographic information technologies provide powerful tools in collecting, managing, modeling, simulating and visualizing this complex behavior. This system will be useful for transportation planning, emergency responses and public safety. But also, it is a hard and long-time task to model, validate and integrate this pedestrian behavior.

References

[1] Batty M., 2003. Agent-based Pedestrian Modelling, *Centre For Advanced Spatial Analysis Working Paper Series*, Paper 61.

[2] Batty M., Desyllas J. and Duxbury E., 2002. The Discrete Dynamics of Small-Scale Spatial Events: Agent-Based Models of Mobility in Carnivals and Street Parades. *Centre For Advanced Spatial Analysis Working Paper Series*, Paper 56.

[3] Cutter, S. L., Richardson, D. B. and Wilbanks T. J., 2003. *The Geographical Dimensions of Terrorism*, Routledge: New York and London.

[4] Fruin, J. J., 1993. The Causes and Prevention of Crowd Disasters, Available at http://www.crowddynamics.com/Myriad/Fruin%20-%20causes.htm.

[5] Haklay M., O'Sullivan D., Goodwin M. T., Schelhorn T., 2001. "So go downtown": simulating pedestrian movement in town centres. *Environment and Planning B: Planning and Design*, 28: 343-359.

[6] Helbing D., Molnar P., Farkas I.J., Bolay K., 2001. Self-organizing pedestrian movement. *Environment and Planning B: Planning and Design*, .28: 361-383.

[7] http://education.mit.edu/starlogo/

[8] http://www.swarm.org.

[9] Papacostas, C. S. and Prevedouros, P. D., 2001. *Transportation Engineering and Planning*, 3rd Edition, Prentice Hall.

[10] Schreckenberg M., Sharma S. D., 2002. *Pedestrian and Evacuation Dynamics*, Springer.

[11] Transportation Research Board, 1997. *Highway Capacity Manual, Special Report 209*, 3rd ed., National Research Council, Washington D.C.