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FUZZY PERCEPTIONAL SPACING FOR INTELLIGENT MULTI AGENT PEDESTRIAN SIMULATION

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ABSTRACT: Multi agent pedestrian model is a very promising current research topic because it can be applied to many fields. The current multi agent pedestrian models, however, are dealing with individual movements of pedestrian under a single situation. The fact that real pedestrians behave differently under different situations, such as queuing situation and normal condition, have not been addressed by the existing models. Large numbers of pedestrians in one group behave as a platoon which has different walking speeds compared to if they walk as individuals. In this paper, we describe the idea on how to incorporate pedestrian group behavior and multi state situation such as queuing and normal state into multi agent pedestrian simulation seamlessly using fuzzy logic. As the result, by means of this simple scheme the pedestrian agents have been advanced further with capability to behave more realistically in a group or platoon behavior.

Keywords: pedestrian, group behavior, perceptional spacing, fuzzy, multi agents, queuing, platoon.

INTRODUCTION

Multi agent pedestrian model is a very promising current research topic because of its usefulness in different applications covering many areas such as evacuation (Keßel (2001), architecture (Dijkstra et al (2001)) and urban design (Jiang (1999) to military (Hughes and Turner (2002), and game development (Reynolds (1999). From a transportation and urban planning view microscopic pedestrian models are valuable for evaluation, design and planning of pedestrian related facilities such as terminal, subway stations, bus stop, parking, and shopping mall. In case of low and flat spatial ground such as in lowland cities, this model is even more suitable. In fact, the model does not include any gradient nor different level of the space.

The current multi agent pedestrian models, however, are dealing with individual movements of pedestrian under a single situation such as evacuation or normal walk or crossing. The fact that real pedestrians behave differently under different situations, such as a queuing situation and in normal conditions, have not been addressed by the existing models. Moreover, many pedestrians walk together as a group such as a couple or a family with children or walk with friends. School children who cross the school are often holding hands and walk as a group. Large numbers of pedestrians in one group behave as a platoon which has a different walking speed compared to individuals walking separately. Modeling pedestrian as an agent may broaden our view and comprehension on pedestrian characteristics. For example, different platoon waking speeds should eventually imply the proper design of traffic signal timing especially for pelican crossings in front of schools.

In this paper, we describe the idea on how to incorporate pedestrian group behavior and multi state situation such as queuing and normal state into a multi agent pedestrian simulation seamlessly using fuzzy logic. This simple additional logic not only enhances the capability of the model, but also introduces some simple intelligent characteristics into the model. As the result, the pedestrian agents behave more realistically. We therefore call the model as intelligent multi agent pedestrian simulation or IMAPS.

RELATED THEORY

Hall (1966) stated from his anthropological studies that people tend have perception of inter personal spacing that depending on the person they are related to. This inter personal spacing is affected by cultural viewpoint (some cultures may accept closer spacing), human sensory characteristics (i.e. eye, smell, hearing), age, social economic status and gender. Based on his

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study, Hall categorized space between people into 4 categories namely: public, social, personal and intimate distance. Horowitz, 1964 introduced body buffer zones that are psychological areas around his or her physical body, which if intruded upon, may produce anxiety. Fruin (1971) explained Hall's interpersonal spacing for pedestrian with some vague boundary between intimate, personal, social and public distance about 0.5, 2.0, 3.5 and 7.5 meters respectively. Beyond 7.5 meters, pedestrians usually don't care much because of sight reduction capability. In normal condition, pedestrian tend to give more priority to more aggressive pedestrians, formidable-looking pedestrians, a couple or people walk in group, elderly and handicapped.

Within the public distance, people can do non-verbal communication and detect some gesture, stance and

also done within this distance. In a pedestrian's case, they still easily can avoid body contact and this distance is also acceptable for queue, even for people that they don't know. A pedestrian can detect change of situation from normal walk to queue and change the acceptance of body buffer zone intrusion accordingly. Except in very dense queue like crowded elevator and very close friend or family members, intimate distance is usually not acceptable in normal condition. In intimate distance, people can detect the smell and involuntarily body contact is unavoidable. The sight is also distorted because of the same height.

FUZZY PERCEPTION OF INTER-PERSONAL SPACING

To interpret Hall's Inter-Personal Spacing into a multi agent pedestrian model, we proposed a transformation of the four distance category into a fuzzy set as shown in Figure 2. The threshold suggested in the figure is based on Fruin's description but it can be adjusted by users of the simulation according to the local culture and condition. The fuzzy value of intimate distance starts with the agent position up to 0.75 meter while the personal distance starts at 0.5 up to 2 meter with peak of 1.25 meter. At 1.25 meter unfamiliar person start to avoid each other, thus we can use it as the starting point of social distance. The peak of social distance is chosen to be the same distance as the beginning of public distance and the end of personal distance. The overlapping region will be decided by the maximum value.

Avoidance intention to unfamiliar people is started at public distance and getting stronger as the other pedestrian is getting closer. Within 7.5 meter of sight distance the pedestrian agent will evaluate (from surrounding density) whether the condition will change from normal walking speed to queue or remain in the normal condition. Queuing situation can be easily detected if the pedestrians within the sight distance along the path to destination have average interspacing less than 1.20 meters (or area module less than $1.2\ m^2$/pedestrian). This threshold is taken from the

Table 1. Decision table in normal condition

Social Relationship	**Personal Inter-Spacing**			
	intimacy	Personal	social	public
Family/ very close friend	keep	Closer	closer	much closer
Friend	avoid	Keep	closer	closer
Acquaintance	avoid	Avoid	keep	keep
Other people	strongly avoid	Avoid	avoid	keep
Formidable - looking	strongly avoid	strongly avoid	avoid	avoid

Table 2. Decision table in queuing condition

Social Relationship	**Personal Inter-Spacing**			
	intimacy	personal	social	public
Family/ very close friend	keep	closer	closer	much closer
Friend	keep	keep	closer	closer
Acquaintance	keep	keep	keep	keep
Other people	avoid*)	keep	keep	keep
Formidable - looking	avoid	avoid	avoid	avoid

*) depending upon density, in high density, keeps intended velocity

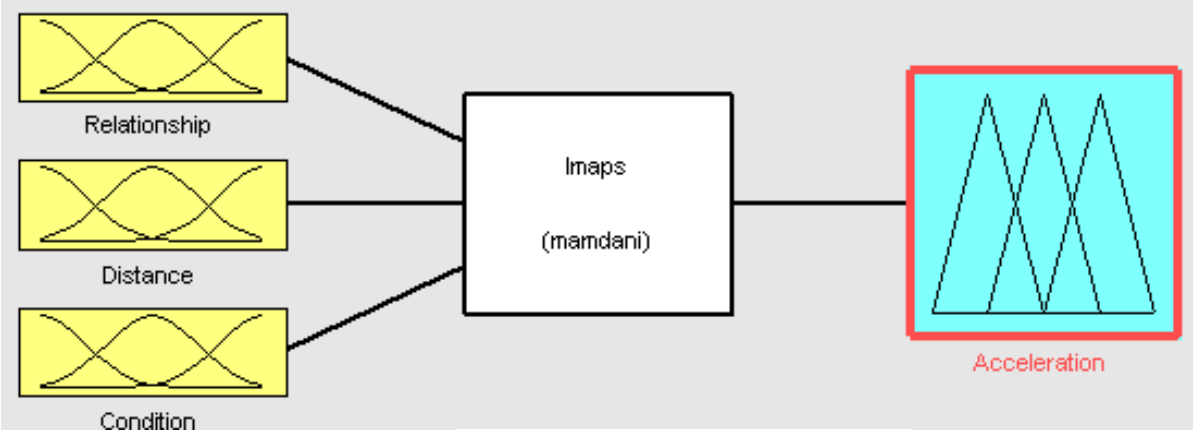

Figure 3. Fuzzy engine

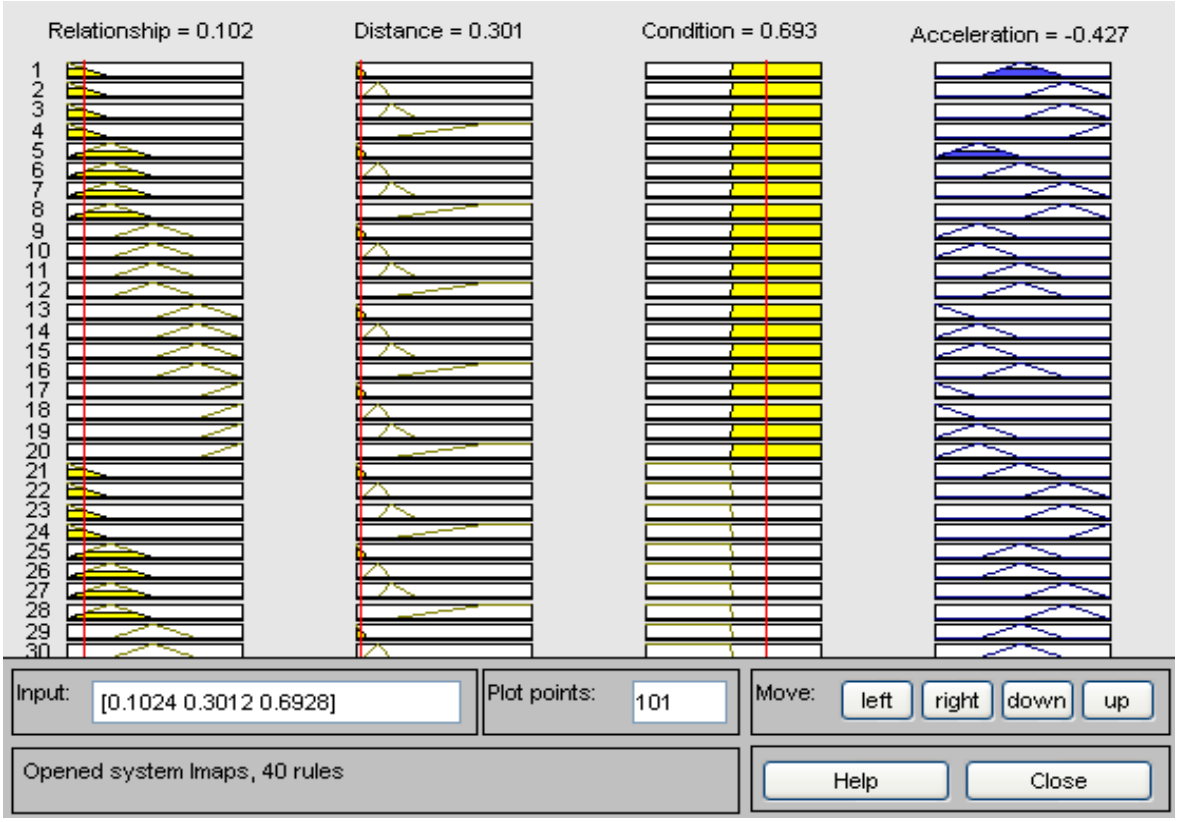

Figure 4. Fuzzy Simulation

LOS standard for queuing.

When pedestrian agent is facing a normal walking situation, the avoidance intention is getting much stronger as the distance is closer, while in queuing situation the avoidance intention is reduced except for formidable looking people. Among friends and acquaintance that walk together, personal distance between 0.75 up to 2 meter is a good choice. Stronger relationship between people tends to make closer inter-personal spacing.

For simplicity we classify 5 types of relationship between pedestrians and the decision table for each relationship with other people in group and inter-personal spacing is given in Table 1 for normal walking condition and Table 2 for queuing condition. Keeping inter-personal spacing indicate the agent will maintain

speed & direction. Avoid means that the agent will move away as far as possible, closer distance makes much stronger intention. Closer denotes move toward that person, farther distance makes greater intention. In a queuing situation, pedestrians tend to bear a closer distance up to a minimum distance.

IMPLEMENTATION

The idea of fuzzy inter-personal spacing was implemented as one of internal layers in our existing intelligent multi agent pedestrian simulation. We use Mamdani type fuzzy engine inference as illustrated in Figure 3. In total, 40 fuzzy rules were inputted for the three input fuzzy sets. Fuzzy simulation is shown in Figure 4 generated in Matlab. Figure 5 shows the relationship between distance between pedestrians (in meter) and social relationship toward the output of acceleration (in m/s^2).

SIMULATION MODEL

The simulation model can be based on a set of non-linear dynamical system representing positive and negative feedback loop (see Teknomo & Gerilla, 2005). The feedback loop is a closed loop structure that utilizes previous outcome of the past action of the system to direct the future action. In order to make the pedestrian move closer to the people familiar with, negative feedback loop is implemented to decrease the space discrepancy between the current location of the agent and the target agent. To avoid the unfamiliar pedestrian, positive feedback loop is applied. Action with positive feedback loop increases the spatial discrepancy between the current location of the agent and the target agent. Balance between positive and negative feedback loop is applied to keep the distance. In this case, the target pedestrian agent is set as equilibrium or fixed point in which the dynamical system may be repelled or attracted.

Pedestrian agents are loaded from pedestrian generator or to be set manually. The pedestrian generators give greater flexibility to set internal parameters of each pedestrian type as well as spatial location of the generator. Interspacing between pedestrian is simply as minimum distance between a pedestrian and its neighbor. The social relationships between agents are inputted by users.. In general, one pedestrian agent can be set as one pedestrian type. Then several pedestrian types can be group together to show the relationship as family, friend, or other people and certain color codes are assigned to distinguish each type. Origin and destination of each pedestrian are determined

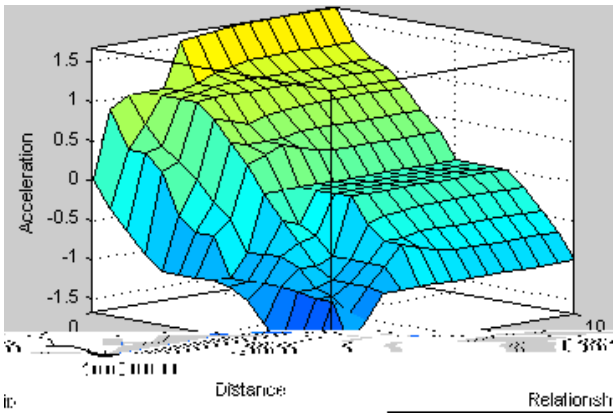

Figure 5. Surface plot of input and output of the fuzzy simulation

before hand in sequential manner while timing distribution pattern of pedestrian generation can also be specified.

CONCLUSION AND FUTURE WORKS

We have integrated multi state of pedestrian situation and pedestrian group behavior into the intelligent multi agent pedestrian simulation through the concept of fuzzy inter-personal spacing. The model is suitable for general usage including lowland cities where the ground is flat. Fuzzy rules give non-linear relationship between input and output. Closeness of social relationship is not guarantee to keep the distance. In normal condition, it will be a repulsion effect, while in queue condition, just keep the distance. By means of this simple scheme the pedestrian agents have been advanced further with the capability to behave more realistically in group and platoon behavior. We plan to investigate further the pedestrian characteristics of the platoon and applications toward pedestrian crossing signal timing for our future work.

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