A Pedestrian Agent Model Using Relative Coordinate Systems

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Summary. Pedestrian agent simulation is useful for not only the analysis of an accident but also designing pedestrians' spaces. Agent Simulation of Pedestrian Flow (ASPF) has been evolved from a CA model; ASPF uses a pedestrian agent simulator with a cell space model. However, ASPF expresses an agent's position by a cell unit, which restricts the movement of a pedestrian to only four directions; this causes unnatural behaviors of pedestrians. In addition, it does not allow individual differences in the walking speed of pedestrians. This paper is to address a pedestrian agent model – ASPF ver.3 -- using a relative coordinate system by revising ASPF ver.2, and also demonstrates the special characteristics of this model by the simulation of the intersection with straight and diagonal crosswalks in front of Shibuya Station.
The pedestrian agent model proposed in this paper allows an agent to walk in any direction and also accurately simulates individual differences of walking speed. From the simulation results, it can be shown: (1) in a pedestrian agent model where multidirectional flows exist, simulated behavior closely matches actual pedestrian behavior, as demonstrated by the successful modeling of a stratification phenomenon; and (2) due to the introduction of individual differences of walking speed, a trial calculation of the percentage of remaining pedestrians has become possible.

Keyword. Pedestrian Flow, Accident Analysis, Relative Coordinate Systems

1. Introduction

Pedestrian agent simulation is useful for not only the analysis of an accident but also designing pedestrians' spaces. Agent Simulation of Pedestrian Flow (ASPF) has been evolved from a CA model; ASPF uses a pedestrian agent simulator with a cell space model. However, ASPF expresses an agent's position by a cell unit, which restricts the movement of a pedestrian to only four directions; this causes unnatural behaviors of pedestrians. In addition, it does not allow individual differences in the walking speed of pedestrians. This paper is to address a new pedestrian agent model using a relative coordinate system by revising ASPF, and also demonstrates the special characteristics of this model by the simulation of the intersection with straight and diagonal crosswalks in front of Shibuya Station.

2. Existing Pedestrian Dynamics Studies and the Feature of this Study

Pedestrian dynamics studies aim at explaining that pedestrian flow's macro phenomenon is emerged from the accumulation of the individual pedestrian's micro motive, and many existing models of the pedestrian dynamics had been reported especially on the boundary of about 2000 (Schreckenberg & Sharma, 2001). In this section we describe the feature of our model type here while comparing with the existing typical models especially focusing on the difference of continuity and discreteness on walking-space expression and agent's behavior rules and so on.(See Table 1).

Although the actual walking space is continuous, there are two categories of the model types:--the models with xy continuous coordinate system and the models that use the discrete cell-grid--, in existing models for pedestrian dynamics. Helbing et.al (1991) can be representative for the former types. His theoretic model is expressed an equation of acceleration vector for a pedestrian's walk, which is composed of the social force and the unique factors. The social force is expressed as an accelerating force, boundary repulsion power, and the interaction among other pedestrians.

In the latter types, there are cellular automata (CA) and other models that use cell spaces derived and extended from CA (for examples, Fukui &. Ishibashi, 1999, Muramatsu et.al, 1999, Burstedde et.al, 2001). Blue and Adler's model (2001) is an typical example of the cell space models. It is a tendency that the sizes of the cell of these type models are converging into 40cm each side though time slices are various in the recent researches. Further literatures are surveyed by Kaneda (2004).

Cell space models use a set of discrete condition rules for expressing a pedestrian agent's move, corresponding to others agents' locations information. This kind of cell space models is very useful, so we also adopted a cell space model in our study.

The author's laboratory had been dealing with the modeling of pedestrians' shopping-around behaviors for some years and early in the summer of 2001, we started to study the modeling of more basic pedestrian flow with the aim of trying out the performance of an agent simulation software [1]*2); in recent years the usefulness of the software has been significantly improving.

In July while designing a model, a tragic pedestrian accident occured at Akashi City Firework Festival; articles of the event and speculation of the causes were given in the press. These articles became the basis for ASPF ver.1 of the software program which was published in December; the program examined high density

[1] KK-MAS by Kozo Keikaku Engineering Inc., Japan

pedestrian flow in an L-shaped corridor and was modeled on the Asagiri Station Pedestrian Overpass (Kaneda, Yano, et.al, 2003), In January 2002, Akashi City published an accident report – ex-post facto inspection –(Akashi City, 2002) revealing further detailed information, which was then used to review and improve ASPF ver.1, reconstruct the situations of the accident and led the revision into ASPF ver.2. The simulation analysis of this program was published in February 2004 (Suzuki and Kaneda, 2004).

However, there is a fault that he/she acts fundamentally only in four directions of the orthogonalization because of the restriction of the cell grid though he/she decides the action.

In this study, in order to simulate the pedestrians' behaviors for free-angle directions, we aim at revising this model into ASPF ver.3 that have walking space model with a relative coordinate system of xy-coordinate. In this system, each agent keeps the direction of walking in his/her internal model and the conditional rules of the pedestrian behaviors that had been developed as a cell space model. This is a 'hybrid' model. These devices enable the model to simulations on multi-directions of the pedestrian flows.

Table 1. Typical models of pedestrian agent

Pedestrian Dynamics Models	Helbing (1991)	ASPF ver.3 (2005)	Blue, Adler (2001)
Space Represenation	XY-coordination system (Continuous)	XY-coordination system (Continuous)	Cell-Grid (Discrete)
Agent's Behavior Mechanisms	Vector Equations (Continuous)	Conditional Rules (Discrete)	Conditional Rules (Discrete)
Behavior Modes	Two (Ordinary, Panic)	One (Ordinary)	One (Ordinary)
Case Study Target	Mainly Two-Directions (Confronation Flows)	Multi-Directions	Mainly Two-Directions (Confronation Flows)

3. A Pedestrian Agent Model Using Relative Coordinates Systems

This model – ASPF ver.3 -- proposed in this paper is a revised ASPF ver.2 model. The spatial scale is represented by cells with 40 cm each side and the time scale is set at one step per 0.5 second. The following new agent rules are implemented:

(1) As shown in Fig.1 and Fig.2, in order to enable agents' behaviors of 360' directions, a relative coordinate system of cell space corresponding to the walking direction has been introduced for pedestrians; under this condition ASPF ver.2 pedestrian behavior rules (Fig.3) are then applied to the model. This has enabled the same pedestrian behavior rules to even be applied to pedestrians walking in different directions.

(2) It is commonly known pedestrians walk at different speeds and within a base casual distribution of average speed 1.34 m/s and a standard deviation 0.26 m/s (Henderson (1971)). Each agent is given the proper walking speeds within these parameters. Adjustments from integer to real number of forward cell movements are also made in order to represent individual differences of walking speed.

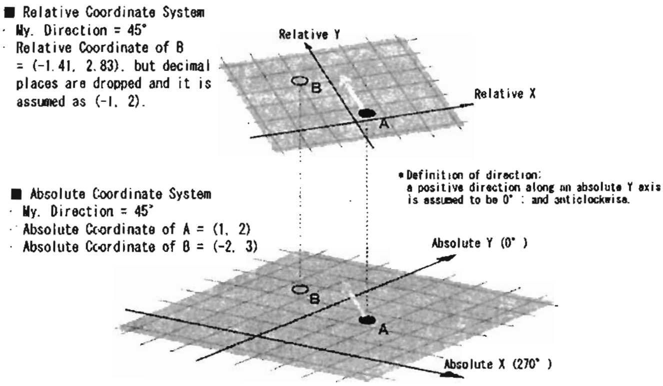
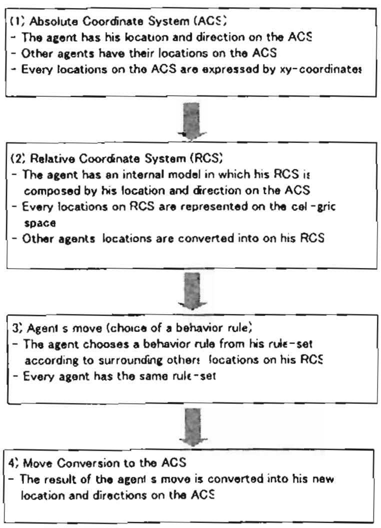


Fig. 1. Digramic Explanation of Relative Coordinate System



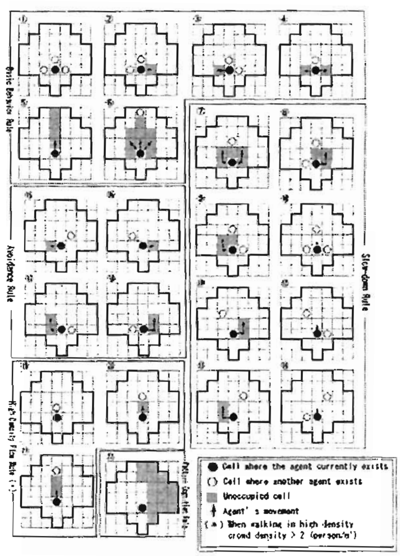


Fig. 2. Outline of Conversion between Coordinate Systems (left)
Fig. 3. Pedestrian Behavior Rules of ASPF ver.3 (right)

4. Simulation of a 'Scramble' Intersection with Straight and Diagonal Crosswalks

4.1 Target Area for the Simulation

In order to show the characteristics of the designed model, the crosswalk on a 'scramble' intersection in front of Shibuya Station was turned into a model. The 'scramble' intersection is a crossroads where traffic lights allow pedestrians to cross in any direction simultaneously. According to an on-the-spot survey, the signal cycle of the intersection is about 140 seconds. A corresponding signal control rule was introduced into the model. Fig. 4 shows a simulation algorithm. Fig. 5 shows a typical weekday evening at the Shibuya station intersection. According to the survey, at this time about 600 pedestrians are on the intersection; at an evening holiday time the number was found to be double, about 1,200 pedestrians.

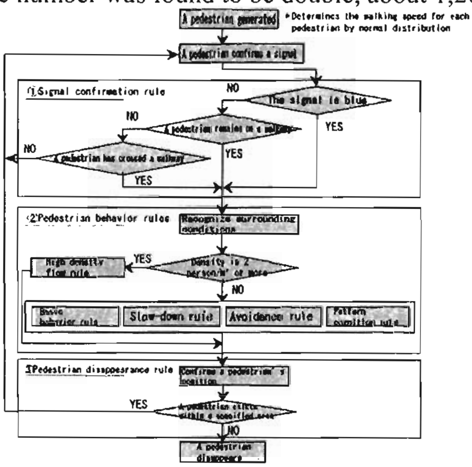
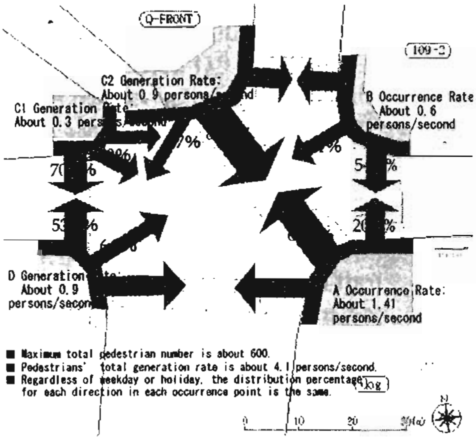


Fig. 4. Simulation Algorithm of ASPF ver.3

4.2 Simulation Outline

Based on the survey results, a weekday evening is taken to be the base case with an assumed pedestrian arrival ratio of 4.1 persons per second. The arrival ratio for a holiday evening is assumed to be double, about 8.2 persons per second. In addition, to simulate an extremely crowded situation caused by a special event for example, the arrival ratio is assumed to be 4 times the base case, giving a figure of 16.4 persons per second. The simulation focused on changes in crowd density levels and the number of pedestrians who remain at the intersection, as well as a validation check of the model. Fig. 6 shows the areas for density measurement.



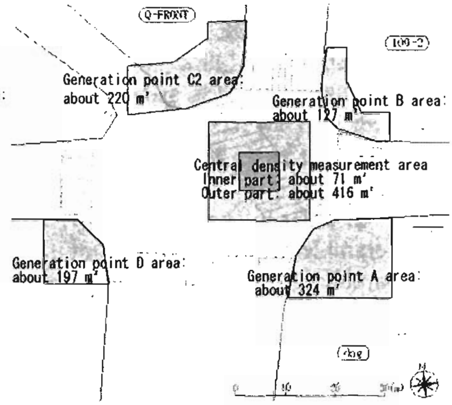


Fig. 5. Observation Results (for a Weekday Evening) (left)
Fig. 6. Density Measurement Area (right)

4.3 Results of the Simulation

Fig. 7 shows the pedestrian flow at the central part of the intersection with a holiday evening flow of double the base case. The appearance and disappearance of a stratification phenomenon between the confronting pedestrian flows can clearly be observed. Fig. 8 shows a timed change of the crowd density for each area and for the three different evenings; weekday, holiday and event cases. For each evening the maximum crowd density was measured within the inner part of the central density measurements area; for an event evening with 4 times the base case, the density substantially exceeded the critical standard of 2.0 person/m^2. In this case, the pedestrian flow speed decreases and when the pedestrian crossing signal changes from blue to red, the number of pedestrians remaining on the intersection becomes extremely large. In addition, even on a weekday and holiday evening with base case and double the base case arrival ratios, although the crowd density did not exceed 2.0 person/m^2 in any area, pedestrians still remained on the intersection. These simulation results were also observed and confirmed by the on-the-spot survey taken at the intersection. For reference, the maximum total number of pedestrians and the percentages for the remaining pedestrians on each simulated and surveyed evening are shown in Table 1.

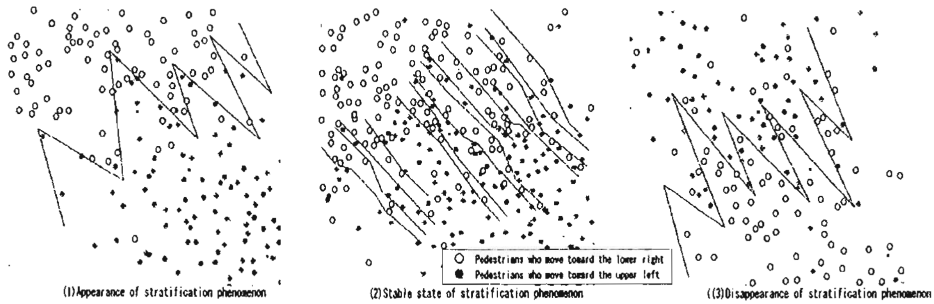


Fig. 7. Stratification Process in a Simulation

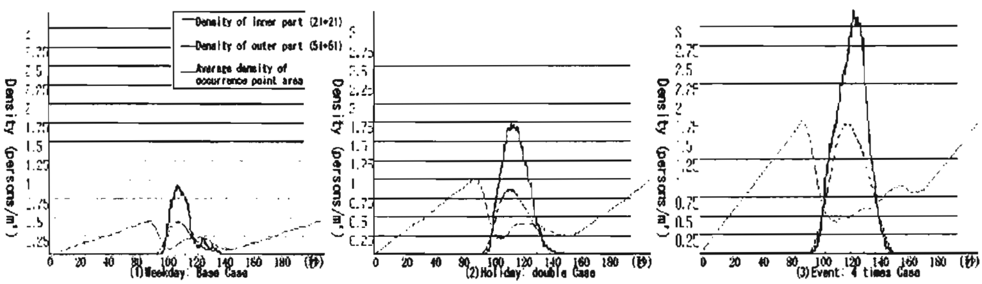


Fig. 8. Density Measurement Results

Table. 2. Percentage of Remaining Pedestrians

	Base Case	Double Case	4 times Case	Observation on weekday evening	Observation on holiday evening
Estimated number of remaining pedestrians	30	120	550	80	180
Estimated total number of pedestrians	580	1250	2250	600	1200
Percentage of remaining pedestrians (%)	5.17	9.60	24.4	13.3	15.0

4. Conclusion

The pedestrian agent model proposed in this paper allows an agent to walk in any direction and also accurately simulates individual differences of walking speed. From the simulation results, it can be shown: (1) in a pedestrian agent model where multidirectional flows exist, simulated behavior closely matches actual pedestrian behavior, as demonstrated by the successful modeling of a stratification phenomenon; and (2) due to the introduction of individual differences of walking speed, a trial calculation of the percentage of remaining pedestrians has become possible.

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