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# Adding Higher Intelligent Functions to Pedestrian Agent Model


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**Summary.** Pedestrian dynamics studies have brought the potential for application to a wide variety of urban planning field, not only crowd accident risk analysis but also simulation-oriented spatial design. Our up-versioned ASPF (Agent Simulator of Pedestrian Flows) ver.4 has newly introduced higher function such as a target maintaining (Helmsman) function, a route-choice function etc. into a pedestrian agent. In an example case of patio-shaped shopping mall, Asunal Kanayama, we have verified that pedestrian agents can walk autonomously along way points to destination points in a complicated space, and that ASPFver.4 can be a useful tool for ordinary commerce space design. We also refer to the ASSA (Agent Simulator of Shop Around) project for implementing much higher functions.


## 1 Introduction

Pedestrian dynamics studies have brought the potential for application to a wide variety of urban planning field, not only crowd accident risk analysis but also simulation-oriented spatial design in corporation with the progress of agent technology. Our ongoing project ASPF (Agent Simulator of Pedestrian Flows) that derived from Cellular Automata model has been up-versioned step by step. In a previous paper, ASPFver.2 had demonstrated a crowding process on a L-shaped corridor, as a model of the Asagiri overpass accident of 2001 [1].

By using a flexible agent modeling platform artisoc (former KKMAS), ASPFver.3 adopted a hybrid style of discrete (cell space)-based behavioral rules on continuous (xy-coordinates) space, so each agent can walk in any direction across the restriction of grid [2]. However, in this version, a pedestrian agent still merely walks straight ahead and simply avoids other agents, and it was impossible to analyze crowd flows on a large-scale space with a complicated shape. Therefore, in ASPFver.4, some higher functions are required such


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as Helmsman and route-choice functions, etc. These functions were suggested by an existing research.

Following this context, this paper first explains artisoc briefly that supplies a pedestrian modeling platform, next it explains the features of ASPFver.4 that simulates Multipurpose MultiStop (MPMS) trip behavior of shopping visitors in an example case of a patio-shaped shopping mall. We also refer to a new project ASSA (Agent-Simulator of Shopping-Around behavior) to deal with much higher functions of shopping visitor agent.

## 2 Pedestrian Modeling Platform for Hybrid Space Representation System

In ASPFver.3 or later, the relative coordinate system is used for space representation. In this system, each agent has his/her own cell space based on walking direction and applies a cell-based behavioral rule. As the random sequential update is adopted, they all interact on the real one continuous space without conflict. This system is a hybrid representation of discrete (cell) and continuous (real) 2D space, thus each agent is allowed to move in any direction of 360 degree. This is a useful feature comparing against only four direction moves in a pure CA-derived models (Fig. 1). In this section, we address an agent modeling platform artisoc (former KKMAS) that realizes this system easily.

### 2.1 Introducing Artisoc

Artisoc is an agent based simulator which is designed for applications in mainly social science fields [3]. The key features of artisoc are an ease of model complex building and modeling capability and an ability to link with other applications. artisoc simplifies the modeling processes; the user interface is designed in a way that allows intuitive adding and editing of agents. Also, the behavior rules for agents are written in BASIC language thus behaviors of agents can be easily described. In addition, the mapping outputs and chronological graphs of the simulation results can be easily defined in only a few steps. In order to initiate complex modeling, artisoc is designed with a capability to define freely multiple spaces, agents and variables.

When linking with other applications, artisoc is designed with a network link function which corrects information from a web servers while running a simulation, and with a database link function which acquires values from databases, too. When building large scale models, artisoc has a distributed execution function which enables rapid modeling by linking multiple PC's. It also has log function which saves calculation results in a database and can execute a high-speed playback.



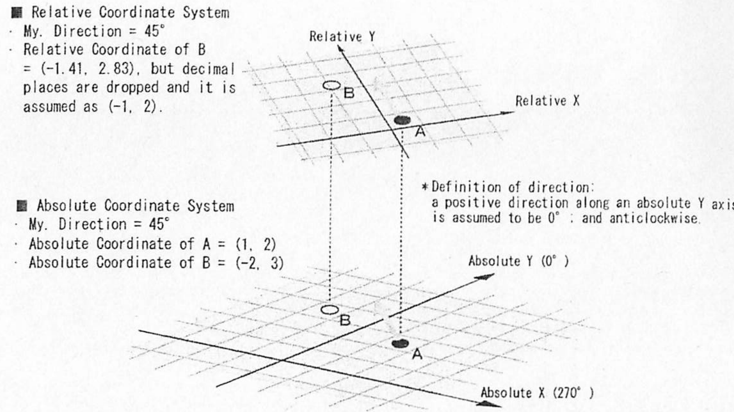


**Fig. 1.** Hybrid space representation of ASPFver.4.

## 3 ASPF(Agent Simulator of Pedestrian Flow) ver.4—Implementation of Autonomous Pedestrian Agent

ASPFver.4 has inherited the basic design of the previous version. The spatial scale is represented by 40 square cm cell and the time scale is set at one step per 0.5 seconds. The pedestrian agent's 'cell-to-cell' conditional behavior rules are also taken from the previous version, 6 basic behavior rules, 8 slow-down rules, 4 avoidance rules, 3 high density flow rules and 1 following rule. In addition, 14 wall avoidance rules were newly designed to avoid a wall. The relative coordinate system in that each agent behaves on his/her own cell space based on walking direction and the interaction on the real continuous space is also inherited. This is called 'Mover' function, but a pedestrian agent still merely walks straight ahead and simply avoids other agents and obstacles.

Thus, the second basic function, the Helmsman (target maintaining) function is introduced. This function refers to a function that firstly determines the direction of movement towards a given (visible) target and secondly by regularly reconfirming the location of the target correcting any difference of directions between movement and target; such differences may occur because of behavior to avoid other pedestrians and walls while moving towards the target.

In addition, in a large-scale and complicated shaped space, there is no guarantee that a destination can be always confirmed visually; in this case, a list of way points which satisfy the visual confirmation conditions from the starting point to the destination is given in advance and a pedestrian agent walks along the list of the way points. The target mentioned above is either the final target destination or a way point. Update of the target means that agents regularly confirm whether they are closing on their target and when they arrive in the neighborhood of the target, they update their target to the next one.

In ASPFver.4, the following parameters were set: confirmation to maintain a target was carried out every 10 steps, target update was confirmed every 2 steps by checking whether they were located within the 2 cells from a way point.

In order to simulate pedestrians' shop-around behavior in a complicated shape shopping mall, we need to find the route to move from a shop to another shop. This is called 'Route chooser' function. In ASPFver.4, on a given visible way point network, each agent has to search the shortest route by Dijkstra method. It implies all agent have knowledge on shop location, etc. [4].

We had studied the actual mall, Asnal Kanayama, as a case. Firstly, by using data of visitors' behavior research which was conducted in the previous year, we created a list of shop-around facilities from research data by attributes. Then, this time, as an expedient, we aggregate a 'between-shops' Origin–Destination (OD) matrix, and form the OD transition probability matrix. Visitor Agents decide the next destination probabilistically. This is also 'Planner' function as an expedient.

In ASPFver.4, pedestrian agent behaves in the following order: (1) decide the next destination; (2) set a route; (3) maintain the target; (4) apply behavior rules; and (5) update the target. Table 3 shows each feature of Mover, Helmsman, Route chooser, and Planner functions comparing to a functional layer suggested in the STREETS project [5, 6] (Table 3).

Here, the target maintaining function was demonstrated. In a cross-shaped space, 40 cells in road width, opposing flows with a flow coefficient of 0.5 person/m · sec were generated from both sides (right and left), and after the number of pedestrians had become steady, three crossing pedestrians were generated from the lower part and the locations of these pedestrians were examined (Fig. 2). Target maintaining behavior by agents crossing a pedestrian flow from two different directions was confirmed. We can see that the agents kept holding their target destination by correcting their direction though he/she had drifted by the flows. Moreover, in this study simulations were tested in

| Layered-modules proposed by STREETS project | | Implementations in ASPFver.4 |
|---|---|---|
| Higher | (5) Planner | Choice of the next destination by given transition probability matrix |
| | (4) Route Chooser | Optimization by Dijkstra method (rational model) |
| | (3) Navigator | Not implemented (necessary in dark/panic cases) |
| | (2) Helmsman | A way point-check and direction modification each ten steps |
| Basic | (1) Mover | Existing functions of ASPFver.3 (hybrid space representation, 22 rules and proper speed) |

**Table 1.** Functional features of ASPFver.4 in comparison with STREETS project.



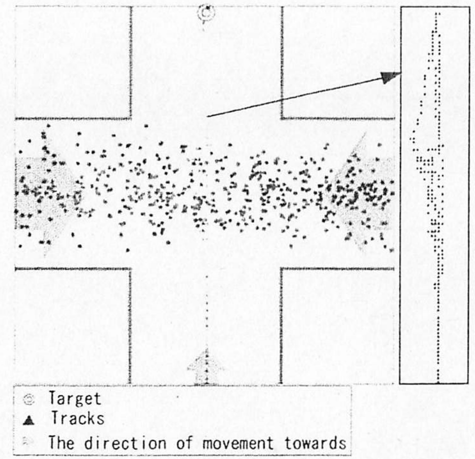


**Fig. 2.** Performance of Helmsman function, ASPF ver.4.

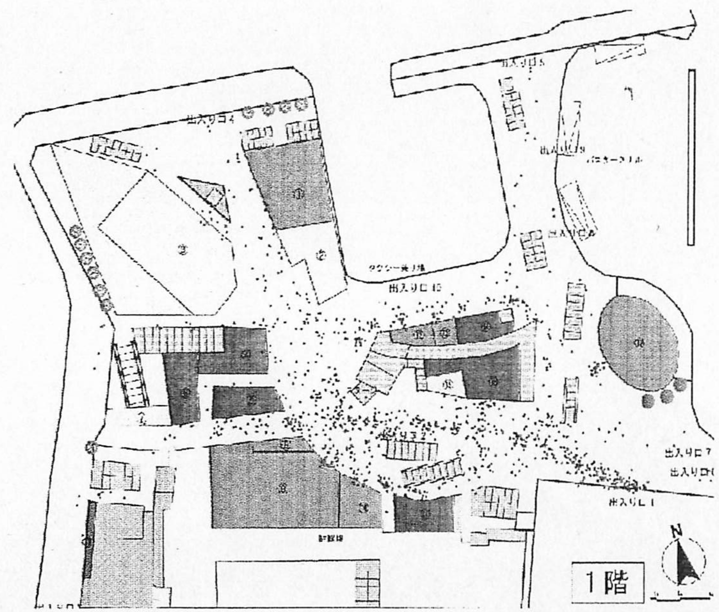


**Fig. 3.** Snapshot of pedestrian flows in patio-shaped shopping mall.

case of relationship between density and speed with a straight movement flow and in an L-shaped corridor. The same results as in the previous version were confirmed.

Figure 3 shows a snapshot of a pedestrian flow simulation on Asunal Kanayama. Based on measurements of crowd densities of four different simulation cases ((1) weekday case, (2) weekday double case, (3) holiday case, and (4) at time of a music event in holiday case) the performance of ASPFver4 was also verified. Due to a series of these version-ups, we can conclude that ASPF is now available for analyzing crowd flows and density in space with complicated shapes.

## 4 Concluding Remarks—ASSA Project as Further Study

ASPFver.4 has newly introduced a target maintaining (Helmsman) function, a concept of way point (target), and a route-choice function for searching a route (list of way points) to visible/invisible destinations by using a Dijkstra method. So, ASPFver.4 enables each agent to walk along a list of visible target 'way points' towards a destination by keeping directions to each of the targets against the crowd flows. Moreover, MultiPurpose MultiStop (MPMS) shopping behaviors are expressed by Origin–Destination (OD) transition probability matrix, a still simple planner function. In comparing with the functions that had suggested by the STREETS project, (1) Mover, (2) Helmsman, (4) Route-Chooser, and (5) Planner functions are implemented, thus it is enough to be a useful tool for ordinary commerce space design.

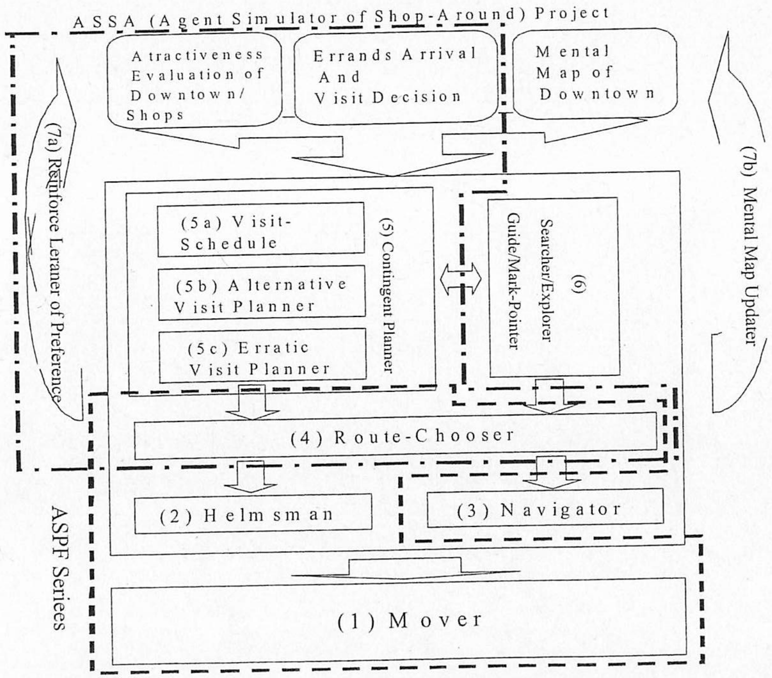


**Fig. 4.** Diagram of 'adaptive' pedestrian agent model.



We have also illustrated an example case of patio-shaped shopping mall, Asunal Kanayama, 150 m × 100 m scale, 11 entrances/exits, 19 shops on ground floor, 105 way points and 7,656 sets of the route. An OD transition matrix is based on an actual survey on the visitors' Shop-Around behaviors. In this case, we have verified that pedestrian agents can walk autonomously along way points to destination points in a complicated space by setting way points in appropriate locations and a fixed OD transition matrix.

From the viewpoint of real shopping visitors, fixed OD transition probability is a too strong assumption, because they have neither historical memory, schedule planning nor ad-lib behaviors. So, the authors have started a new agent development project, ASSA (Agent Simulator of Shop Around). Features of ASSA are to implement schedule planning function, contingent re-scheduling function, and adaptive learning function on shop-preference etc. Our further research includes an integration of ASPF and ASSA (Fig. 4).

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