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A Participant Stream Model in Event Site Based on Multi-Agent System with Interaction between Walking Participants and Queues

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Abstract– This paper proposes a model of the participant stream in an event site, based on the multi-agent system. The event site has the participants and the booths. The booth provides the service for the participant. The participants visit the booths, and they form the queues besides the booths. We consider the interaction between the walking participant and the queue. The walking participant has a field of view, and it plays an important role to avoid the collision with the queue whose length changes dynamically. The behavior of our model is demonstrated by the calculation using a simple example.

1. Introduction

In the fields of the information technology and machine learning, the term "agent" means the subject which determines its action, based on the knowledge collected from its environment [1]. The Multi-Agent System (MAS) consists of the agents which have influences on each other. Each agent has its state and action rule, and it executes the action determined by them. The agents have interactions between them which are caused by their actions, and the interactions have influences on the states of the agents. Recently, the many researchers have proposed models of the pedestrian stream [2] and the vehicular traffic flow [3], based on MAS.

We consider a model of the participant stream in an event site. The event site has the participants and the booths. The booth provides the service for the participant. The participant walks the event site to receive the service, and it visits the booths. As a result, the participants form the queues besides the booths.

Suzuki and Arita have proposed its model, and they have examined the effects of the information sharing with the portable terminal devices on the congestion of the participants [4][5]. They have focused on the case where the congestion is not so heavy: the site is large enough, or the participants are not so many. Therefore, they have neglected the volume of the queue besides the booth for the simplification, and they have examined the change of the queue's length. Their simplification is valid in this case, but the interaction between the walking participant and the queue is not considered.

In this paper, we focus on the case where the congestion is so heavy, and we propose a model of the participant stream. If we construct a framework to predict the participant stream in this case and to evaluate it before the event is held, it will contribute to the safety of them in an event site. We do not neglect the volume of the queue, and we consider the interaction between the walking participant and the queue. The walking participant has a field of view which plays an important role to avoid the collision with the queues, the other walking participants, and the obstacles. As a result, the walking participant avoids the collision with the queue whose length changes dynamically. The basic behavior of our model is demonstrated by the calculation using a simple example.

2. Participant Stream Model in an Event Site

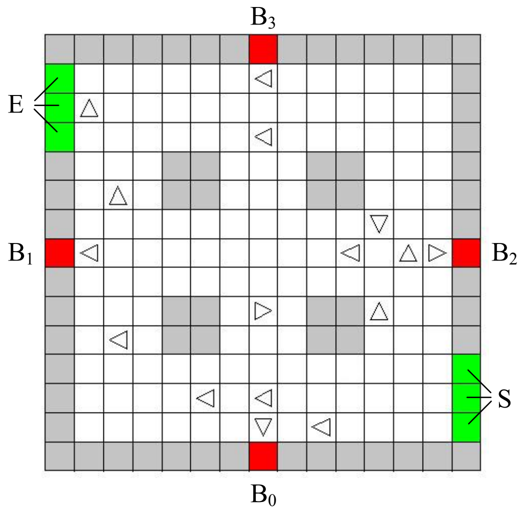
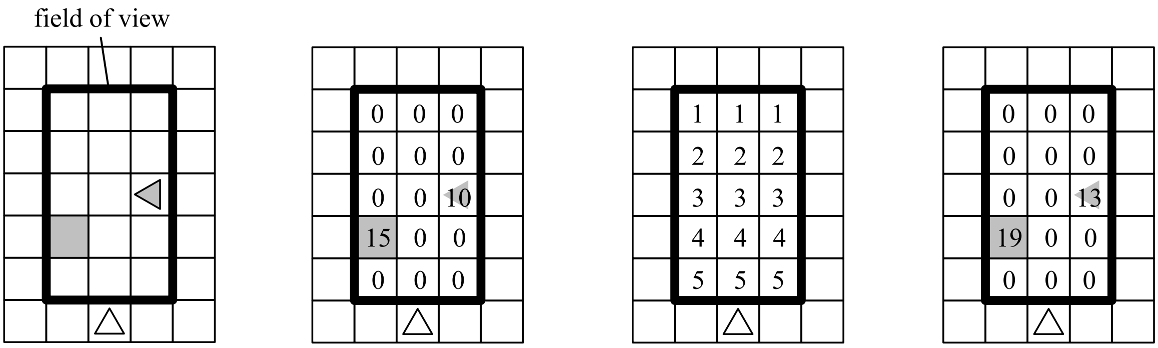


Fig.1 The model of an event site.

Fig.1 shows the model of an event site. This model consists of the stage and the agents. We refer to the unit square in the stage as "the grid". The stage has five kinds of grids: normal grid (white), no-entry grid (gray), start grid S, end grid E, and booth grid B_i where the suffix i denotes the booth number. S and E represent the entrance and the exit in this site, respectively. The triangles mean the agents. The agent represents the participant in the event site. Each agent has the agent number. The agent has its direction which is selected from the top, the bottom, the left, and the right in this figure. The agent changes its direction and goes a grid ahead in a step. The agent starts from S, it visits B_i which is specified by the list



(a) (b) (c) (d)

Fig.2 field of view for the agent.

explained later, and it arrives at E. If the agent arrives at E, it returns to S.

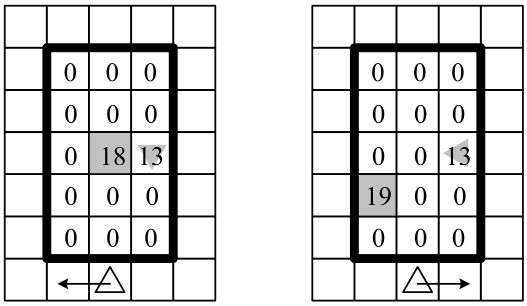
The agent is permitted to enter all grids except the no-entry grids, and the booth grids. The no-entry grids represent the obstacles. The booth grid provides the service to the neighboring agent. The agents want this service and they form a queue beside the booth grid. We give the place of the queue and "service time" to each booth grid. This service time is the time which is required for the service to the agent at the top of the queue. Letting N_S (i) denote the service time of B_i, this value is independently given in each booth grid. Each agent has a list which shows the booth grids to visit and the order of them. We refer to this list as "the list to visit". If plural agents are in a grid at the same time, we regard this situation as "a collision between the agents". If the agent enters the no-entry grid, we regard this situation as "a collision with the no-entry grid".

In this system the algorithm can be briefly described as the following:

(1) All agents select the action.
(2) If the collision occurs as the result, the involved agent selects the action again to avoid it.
(3) All agents execute the action.

In the selection of the action, the agent has two modes: pedestrian mode and queue mode. In the pedestrian mode, the agent follows the list to visit, and goes to the tail of the queue of the booth grid. In the queue mode, the agent becomes a part of the queue, and it is not influenced by the agent in the pedestrian mode. In the pedestrian mode, the agents determine the action in order of their agent number. In the queue mode, the agents determine the action in order of the booth number and the queue of each booth.

We explain the agent's selection of the action in the pedestrian mode. Let (x, y), and (x_p, y_p) denote a candidate of the place where the agent moves to, and its destination at the time (the booth grid or the end grid), respectively. (x, y) is calculated by the following formulae: If $|x_p - x| > |y_p - y|$ then $x \leftarrow x + \mathrm{rsgn}(x_p - x)$, otherwise $y \leftarrow y + \mathrm{rsgn}(y_p - y)$, where the value of $\mathrm{rsgn}(v)$ is randomly selected from $\{1,0,-1\}$ with a given small probability ε, while it is determined by $\mathrm{rsgn}(v) = 1$ for $v>0$, 0 for $v = 0$, and -1 for $v<0$ with the probability $(1 - \varepsilon)$.



(a) (b)

Fig.3 Selection of the action in the agent.

If the agent selects the candidate of the place, agent's move is not completed, but its direction at the time is determined. Each agent has "field of view" in the direction. The field of view is the region in which the agent can find the no-entry grids and the other agents. Fig.2 shows the agent's field of view. In this paper, the field of view has three grids wide, and five grids long in front of the agent (see Fig.2 (a)). If an agent finds the no-entry grids or the grids in which the other agent is in its field of view, this grid is dangerous for the agent. We define "the degree of danger" as degree of the urgency to avoid the collision. In this paper, we assign the no-entry grid, the grid in which the other agent is, and the other grid to the degree of danger 15, 10, and 0, respectively (see Fig.2 (b)). Also, the bias of the degree of danger is assigned the grid in the field of view beforehand (see Fig.2 (c)). As the distance from the agent increases, the bias becomes the smaller value. The agent adds the degree of danger in Fig.2 (b) to its bias in Fig.2 (c), and it resets the sum to zero in the grid where the degree of danger in Fig.2 (b) is zero (see Fig.2 (d)).

The agent evaluates this result. Letting Th_E denote the threshold of the sum in this evaluation, the agent finds the grid where the sum is greater than Th_E and it has the largest value in the field of view. The agent's selection of action depends on what this grid is. Fig.3 shows the examples at $Th_E = 12$:

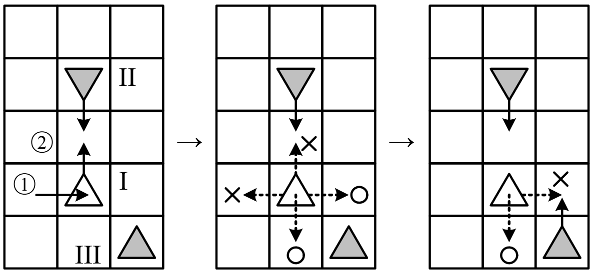


Fig.4 Reselection of the action in the agent.

- If this grid is the no-entry grid, the agent selects the action according to the following procedure:
  If the no-entry grid is in front of the agent, even if the grid does not neighbor on the agent, the agent selects the action from among the right-hand side and the left-hand side, in order to leave from the grids (see Fig.3 (a)). Otherwise, the agent does not avoid the no-entry grid.
- If the other agent is in this grid, the agent selects the action which is the opposite one of the other agent (see Fig.3 (b)). In Fig.3 (b), the no-entry grid has the largest value of the sum in the field of view, but this grid is not in front of the agent. Therefore, the agent selects the action to avoid the collision with the other agent.

In the following two cases, the agent does not try to avoid the collision with the other agents, because the collision does not occur actually:

(a) The agent follows the other agent.
(b) The other agent looks toward the outside of the agent's field of view.

The above procedures determine a candidate of the place where the agent moves to. If the candidate of the place is the no-entry grid, or if it is the same as the other agent's one, the agent has not avoided the collision yet. In this case, the agent follows the following procedures (see Fig.4):

1. The agent checks its action which causes the collision, and the previous action (see Fig.4 (a)).
2. Based on the combination of these actions, the agent determines the order of the search of the place where the agent can move to (see Fig.4 (b)).
3. The agent executes the search in the order determined by 2.
4. If the agent cannot avoid the collision by the move to the searched place, the agent searches the next place in the order (see Fig.4 (c)).
5. If the agent cannot avoid the collision by the move to all searched place, the agent abandons the move and stays there.

Next, we explain the action of the agent in the queue mode (see Fig.5). If the agent arrives at the tail of the queue of the booth grid specified by the list to visit, the agent changes the pedestrian mode into the queue mode. At the top of the queue of B_i, the agent stays there for the service time N_S (i)-steps. After that, this agent changes the queue mode into the pedestrian mode, and it leaves from the queue. Simultaneously, all agents left in the queue move a grid to B_i. After the agent leaves from the queue, it goes to the next booth grid specified in the list to visit.

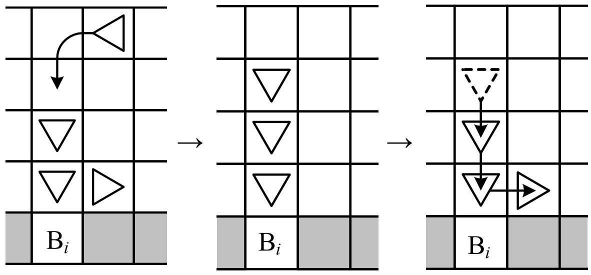


Fig.5 The action of the agent in the queue mode: (c) is $N_S(i)$ steps after (b).

3. The Agents' Behavior

We demonstrate the behavior of our model by using the stage in Fig.1. This stage has 4-booth grids, and the booth numbers are i = 0, 1, 2, and 3. We use 64-agents, and the agent numbers are j = 0, 1, 2, …, 62, and 63. Let 1-booth be described in the list to visit of each agent.

The agent-j starts from S, and it arrives at E via a booth grid B_i which is specified by $i = j$ (mod 4). For example, if j = 6 then i = 6 (mod 4) = 2. The service times of the booth grids are fixed at N_S (0) = 50, N_S (1) = 30, N_S (2) = 30, N_S (3) = 50, respectively. The other parameters are fixed at $\varepsilon = 0.1$ and $Th_E = 13$. They are the common values to all agents.

Fig.6 shows the snapshots of the agents' behavior in this site. The square in the grid represents the agent which selects "staying there" as the action at the step in the pedestrian mode. In this figure, we can find that the agents form the queue beside B_0, and one of them leaves from the queue. Also as shown in Fig.7, we have observed that the agent in the pedestrian mode avoids the collision with the queue beside B_0, and it makes detour around the queue, from 40-steps to 50-steps.

We try to quantify the congestion of the agents in this model. Fig.8 shows a transition of the number of the agents in the site. The queue's volume is considered in the bold transition, while it is neglected in the fine transition [4][5]. We define the calculation of 1,000-steps as "1-set". These transitions are obtained by the average of the transitions calculated from the individual 20-sets. In this calculation, we have stopped the agent's entry to this site (the agent is placed to S) after 600-steps.

The number of the agents in this site increases till 180-steps, it almost keeps the maximum value 64 from 180-steps to 600-steps, and it decreases after 600-steps. In this transition, the decrease is more gently than the increase. The fine transition has the similar feature to the bold one. However, the decrease in the bold transition is more gently than that in the fine one. This fact relates that the agents' arrival steps to E in the bold transition have the large variance than that in the fine one. It is caused by

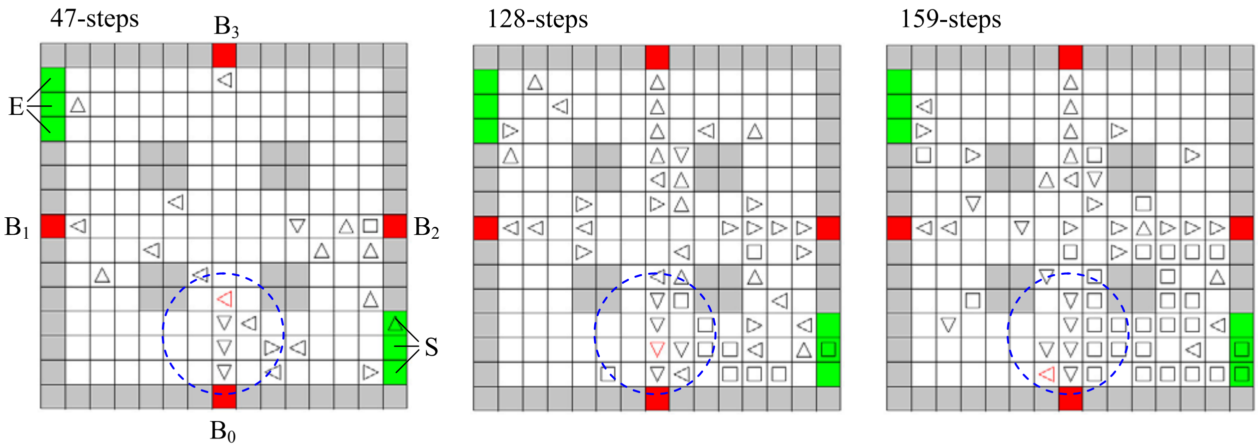


Fig.6 Snapshots of the agents' behavior in this site.

the interaction between the walking participants and the queues.

4. Conclusions

This paper has proposed a participant stream model in an event site based on the multi-agent system with interaction between the walking participants and the queues, and it has demonstrated the basic behavior of this model. In this model, the action rule of the agent is natural and rational as the participant in the event site.

As the future problems, we can enumerate the construction of more realistic site model, more detailed quantification of the agent's congestion, and its evaluation.

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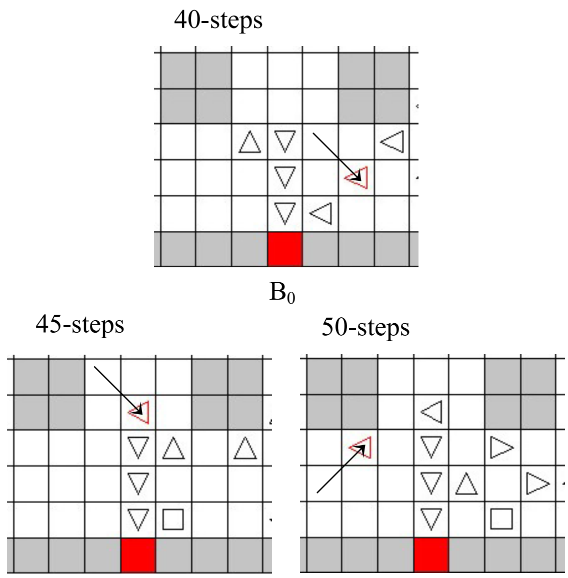

Fig.7 The agent's detour around the queue.

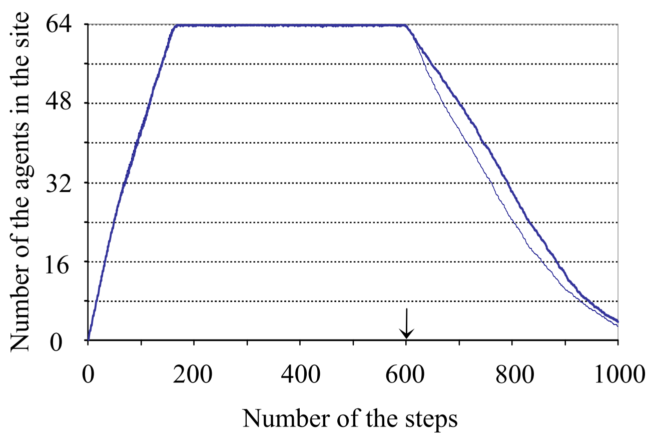

Fig.8 A transition of the number of the agents in the site: the queue's volume is considered in the bold transition, while it is neglected in the fine transition [4][5].