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Behavior of A Multi-Agent System in Which Each Agent Selects the Destination with the Combination of Two Indices

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Abstract– We consider the multi-agent system in which each agent selects the destination with the combination of two indices. The agent is the model of the pedestrian in an event site, a supermarket, and so on. The agent selects its destination minimizing the weighted sum of two indices (the queue length and the popularity of the booth), and it goes to there. This paper observes the influence of the scale expansion of the system on the agents' behavior.

1. Introduction

An agent is the entity which determines its action, based on the knowledge collected from its environment, in the fields of information technology and machine learning [1]. 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 these interactions have influences on the agents' states.

The environment in MAS is often represented by lots of the unit squares. This type of MAS deeply relates to "Cellular Automata (CA)". CA is a kind of the mathematical model for the dynamical system which is characterized by the discrete time and the discrete state.
Based on such MAS, many researchers have proposed the models of the vehicular traffic flow [2][3] and the pedestrian stream [4][5].

We consider the MAS in which each agent selects the destination with the combination of two indices. This MAS consists of the agents and the stage. The agent is the model of the pedestrian in an event site, a supermarket, and so on. The stage has the booths which provide the service to the neighboring agents. They are the candidates of the destination. The agents form a queue beside the booth to receive its service. In this MAS, the queue is an obstacle for the agents. This interaction is one of the causes of heavy congestion.

The agent selects its destination minimizing the weighted sum of two indices (the queue length and the popularity of the booth), and it goes to there. If the agent moves for the ample time in the stage, and if it cannot arrive at its destination because of the obstacles and the congestion, it gives up the arrival and reselects the destination. They are the reflection of the pedestrian's action pattern in the real world.

This paper observes the influence of the scale expansion of MAS on the agents' behavior. In general, the scale of MAS is determined by the size of stage and the number of the agents. Because the scale has been fixed in many previous researches, the influence has not been clarified. We approach to this problem. This observation can be utilized to understand the characteristic of the pedestrians in such place.

2. Framework of the MAS

2.1 The stage and the Agents

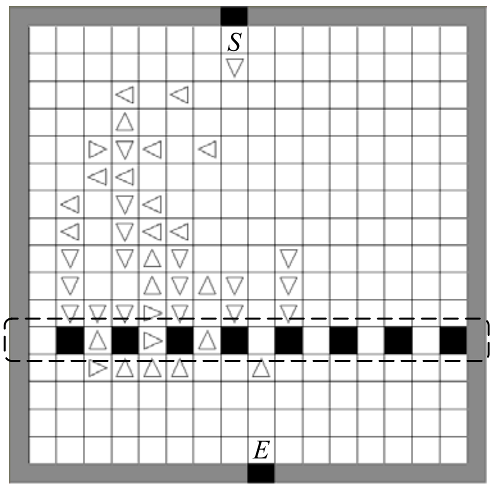

Fig.1 The proposed MAS:
The black grids inside the broken box are the booth grids, which are B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8 from the right-hand side.

Fig.1 shows the proposed MAS. This MAS consists of the stage and the agents. We refer to the unit square in the stage as the grid. This 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 stage, respectively.

The triangle means the agent. The agent is a model of the person. Each agent has 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 gets forward a grid in a time step.

The agent entries to the stage from S. It selects the booths by the indices which are explained later, and visits them. After then, it exits the stage from E, and prepares the next entry. In a bird's eye view, the area occupied by a person can be approximately expressed well by the square in which the side length is 0.5m [6]. Therefore, we consider the side length of the grid at 0.5m in the real world.

The agent is permitted to enter all grids except the no-entry grids, and the booth grids. We refer to the region which consists of all the entry grids as "the permitted region". The booth grid provides the service to the neighboring agent. The agents who want this service form a queue beside the booth grid. We give "service time" to each booth grid. The 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.

For the detailed description of the interaction between the agents, we use the asynchronous update of the agents' positions in order of the agent number. In the asynchronous update, if the order of update is completely fixed, the agents' behavior depends on the order. On the other hand, if the order of update is completely randomized, it is difficult to describe the interaction between the agents in detail.

Therefore, we employ the following initialization of agents: Before the entry to the stage, all agents make the queue outside of *S*. All agents in this queue follow the behavior in "the queue mode" which is explained later. Top agent of this queue must first enter the stage. In this queue, we use randomized order of the agents' number. The agents in the queue enter the stage by an agent every 4-steps.

2.2 Selection and reselection of the target booth

The agent selects the booth which it should visit by the indices. We refer to the booth which the agent should visit as "the target booth". As the typical indices for this selection, we have the length of the queue, the distance from the agent's position, and the popularity. In this paper, we consider the length of the queue and the popularity. The queue length is a time-variant index, and it is important to visit the target booths with efficiency. The popularity is time-invariant index in the time scale of this MAS, and it is important to let the agent reflect the preference of real human. Letting l_i denote the queue length of the booth i, we define l_i as the number of the agent in the queue. Letting f_i denote the order of popularity ranking of the booth i in all booths, we set f_i the booth number tentatively in this paper. The smaller value both l_i and f_i have, the preferable they are.

If the agent selects the target booth by either l_i or f_i, the indices in the plural booths have the common value, and the agent cannot complete to select the target booth. Also the time-invariant index such as f_i makes all agents rush to a grid.

Therefore, we consider the selection of the target booth by the combination of l_i and f_i in this paper. This selection is given by the following formula:

$$K_{lf} = \arg\min_i \left\{ \alpha\left(\frac{l_i}{L_{\max}}\right) + (1-\alpha)\left(\frac{f_i}{F_{\max}}\right) \right\},$$

where L_{max} and F_{max} are maxima of l_i and f_i, respectively. L_{max} is the number of grids from the booth's upper adjacent grid to the no-entry grid. F_{max} is the maximum of the booth number. α is the parameter which gives the weight in l_i and f_i. In this paper, the value of α is fixed at 0.5. In the selection of the target booth, the agent excludes the booths which it has already visited. The agent selects the target booth in the following three cases: just after the entry to this stage, just before the departure from the queue, and reselection of the target booth which is explained later.

If the human moves for the ample time in the place such as this stage, and if it cannot arrive at its destination because of the obstacles and the congestion, it usually gives up the arrival. Based on such human's action pattern, if the agent moves for "the ample steps", and if it cannot arrive at its destination, it reselects the target booth. We consider "the ample steps" as the period for the agent's detour from a lower corner to the other one in the permitted region. The agent counts the steps during its move to the destination, and the count is compared with "the ample steps". If the target booth is selected or reselected, this count is reset. If this count reaches "the ample steps", the agent reselects the target booth with a probability. This probability is determined by the distance from the agent's position to the destination. Letting z denote the Manhattan distance from the agent's position (x, y) to the destination (x_p, y_p), z is defined by the following formula:

$$z = |x - x_p| + |y - y_p|$$

z must have the integer value. We set the value of the reselection probability 0.1 for $z \le 2$, 0.5 for $z = 3$ or 4, 0.9 for $5 \le z$.

2.3 Pedestrian mode and queue mode of the agents

The agent has two modes: pedestrian mode and queue mode. In the pedestrian mode, the agent basically goes toward its destination. The destination is the tail of the queue of the target booth. Letting (x, y) and (x_p, y_p) denote the agent's position and its destination respectively, (x, y) is updated as the following:

If $|x_p - x| > |y_p - y|$ $x \leftarrow x + \mathrm{rsgn}(x_p - x)$,

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 $(1 - \varepsilon)$. The randomness in $\mathrm{rsgn}(v)$ gives the perturbation to the agent's behavior, and it breaks through "the deadlock" between the agents. In this paper, the value of ε is fixed at 0.2.

Each agent has "field of view" as shown in Fig.2. The field of view is the region in which the agent can find the no-entry grids and the other agents. If the agent finds the

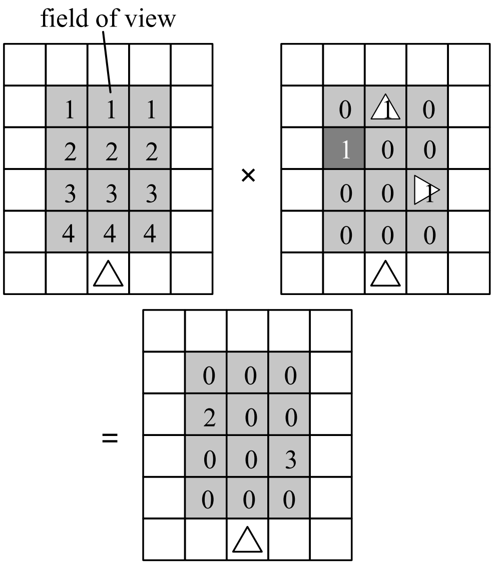

Fig.2 The field of view for the agent.

no-entry grid and the other agent in the field, it avoids the collisions with them by the following rule, instead of the above-mentioned update rule: As shown in Fig.2, the field of view has 3-grids wide and 4-grids long in front of the agent. This field is based on “the social space” in the environmental psychology [7]. This space is used for the interactions among the acquaintances except the good friends and the family members [8]. The agent regards the no-entry grid and the other agent which has the different direction from itself in the field, as the obstacles. We define the degree of the urgency to avoid the collision with the obstacles, and refer to this to “the danger degree”. Beforehand, we assign the bias of this degree to the grid in the field. Based on this bias, the agent can evaluate higher the urgency to avoid the collisions in more near grids. The danger degree is the bias value for the grid in which the obstacle is, and it is 0 for the other grid, respectively. In this field, the agent selects the row which has the least danger degree in the left row, the center row, and the right row. Based on this selection, the agent moves a grid to either of the front, the left, and the right. If this move is impossible, the agent stays there.

In the queue mode, the agent behaves as a part of the queue. The queue is an obstacle for the agent in the pedestrian mode. If the agent in the pedestrian mode arrives at the tail of the queue of the target booth, the agent changes its 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 then, this agent selects the next target booth, it changes its mode into the pedestrian mode, and it leaves from the queue. Simultaneously, all agents left in the queue move a grid to B_i.

3. Configuration the MAS

Fig.3 shows the basic configuration of this MAS. This stage has the permitted region which has 8-grids long, 8-grids wide, and it includes 4-booths. The booths B_1, B_2, B_3

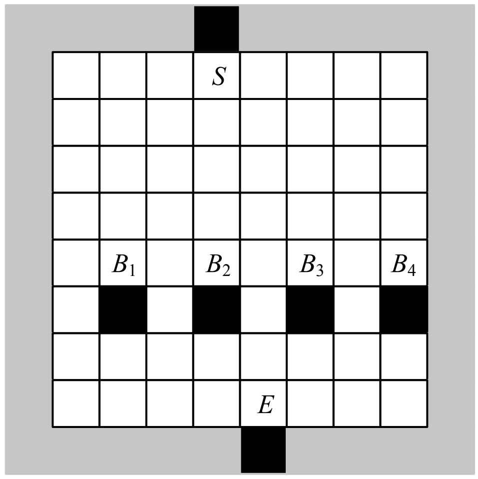

Fig.3 Basic configuration P_{11}.

and B_4 have the service times 15, 10, 10, and 20, respectively. Two adjacent booth grids have the distance 1-grid. This configuration has this stage and 32-agents. The agent visits two target booths. In order to observe the influence of the interaction between the agents and the queues on the agents’ behavior, we align all booths and make their queues form toward the common direction. We refer to this basic configuration as P_{11}.

Based on this P_{11}, we expand the size of stage and the number of the agents. Letting q denote the coefficient of the size of stage, the expanded stage has $8q$-grids long, $8q$-grids wide, and it includes $4q$-booths. The booths B_{4q-3}, B_{4q-2}, B_{4q-1} and B_{4q} have the service times 15, 10, 10, and 20, respectively. On the other hand, letting r denote the coefficient of the number of agents, the expanded number of agents is $32r$. We refer to this expanded configuration as P_{qr}.

4. Calculation results

This paper focuses the case where r increases with q = 2. We define the period from 0-step to the step at which all agents exit this stage as “1-set”, and we refer to the number of steps in 1-set as M_e. As shown by the solid curve in Fig.4, M_e exponentially increases as r increases with q = 2. In this figure, M_e in each combination of q and r is the average of M_e calculated from the individual 10-sets. We consider this solid curve agrees with the many people’s supposition.

Also in this case, as shown in Fig.5, the population density increases in the stage. This tendency increases the generation of “the crowd”, which is one of the characteristic behaviors of the agents in this MAS. If the agent cannot move because of the obstacles, it stays there.

Such agent is the obstacle for the other agents, and some of them stay their current position. Thus, the agent’s stop causes the cluster of the agents who cannot move. We refer to this cluster as “the crowd”. If the agent is involved in the crowd, it gives up the arrival at its destination, and it reselects the target booth. In this way, the outermost

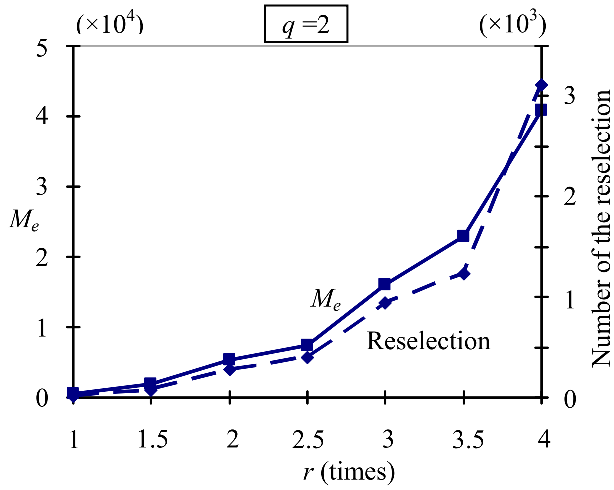

Fig.4 Dependence of M_e and number of the reselection on r with q = 2.

agents of the crowd first leave the crowd. As such agents increase, the crowd becomes small, and disappears before long.

As shown by the broken curve in Fig.4, the number of the reselection exponentially increases as r increases with q = 2. In this figure, the number of the reselection in each combination of q and r is the average of the numbers of the reselection calculated from the individual 10-sets. In Fig.4, the solid curve has the similar characteristic to the broken curve. If the agent moves for the ample steps, and if it cannot arrive at its destination, it reselects the target booth. Therefore, the number of the reselection deeply relates to M_e. Fig.4 strongly suggests the validity of this explain.

4. Conclusions

We have considered the MAS in which each agent selects the destination with the combination of two indices, and we have observed the influence of the scale expansion of the system on the agents' behavior. In this paper, we have investigated the case where r increases with the fixed q. Now we are investigating the case where q increases with the fixed r.

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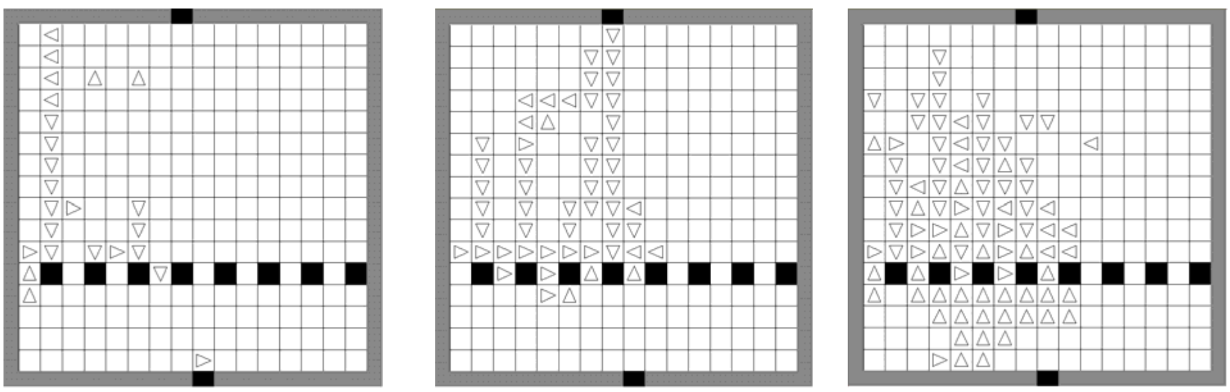

(a) r = 1 (32-agents), 84-steps.
(b) r = 2.5 (80-agents), 1381-steps.
(c) r = 4 (128-agents), 7952-steps.

Fig.5 Snapshots of MAS when r increases with q = 2 (16-grids long, 16-grids wide, and 8-booths).