An Analysis on the Effect of Speed Seats for Congestion Mitigation in a Campus Restaurant Using Multi-Agent Simulation

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***Abstract*—Campus restaurants in many universities in Japan are crowded during lunch time and the seats in restaurants are not shared efficiently by customers because of a lack of public manners. Some restaurants introduced a system, named speed seat system, which encourages customers to give a seats as soon as they finish their lunch. The speed seat system was reported to be effective and recently of interest among the managers in campus restaurants. It is desirable for the managers to assess the effect quantitatively in advance of its introduction. In this study, a multi-agent simulation model is proposed for the situation during lunch break in a campus restaurant in our university. The model represents both a series of behaviors of customers in the restaurant and interactions among customers. The speed seats are introduced in the model and its effect for congestion mitigation in lunch time is estimated through simulation experiments.**

***Index Terms*—campus restaurant, congestion, multi-agent simulation, speed seat system**

I. Introduction

The campus restaurant in our university is usually very crowded during lunch break. Students have to go into a queue to a pick-up counter for their dishes and they spend their much time to prepare their meal. Some students give up having a lunch in the restaurant and purchase a lunch pack at a campus store instead. The congestion causes damage to the university cooperative in our university, who manages the campus restaurant, because of sales decreasing. The congestion problem is to be tackled for the university cooperative not only for student's benefit but also from the managerial point of view.

There are many campus restaurants operated by university cooperatives in Japan and many of them have the same problem with the congestion in lunch time. In most cases, the reason of the congestion is not from the delay of supplying menu but from the lack of turnover of customers. The seating capacity in a restaurant is usually enough for customers even in lunch rush hour and seats, however, are not utilized efficiently due to a lack of public manners. Some students keep other marginal seats for their baggage space or as a boundary of their private space, and they spend chatting with their mates for a long time after finishing their lunch. The university cooperatives make notices to improve the manners of students to share seats or to give their seat soon after eating. The campaign activity, unfortunately, is not effective to solve the congestion problem.

A system, named speed seat system, was introduced in a campus restaurant at Akita University, Japan for the lunch time congestion [1]. The speed seats are sort of priority seats and the customers sitting on a speed seat are supposed to leave the seats promptly after their eating. The customers who want to have a lunch in a short time are willing to utilize the speed seats and those who enjoy taking with their mates after eating are expected to avoid the speed seats. The speed seat system was reported as an effective approach to solve the lunch time congestion problem and it gradually introduced at other university campus restaurants in Japan such as Waseda University, Okayama University, Niigata University, and Tottori University.

A multi-agent simulation is an important approach to clarify complex phenomena in various study fields such as society, physics, and chemistry [2], [3]. The approach especially provides critical insights to understand emergent features produced by interactions among many agents and it is one of the fundamental method to develop a simulation model for congestion phenomena by pedestrians or vehicles. Kitakami *et al.* [4] constructed a multi-agent simulation model for behaviors of customers in their university campus restaurant. Using the model, they observed the transition of usage situation of restaurant seats in every area of the restaurant. They analyzed the current situation of the target restaurant but did not propose any methods to mitigate the congestion.

This study proposes a multi-agent simulation model representing the behaviors of customers in a campus restaurant aimed at applying to our university restaurant. In the model, customer agents come to the restaurant, seek and keep their seats, select and pick up their menus, have meals at the kept seats, relax for a while, return their dishes, and finally exit the restaurant. Simulation experiments measure the rate of customers who cannot find their seats and give up having a lunch due to the congestion in a different settings of speed seat installations in order to estimate the effectiveness of the speed seat system for the lunch time congestion.

II. Fundamental Model Settings

The target campus restaurant in this study is a one-story building with around 1,000 square meters of floor space. Its

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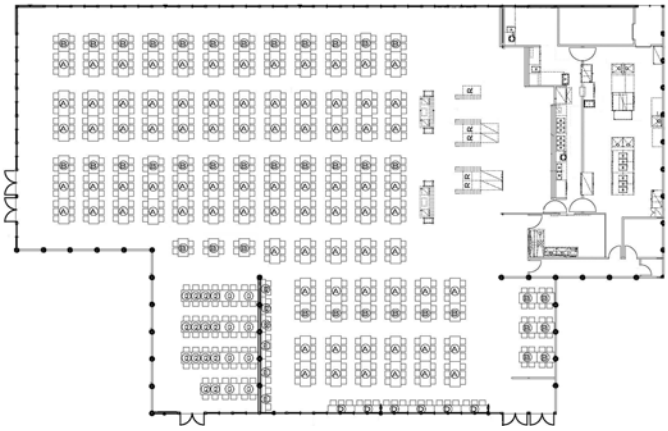

Fig. 1. Floor map of the campus restaurant

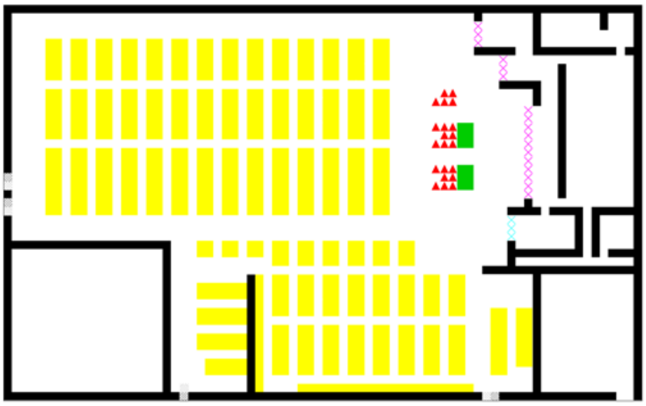

Fig. 2. The proposed simulation space for the target restaurant

floor map is illustrated in Fig. 1 where north is upper and south is lower. The proposed multi-agent simulation model adopts cell space model and a unit length of a cell is set to 0.6 meters. The restaurant is represented by a rectangle cell space with 47 cells in length and 76 cells in width, shown in Fig. 2.

The restaurant has totally 156 tables and 747 seats. There are seven types of tables to which from 2 to 6 seats are placed and most of tables are arranged in a row in a group of two or three tables. The proposed model recognizes a table group as a table agent, represented a yellow rectangle in Fig. 2. There is a doorway on the east side of the restaurant and two doorways on the south. The kitchen is allocated on the west side and three pick-up counters are arranged front onto the kitchen, represented by magenta Xs in Fig. 2. There are five cash registers, modeled by sets of red triangles in Fig. 2, are placed between counters and tables. The green rectangles in Fig. 2 represent refrigerator shelves for small separate menus. Some customers in the real restaurant pick a menu up there but the proposed model skips the behavior and the green rectangles simply play a role as obstructions. Dish return corners are allocated in the middle of the west side, shown by cyan Xs in Fig. 2.

The menus served at the restaurant are categorized into three groups which correspond to the three counters. The probability that customers select a counter was estimated based on the past result of supply quantity. The elapsed time for a staff to serve a menu since a customer orders a menu was set to the average elapsed time measured by on-site survey. Most customers come into the restaurant in a group. This study assumed that the number of customer group is from one to six. When the number of group is one, the customer agent is named as a single customer. The rate of the number of group members was also determined based on the on-site survey. The elapsed times for taking after eating as well as waiting time at the dish return corners were configured using the results of on-site survey.

According to the past result, around 1,400 customers come to the restaurant in a day and around 600 customers come in lunch break. The proposed model treats the time period from 11:30 am to 1:30 pm including the lunch time. The arrival rate of customers depends on the time period in the lunch time. For instance, the arrival rate in the period from 12:10 to 12:30 is the highest because the lectures in the morning finish at 12:10. In the model, the target time period was divided into the following five time periods: 11:30 – 12:00, 12:00 – 12:10, 12:10 – 12:30, 12:30 – 13:00, and 13:00 – 13:30.

The speed seat system actually has not installed in the target campus restaurant. Some candidates for the location and the number of seats were determined through the discussion with the manager and staffs of the restaurant.

III. Behaviors of Customer Agents

The customers in the restaurant were designed as customer agents in the proposed model to have the following six state groups: (1) arrival (2) table choice (3) order and pick-up (4) payment (5) eating and taking (6) wait, return, and exit. This section mentions the states in detail.

A. Arrival

Customer agents are created at one of the three doorways randomly with a prefixed arrival rate which depends on the time periods. The number of a customer group is determined randomly with a given probabilistic distribution. Multiple members in a group are created continuously at the same doorway.

B. Table Choice

The first customer agent who created at a doorway among the group member chooses a table agent which has enough seating capacity for the group. Assume that the number of group members is n, the seating capacity of a target table agent is c, and the number of other customers who have already utilized the table agent is o. The utilities U of a target table agent is computed by (1) through (4) and the customer agent selects the table with the highest utility among all candidate table agents:

$$U = -\alpha r - \beta d + \varphi_0 + \varphi_1 + \varepsilon \quad (1)$$

$$r = \frac{o+n}{c} \quad (2)$$

$$\varphi_0 = \begin{cases} \theta_0, & o = 0 \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

$$\varphi_1 = \begin{cases} \theta_1, & c - o - n \le 2 \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

Equation (2) computes the usage rate r of seats of the target table agent. The functions φ_0 and φ_1 in (3) and (4) respectively define the desirable point for a vacant table and

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for an efficient usage of tables. The efficient usage means that customers despise a situation that another customer group comes to the table while eating. In (1), the function d is the distance between the target table agent and cash registers, ε is a random term within a range [0, 1), and $\alpha, \beta, \theta_0, \theta_1$ are positive parameters. As soon as a customer agent chooses a table agent based on the utility computation, the required seating capacity for the group of the chosen table agent is reserved and unable to be allocated to other customer agents.

When there are no table agents which have enough seating capacity for own group members, the customer agent temporally walks for the middle area of the restaurant with seeking an available table agent. If the customer agent cannot find an available table agent after the elapse of a certain period of time, the customer agent with its group members at last gives up having lunch there and exits from the restaurant in a group.

When a customer group chose a table, the members of the group individually go toward the table. The proposed model adopts a simple potential approach, which could be recognized as a type of the floor field approach [5], to walk toward a destination with avoiding obstructions. Concretely, potential values of cells in the simulation space are computed according to the following steps.

1. All potential values are initialized to Null.
2. The potential value of the destination cell is set to 0.
3. $v = 0$
4. **while** the potential value of the current position is Null
5.   **for** all cells x whose potential value is v
6.   **for** all cells nx in Neumann neighborhood of x
7.   **if** the potential value of nx is Null
8.   the potential value of nx is $v + 1$
9. $v = v + 1$

After execution of the computation of the potential values, the customer proceeds from a current position to a destination by tracing cells with decreasing potential values by one.

C. Order and Pick-Up

After arriving at the target table agent, a customer agent selects one of the counter randomly according to a given probability. The probability is determined based on the supply result of menus served at each counter. When there is a queue for the target counter, the destination is set to the position of the end of the queue, otherwise that of the counter.

While a customer agent walks to its destination, another customer agent is sometimes added to the same queue and the position of the end of the queue varies. In order to adjust the situation, a customer agent executes the computation of the potential values and defines its destination repeatedly at regular time interval. The customer agent is added to the end of the target queue when it come closer to the target destination. Customer agents in a queue make a line designated in advance and follow the agent ahead of them. The top agent in a queue waits for the menu and is relieved of the queue after the menu is served.

Some customers go to multiple counters to take multiple menus in the actual restaurant, the model omit the behavior because there are not so many such customers in the busy lunch break.

D. Payment

Customer agents having their meal walk toward a cash register to make a payment. There are totally five registers and the most desirable register is chosen with considering the length of the queue for the register and the distance from the current position to the end of the queue. As the case of the counters, the customer agent derives the route to its destination by the potential computation and it is added to the queue after arriving.

The top customer agent waits for the payment task, whose processing time is randomly determined based on a given probabilistic distribution, gains release from the queue, and walks toward its reserved table agent.

Some customers in the actual restaurant pick a cup of complimentary drink and put some sauce on their dishes before walking to their tables. The proposed model treats the behaviors as a part of the payment task and its elapsed time is merged into the processing time of the payment task.

E. Eating and Talking

After arriving at the reserved table, a customer agent promptly starts to eating without waiting for the arrival of other group members. The length of mealtime is randomly determined from 15 to 30 minutes based on the result of on-site survey.

The customer agents change their states to talking after finishing eating. A single customer agent, who has no accompanying mates, also has the talking state and it indicates spending free time including using a smartphone or reading a book by oneself. The length of the talking state is also randomly determined from 0 to 15 minutes. Additionally, the talking time is designed to be interrupted with higher probability as 1:00 pm nears when afternoon lectures start. The customer agent who finishes the talking state changes its state to the waiting state mentioned in the next subsection.

Note that the customer agents who take tables designated as speed seats do not have the talking state. They have the waiting state as soon as they finish eating.

F. Waiting, Dish Return, and Exit

The waiting state is a virtual state to wait for other group members to finish talking and it is introduced in the proposed model so that all group members leave the reserved table agent at a same time. After all group members have the waiting state, they walk toward the the dish return slots and the reversed table agent becomes free to other customer agents. A single customer agent, therefore, does not have the waiting state and leaves for the slots as soon as it finishes the talking state. There are two queue lines for dish return slots and a customer agent selects one queue whose length is shorter. As the same manner of the counters and cash registers, the customer agent walks to the end position of the queue.

After being released from a queue, customer agents finally exit from the restaurant. They select a doorway randomly, walk toward there, and are eliminated from the simulation space.

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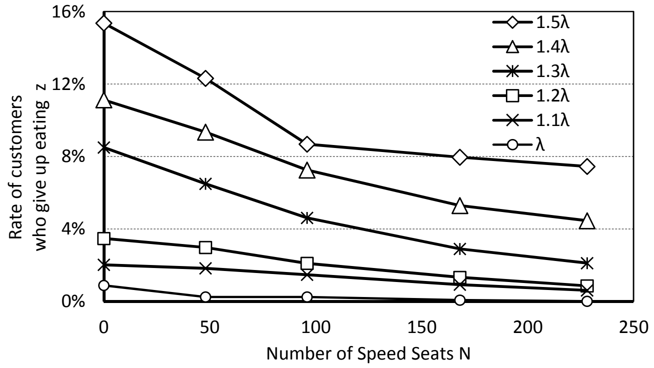

Fig. 3. Effect of speed seats on absorption rate of customers

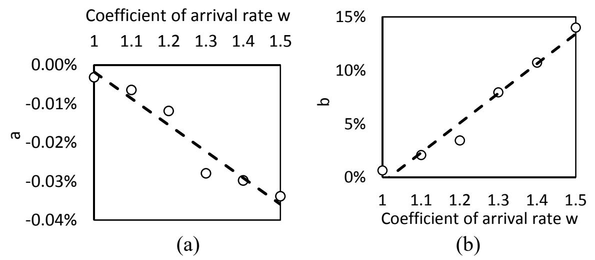

Fig. 4. Coefficients of regression lines for the break lines in Fig. 3

IV. Simulation Experiments

The proposed multi-agent simulation model was developed on artisoc [5], the multi-agent simulation platform made by Kozo Keikaku Engineering Inc. Numerical experiments using the model have been conducted in order to estimate the effect of the speed seat system to mitigate the congestion at the campus restaurant during lunch break. As the result of discussion with the manager and staffs of the restaurant, speed seats were assumed to be assigned to the table slots close to cash registers since it is convenient for customers who want to have a hasty meal. The number of seats for speed seats is denoted by N and five patterns of the assignments of speed seats were adopted in the experiments where $N = 0$, 48, 96, 168, and 228.

The arrival rate of customer agents was also varied in the experiments. First, the arrival rate was adjusted to suit the actual situation and the adjusted rate is denoted by λ. Then, different arrival rates were adopted aiming to estimate the situation where more customers come to the restaurant than at present. Concretely, the adopted arrival rates are denoted by $w\lambda$ where w changes from 1.0 to 1.5 with 0.1 increments in between.

For five and six settings of N and the arrival rates, namely thirty patterns of the setting in total, the simulation using the proposed model was executed ten times for each pattern and measured the rate z of the number of customers who cannot find any available seats and give up having lunch at the restaurant with respect to the total number of customers.

Figure 3 illustrates the fluctuation of z for different settings of the arrival rate where the horizontal and vertical axes mean N and z, respectively. The result indicates that less customers give up having lunch as more speed seats are introduced. The result also implies that the effect to mitigate the congestion become greater as more customers come to the restaurant.

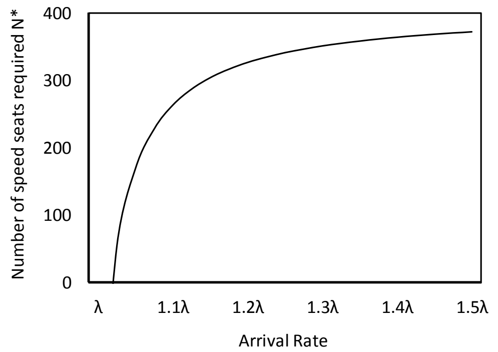

Fig. 5. Number of speed seats in order all customers have a meal

The correlation coefficients between N and z for all arrival rate $w\lambda$ where w is from 1.0 to 1.5 are -0.848, -0.996, -0.992, -0.979, -0.984, -0.913, respectively. Since it means that all broken lines of z approximately decrease linearly in Fig. 3, the regression lines $z = aN + b$ for each broken line are computed. The coefficients a and b for each line are plotted in Fig. 4 where the horizontal axis means w, the coefficient of the arrival rate. Both of the coefficients a and b are also seemed to be linear to w in Fig. 4 and their correlation coefficients are -0.967 and 0.984, respectively. The equation of the regression lines of a and b to w are similarly computed. By summarizing the results, z, the rate of customers who cannot have lunch, can be represented in the following approximate equation:

$$z = (-0.0684w + 0.0666)N + (27.8w - 28.3) \quad (5)$$

By setting $z = 0$, the following result is obtained.

$$N = \frac{27.8w - 28.3}{0.0684w - 0.0666} \quad (6)$$

The left-hand side N of (6) means the required number of speed seats so that no customers give up having lunch at the restaurant, denoted by N^* in the followings. Figure 5 illustrates the fluctuation of N^* in (6) and it shows N^* is concave with respect to w. Figure 5 represents that additional number of speed seats gradually decreases when the arrival rate of customers increases at a constant rate.

V. Conclusion

This paper constructed a multi-agent simulation model to analyze the effect of the speed seat system in a university campus restaurant to mitigate the congestion at lunch time. Numerical experiments using the model have been conducted on several conditions of the speed seats introduction and it revealed that the system mitigated the congestion and it became more effective in the situations where more customers come to the restaurant.

In the future, the proposed model should be modified to deal with the possibility that some customers do not follow the rule at a speed seat. When there are not enough available seats except for speed seats, some customers have a speed seat and might break the rule to stay longer after eating. Such a violation of the rule might influence other customers and create a moral hazard, which will be discussed in the forthcoming paper.

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