Congestion Reduction in Theme Parks

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***Abstract*—The purpose of this study is to investigate how to curtail congestion at theme parks. A method is proposed which involves disseminating congestion information to guests. Based on this method, simulations are carried out to determine the optimum dissemination method.**

***Keywords*-Multiagent; simulation; themepark**

I. INTRODUCTION

Information technology continues to develop. Recently scientific description has progressed greatly. Ubiquitous networked society takes on a third dimension. Mobile telephone and PC use is steadily increasing, and obtaining and sharing information is becoming more and more easy. However, it is not clear whether this information sharing will lead to increased efficiency. We may concentrate on certain resources by having information about them.

In this study, our aim is to reduce congestion at theme parks. I inspect the purpose by information distribution, information sharing. We construct a theme park model to examine problems and an effect. I plan an effect by the concentration and dispersion of the guest in the model. The method of congestion reduction considered is dissemination of real-time congestion information.

II. PRIOR STUDIES

Kawamura, Kurumatani, and Ouchi [1] studied the method of guiding users to reduce congestion. They define the issue of theme parks as the problem of decreasing the congestion when many people visit a theme park consisting of multiple service attractions. They describe an algorithm to guide a person by the "formulation by the multi agent of the issue of theme park and examination about the adjustment algorithm". They examine the following algorithms in the context of a multiagent theme park model:

- Greedy algorithm
- Congestion-Avoidance (CA) algorithm
- Stochastic CA algorithm

Using the Greedy algorithm, guests choose as their next destination their favorite attraction from among those they have not yet visited. When there are multiple candidates, guests choose an attraction at random. They then choose the shortest course to the attraction.

Using the congestion-avoidance algorithm, guests choose as their destination an attraction with a short waiting time as in the attraction that a guest does not visit most. When there are multiple candidates, the guest sets his favorite attraction as the destination.

Using the stochastic CA algorithm, when guests choose their next attraction, they select either the greedy algorithm or the congestion-avoidance algorithm at random. When the standard deviation of the service time becomes large, the greedy algorithm increases waiting time. When there is little deflection of service time, guests visit it for each attraction experimentally. Guests disperse and waiting time decreases. However, guests concentrate on attractions that have long service times when the service time is partial. It follows that the load cannot be effectively dispersed with this algorithm. With the congestion-avoidance algorithm, waiting time decreases when deflection of service time is large. Variation in congestion occurs and the waiting times of some attractions grow large. When the standard deviation of the service time is small, the greedy algorithm is good while the stochastic CA algorithm is good when the standard deviation is large.

These kind of issues have to be considered on a peculiar condition that limited condition of individual customer has to be comparatively relaxed that is, we have to describe the independent schedule of each customer simultaneously in the simulation. It is on this point that the issue of theme parks is different from that of conventional scheduling. So we apply a *multiagent simulation* to this problem for the purpose of guaranteeing the freedom of each customer's scheduling to a high degree. In addition, conventional studies did not consider "individual satisfaction" or "degree of preference for each attraction". We also consider the waiting times of each customer and their decisions concerning which attraction to visit next as depending on the actions of many other users. Further, we treat this as a multipurpose problem that includes a complicated tradeoff. Furthermore, we perform various measure plans in information dissemination and we inspect them.

III. THE ISSUE OF THEME PARKS

A theme park consists of many institutions and many paths. Guests visit the institutions for each intention. Theme parks reduce congestion by adjusting their schedules. It would be better if guests avoided concentrating in one place. Therefore, the movement of the guests should be controlled, as described later. However, because our purpose is to decrease congestion by information sharing, we will transmit information and analyze the change in congestion. Transmitting information may have a positive influence on congestion reduction, a negative influence or no effect. I solve the issue of theme parks from various angles. For this purpose, we construct the theme park model described in the next section.

IV. THE THEME PARK MODEL

A. *Summary of the Model*

The flow of guests in the theme park model is as follows: The guests enter the theme park at the entrance, enjoy some attractions, and finally return home after having been satisfied. Fig. 1 illustrates the theme park model.

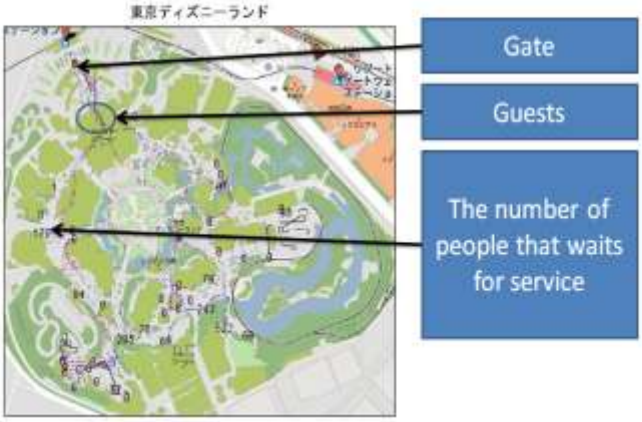


Figure 1. Simulation model

We use a multiagent system for the simulation, that is, a system consisting of many agents acting autonomously. Each agent observes their environment and takes some action to achieve their aim. The behavior of the system as a whole is decided by the agents' interactions. The system's behavior in turn influences the actions of each agent. The placement and transaction speed of each attraction is based on the sixth edition "Tokyo Disneyland Complete Guide". I use "*artisoc2.5*" which *KOZO KEIKAKU ENGINEERING Inc.* developed for simulation.

B. *Characteristics of the Agent*

In this study, we build a more practical model. We set randomly the following characteristics for each guest (agent):

- Preference concerning attractions q ($0 < q < 1$).
- List of attractions already visited.
- Satisfaction: The sum of the preferences of the attractions that were already visited.
- Threshold value for the decision to return home.

The congestion information is disseminated to each agent with probability p. Each agent who received congestion information will decide which attraction to visit next based on this information and circumstances. It is assumed that the simulation conditions (the number of agents, preference for attractions) are fixed for one simulation run. Changing the congestion information possession rate, we evaluate the length of the queue of every attraction by multiagent simulation.

C. *Constants and Variables*

The following are taken as constant in the model:

- The area of the theme park.
- The number of attractions.
- The placement of the attractions.
- Transaction speed (service time and number of vehicles) of each attraction.
- The total number of guests.

The following are assumed to be variables in the model:

- The characteristics of each agent.
- Entrance distribution.
- Arrival distribution for the attraction.
- Queue length.
- Average arrival interval.

The characteristics of each agent correspond to the nature of a guest visiting the theme park. The entrance distribution of guests is variable. Therefore we assume entrance distribution on a multiagent system. As the characteristics of each guest are variable, the arrival distribution of the attraction has a variable factor. Therefore we assume the arrival distribution to the attraction on a multiagent system as a variable factor. The variables queue length and average arrival distance depend on the arrival distribution.

A. *Embodiment of the Congestion Information*

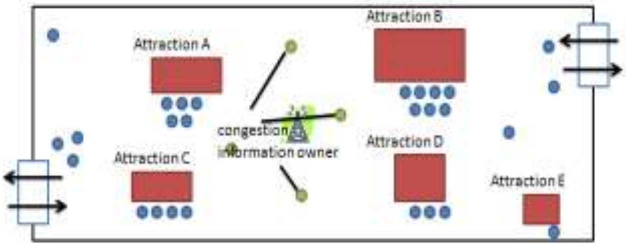


Figure 2. Information dissemination

The guests who do not receive congestion information act according to (1). They are indicated by the blue dots in Fig. 2.

$$Ei,j(t) = Preference\ i,j - \propto \times Distance\ i,j \ldots\ldots (1)$$

Where *Preference*, is the preference for attractions and *Distance* is the distance to the attraction.

The guests decide their next attraction by distance and preference. The attraction is easy to be chosen so as to be near if distance is near. If it is a favorite attraction, the guest may choose a far-off attraction.

The guests who receive congestion information act according to (2). They are indicated by the greens dots in Fig. 2.

$$E_{i,j}(t) = Preference_{i,j} - \alpha \times Distance_{i,j} - \beta \times Congestion_{j} \ldots\ldots(2)$$

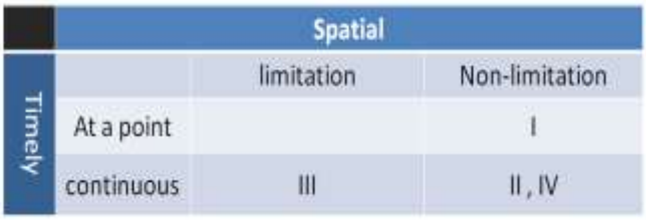
Where *Congestion* is the number of people that are waiting for service. Note that guests have incorporated the congestion information that they received into the rule given in (1). The guests decide the next attraction by distance, their preference for the attraction and the congestion information. Parameters α and β are weights. The reason is because it treats it in the same dimension.

V. PLAN FOR CONGESTION REDUCTION

The following plans for congestion reduction control operational aspects, specifically the dissemination of congestion information:

I. One-time-only dissemination of congestion information.
II. Dissemination of continuous congestion information.
III. Dissemination of spatially-restricted congestion information.
IV. Use of a prediction method.

We also implemented a design-side plan that alters the placement of popular attractions, but in this article we will focus on the above plans.



Timely	Spatial	
	limitation	Non-limitation
At a point		I
continuous	III	II , IV

Figure 3. Plans for congestion reduction

Fig. 3 summarizes the plans for congestion reduction. We examine how effective each is at disseminating congestion information. First we describe the method of operation of each of these plans. One-time-only dissemination of congestion information (Plan I) is a method to deliver information on the current congestion state of all attractions in the theme park to guests at a single point in time.

Dissemination of continuous congestion information (Plan II) refers to a method of continuously delivering congestion information for all attractions in the theme park. The congestion information informs guests of the current lengths of the attraction queues. It means that the guests can feel the line of the attraction by each timing that they deliver information continually. This dissemination-style is more generous to guests than the one-time-only dissemination. In addition, the operator can dissemination the latest congestion information because I deliver congestion information continually.

Dissemination of spatially-restricted congestion information (Plan III) refers to a method of delivering information *for* a crowded attraction only in the area *around* that attraction. The operator does not disseminate congestion information to the whole theme park.

The prediction method (Plan IV) uses a temporal difference (TD) prediction. Using this method, we observe the change in congestion up to the present and predict a congestion state from the observed data. From this we can predict the tendency of congestion to increase or decrease.

Where *Future* is the predicted value, and *Current* is the queue length. The congestion state changes every hour.

Next we consider the issue of placement on the design side and investigate whether this has any influence on congestion. We do not present any results at this time, but will describe the design-side plans. It is not realistic to change the positions of the attractions. In addition, it is unrealizable. The placement of the attraction inspects it by changing the placement of the popular attraction by fixation.

We will consider the following placements of popular attractions:

1. Group popular attractions together (Fig. 4).
2. Separate popular attractions (Fig. 5).
3. Separate popular attractions while avoiding the neighborhood of the entrance (Fig. 6).

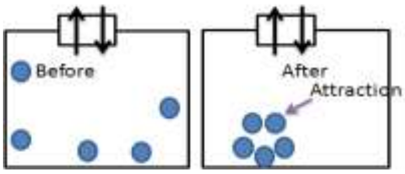


Figure 4. Placement 1: popular attractions grouped together

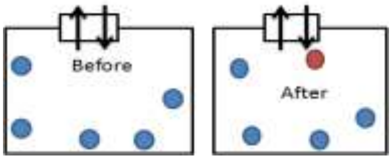


Figure 5. Placement 2: popular attractions separated

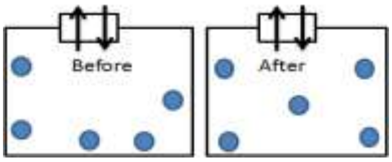


Figure 6. Placement 3: popular attractions separated, avoiding the entrance

Note, simply separating the attractions as in Placement 2 resulted in guests concentrating on the attraction near the entrance indicated by the red dot in Fig. 5. With this in mind, we analyzed the change in congestion for Placement 3, shown in Fig. 6.

VI. EVALUATION OF PERFORMANCE

Figs. 7-14 show the variations with time of the number of people waiting for particular attractions. The vertical axes and the horizontal axes of the following figures share the same labels. The vertical axes show the number of people waiting and the horizontal axes show time. The number of people waiting refers to the number of people not receiving the services of any attraction.

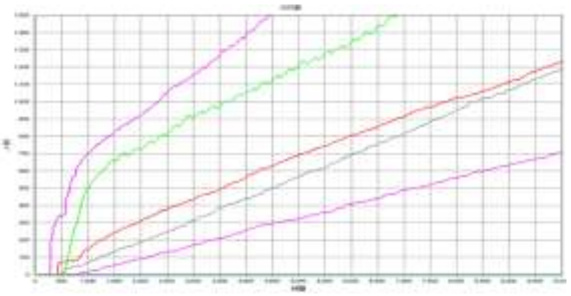


Figure 7. No control

Fig. 7 shows the results when the operator does not disseminate any information to guests. Without information, people concentrate on popular attractions. This is the general state of theme parks. No one has more information than anyone else. In other words, all guests are equal. The model measures time in steps of 1 second. The congestion of popular attractions increases quickly while the congestion of the unpopular attractions increases gradually. It is hard to come to understand that I put a change of the number of the guests in the garden of 1st. I am hard to come to see a graph about increase of the congestion. The graphs use noon as the starting time, which is the time when the theme park is most crowded. We assume that about 40,000 guests enter the theme park in a day.

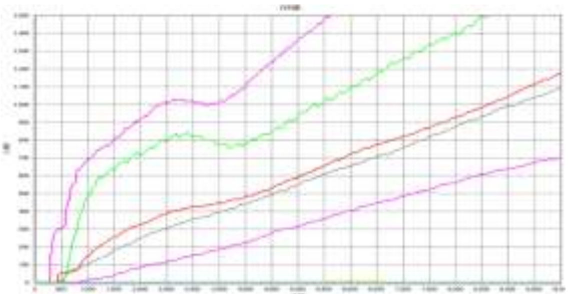


Figure 8. One-time-only information dissemination (Plan I)

Fig. 8 shows the results when using one-time-only dissemination of congestion information (Plan I). This was carried out at step 2000 in the simulation. The distribution was analyzed for delivery rates from 0% to 100%.A delivery rate of 100% resulted in the greatest reduction of congestion, and this is the rate used in Fig. 8. Congestion is suppressed only for a short time after information dissemination and the attraction soon becomes crowded again. The timing of this information dissemination is important. If the timing is poor, disseminating the information will not have much of an effect. There is the attraction that does not receive most of the influence of the information dissemination. The number of people waiting for service does not have a change. I do not seem to be useful practically very much.

The operator cannot know what kind of influence he has on each attraction. It is really assumed that I performed information dissemination at the point at one time in a theme park. However, the operator does not know at what time to perform the information dissemination. In addition, the operator does not understand the effect on the attractions. In this case, it is not so preferable to apply it in practice.

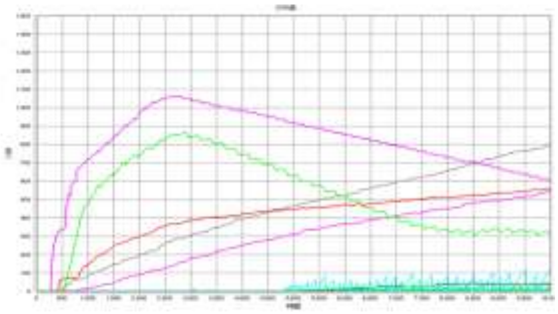


Figure 9. Dissemination of continuous congestion information (Plan II)

Fig. 9 shows the results when information is disseminated continuously (Plan II). The operator begins continuously disseminating congestion information to guests from step 2000. Because the congestion situation is changing continuously, the information is updated once per minute. This prevents sudden congestion from occurring. Under this plan, an information distribution rate of 100% gives the best results as far as suppressing congestion. Congestion of popular attractions decreases while the congestion of some other attractions increases. Guests are less concentrated and the average congestion of the theme park decreases. During the most crowed time, the number of waiting guests does not exceed 1,050 at the most busy attraction. It is clear that dissemination of continuous congestion information is more effective than disseminating no information. Because of the continuous nature of this operation, it is not necessary to consider the effects of timing, and all attractions are impacted in some way. Based on these results, we can conclude that continuous information dissemination is a realistic method of reducing congestion in a theme park.

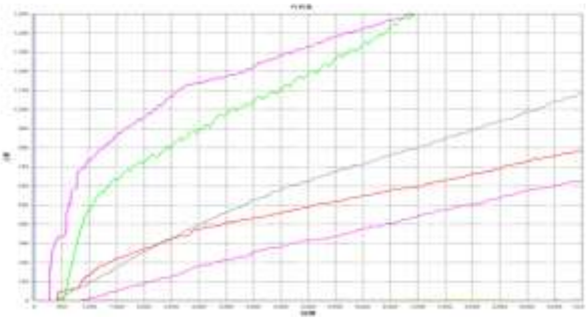


Figure 10. Dissemination of spatially restricted congestion information

Fig. 10 shows the results of disseminating spatially-restricted congestion information (Plan III). Under this plan, information is disseminated only in a limited area around popular attractions In this case, it can be seen that congestion of some popular attractions increases. This is because the many guests who do not receive congestion information concentrate on those attractions. Guests having some congestion information avoid the congested attractions. This delivery method (Plan III) holds congestion in check better than the case of no control. However, it is inferior to disseminating continuous congestion information to guests. It cannot reduce congestion, but merely slow its growth. If an operator wants to suppress only some congestion in a theme park, this method may be effective.

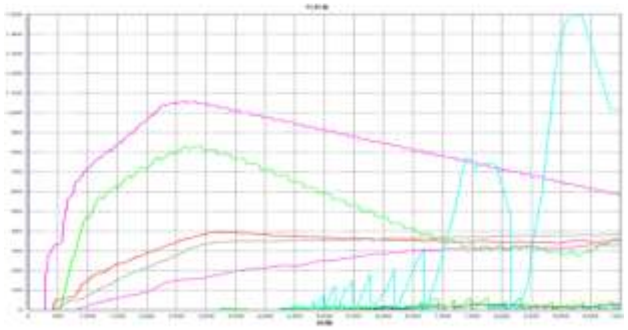


Figure 11. Prediction method 1

Fig. 11 shows the results for prediction method 1 (Plan IV model 1). The simulation system collects information for the first 2000 steps. Following this, the operator uses a prediction method to control guests based on TD prediction. It looks back at the previous three congestion information update intervals and stores the congestion states. From this it predicts a future congestion state. This is then disseminated to guests as future congestion information. Note the blue line in Fig. 11, which shows sudden congestion occurring. The guests who receive future congestion information through the prediction method always concentrate on attractions that are not crowded. The congestion of some attractions increases steadily so that it vibrates. We have a study sympathizing with for the movement of the person. This result may prove it. This is because the update interval of the congestion information was long. I do update distance by this prediction method for eight minutes. The operator continues delivering information that an attraction has become vacant for 8 minutes. Because there are many guests who receive this information, they concentrate on that attraction. If the update interval is shortened in order to increase the precision of the prediction, the average congestion can be suppressed more than when using the continuous delivery method. In the attraction that congestion of suddenly increases, the prediction method comes into force.

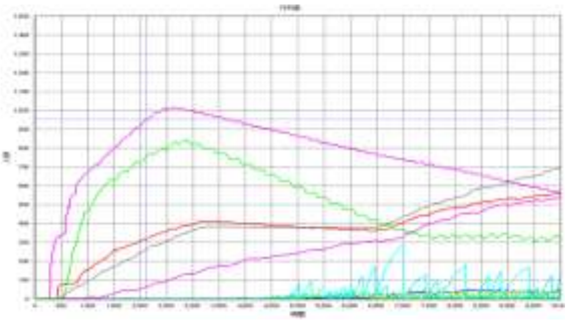


Figure 12. Prediction method 2

Fig. 12 shows the results for prediction method 1 (Plan IV, model 2), when information updates are every 4 minutes, half of that used in model 1. The simulation system collects information from step 1. And delivers predicted values to guests from this step onward. Note the change in the congestion curve for the attraction indicated by the blue line. The initial sudden congestion is strongly reduced using this method. In the case of the pink curve, congestion is maintained at around 1,000 people. The prediction method is effective for congestion reduction here. By step 8000, the gray line has reached 650 using the continuous delivery method (Plan III), but stays at about 350 using the prediction method, and then increases later. However, the prediction method does better than the continuous dissemination method. The red and pink lines are similar. Congestion is suppressed more than with continuous dissemination.

However, we do not think that an effect is given than continuous delivery. Therefore I plan continuous delivery and a difference of the prediction method. Finally, we analyze the results for the case in which when congestion information is delivered from the beginning of the simulation rather than waiting until step 2000.

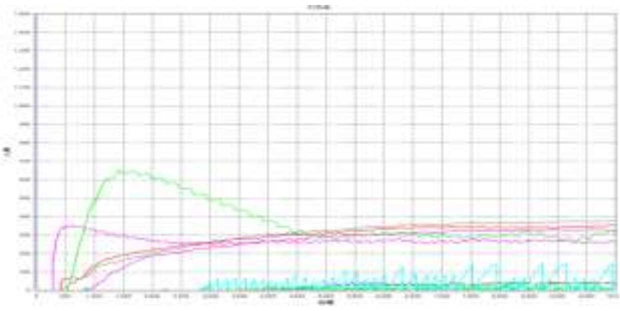


Figure 13. Continuous dissemination from the beginning

As seen in Fig. 13, when the operator disseminates congestion information continuously from the beginning, the number of guests at even the most crowed attraction stays under 650. The number of guests at most attractions moves toward the average congestion level, which is around 300.

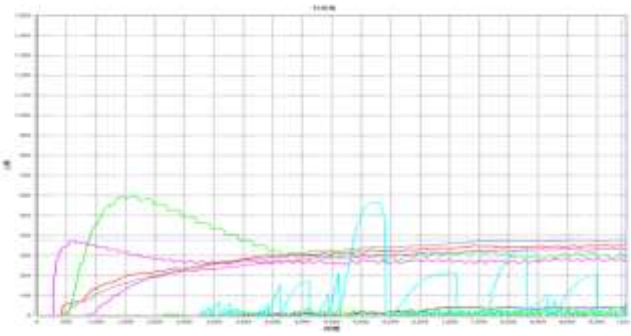


Figure 14. Dissemination using prediction method from the beginning

As shown in Fig. 14, when the operator uses the predictive method from the beginning, the number of guests at most attractions converges to the mean. However, there is an attraction that sometimes becomes spontaneously crowded. You had better do the information sincerity from the beginning continually.

When the operator disseminates congestion information in uniform intervals, the prediction method works well. In addition, the prediction method approaches that of the continuous delivery method as the update time is shortened.

VII. CONCLUSION

We have demonstrated that dissemination of congestion information is useful for congestion reduction. In addition, we could confirm differences in the degree of congestion reduction depending on the information delivery method. In this study, we focused on only a single theme park. However, the suggestion to be common to all theme parks is not done. We considered (I) one-time-only dissemination of congestion information, (II) continuous dissemination, (III) dissemination of spatially restricted congestion information and (IV) use of a prediction method. With one-time-only dissemination, it was difficult to determine the optimum timing. In addition, an attraction with the influence is incomprehensible. The continuous dissemination method was generous to guests and is expected to be effective for congestion reduction. A distribution rate of 100% worked best. Although the spatially-limited method was generally able to hold some congestion in check, it could not reduce the congestion level. In the case of the prediction method, the update interval for congestion information was important. The operator can avoid sudden congestion by changing the update timing. The prediction method was found to hold congestion in check more than the continuous information distribution method, and was capable of congestion reduction. When information was disseminated from the beginning, this method performed better than the continuous information dissemination method. The prediction method was useful for lowering the congestion of popular attractions experimentally. However, sudden congestion may occur for other attractions.

In this work, we focused on the operational aspects of congestion reduction schemes. However, there is also a design-side approach to reducing congestion in theme parks, involving choice of placement of attractions. I change a meeting place scale, arriving customer traffic and take various samples and want to analyze it in future.

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