Analysis and Simulation of Theme Park Queuing System

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Abstract—**It has been an important issue to improve customers' satisfaction in theme parks for which become a major role of recreation in our daily life. Waiting for rides has been identified as a factor decreasing satisfaction. A previous study indicated that a virtual queuing system can reduce the total waiting time so the customer's satisfaction is improved. The results from a simulation tool Arena show that an index Satisfaction Value (SV) increases when the queuing system is introduced. In this study, a more complex scenario of theme park queuing system (TPQS) is first designed, followed by comparison of a number of combinations of the rides with various waiting time and distribution factors. Analysis is also carried out.**

Keywords- theme park; queuing system; Arena.

I. INTRODUCTION

Recreation becomes more important when the society is well developed [1]. Theme parks which consist of massive entertainment facilities thus play a major role for people. The famous theme parks namely Happy Valley, Kings Dominion, Disneyland, or Disneyworld have been well known in terms of their complicated designed facilities, interesting demonstrated culture, and enjoyable atmosphere, including thrill rides, interesting shows, arcade games, and food [2]. Many people have been to a theme park for many times for its attractive facilities. However, it is also frustrating when the number of customers is large enough that one has to wait for a long time to take a favorite ride. As previous stated, it is difficult to evaluate customer preferences as the various satisfactions are never uniform [3]. Nevertheless, waiting in a long queue is never desirable. The frustration can be significant enough to stop the customer visiting the theme park again. Therefore if queuing can be organized or designed into a mechanism in which people do not repeatedly queue for a ride, satisfaction must be significantly increasing.

In a civilized society, queuing is symbolism of decency that people follow certain regulation or understanding. Under such regulations, one must wait for others until he or she reaches the goal. If the regulations are not clear enough, dispute and conflict must occur. In some special cases such as seeing a dentist, booking a tennis court, or booking a table in a restaurant, standing and waiting are not necessary as they are well scheduled events. Standing and waiting in a queue only occur in un-scheduled events such as waiting for service in a post office, buying tickets for a popular movie, or waiting for a ride in a theme park. The queue must be recognized by physically standing on sight. If the queue can be recognized by certain means without standing in it, the frustration can be reduced.

For example, standing in a long queue for service in a post office or a bank is frustrating. Instead, taking a numbered ticked at the entrance of the post office can certify the order to be served. The customer can enjoy the ease instead of standing there. This is not only saving the waiting time but also eliminating the suffering of standing in the queue. The same idea can be applied in the theme park if identification of a customer can be recognized.

Analysis of visitor behavior is very difficult since there are large scale entertainment facilities consisting of various properties. Customers select arbitrary directions according to their interest that are complicated, and difficult to predict [4]. A possible method is to observe the number of visitors at each ride to find the popularity factor f_p , followed by comparing with the capacity to evaluate the waiting time in the queue. However, verification of improvement is almost impossible unless that can be applied to a real theme park. As a result, a sensible method to evaluate the success of the improvement is required.

The first stage of design and analysis of a novel theme park queuing system (TPQS) was carried out. The input parameters were simplified in order to verify its feasibility. The aim of this research is to develop a more complex of TPQS with various parameters, and to compare the patterns among them.

This paper consists of the following sections: a brief introduction is presented in section 1 followed by the related work in section 2. The system architecture is described in sections 3. Section 4 describes the simulation procedures and results. The last section is discussion and conclusion.

II. RELATED WORK

Arena is a computer simulation tool from which models for various areas can be created, namely process management in a factory, customer service in a fast food shop, or military operations [5]. The advantage of using Arena is that the queuing theory has been the core of the simulation tool, as well as its lower cost compared with other larger scope of simulations.

From recent studies describing the processes in theme parks, Li [6] investigated and indicated that waiting is an important factor decreasing customer's satisfaction including waiting time, information of current status, and waiting environment. Research shows that waiting before served is the most significant part to customer satisfaction. Ohtani et al. [7] presented that the theme park keeps sending messages to customers in congestion. The most desirable messages are predicted information. Huerre [8] developed with an agent-based crowd simulation tool for theme park environment for Walt Disney group. However, researches to multiple queuing system related to simulations have not been found.

In Taiwan, smart cards are used for National Health Insurance (NHI). Smart card is a pocket-sized plastic card with an embedded integrated circuit on which limited personal information can be stored. The user needs to insert the smart card into a card reader to access any services. The advantages of using a smart card are that data access is reliable, and security is satisfactory. However, the card must contact the reader that access time is considerably long.

A near field communication (NFC) pass which is a contactless card with a 10-15 cm-working range can take over the task. NFC pass has been used for years in Taiwan MRT (Mass Rapid Transit) system. Since the pass is contactless, people can pass the gates quickly, i.e., the user can use it as identification in crowded area without delay. In addition, a NFC pass can be used as electronical wallet on which top-up can be performed.

Global positioning system (GPS) has been applied for decades. The precision reaches within 40m. Most of smart phones equip build-in GPS that indicates the user's location as long as transmission is available. With the previous stated technology, the position of a visitor in the theme park can be located if his GPS mobile phone has registered to the system. In addition, NFC function can also be integrated on a smartphone for more advanced use.

The queuing time and popularity vary according to the capacity of the theme park. When the number of visitors exceeds the boundary capacity, it is impossible to reach the optimum results.

Therefore it has been decided to design a queuing system for multiple rides in theme parks simulated by using Arena. The first TPQS described in the previous paper consists of 3 facilities with identical riding time and waiting time. The small scale of facilities is not able to represent customer's behavior in a real theme park. In addition, identical riding time and waiting time could eliminate the deviation that conceals the real trend. The new TPQS consists of two parts: The first part consists of 5 cases with different sets of popularity factors among which the correlation of the improvement rate of satisfaction value and the standard deviation of the popularity factors is investigated. The second part consists of 5 cases with identical popularity factors but different total waiting time among which the correlation of the improvement rate of satisfaction value and the standard deviation of the total waiting time is investigated.

III. SYSTME STRUCTURE

A theme park consists of the following sections: rides, food courts, and show houses. When entering the theme park, some of the visitors would start with the nearest rides, while the others would directly go for the favorite rides. Fig. 1 presents the possible movements of the customers.

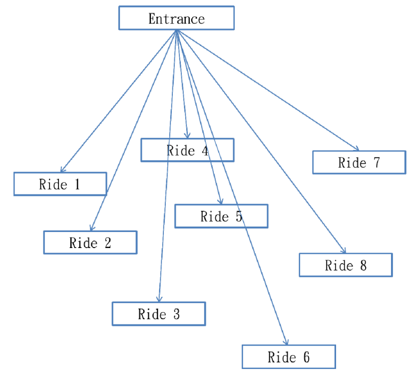

Figure 1. Layout of a theme park

A satisfaction value S has been defined as follows:

$$S = \frac{T_r}{T_q} \quad (1)$$

where T_r is total time on rides, and T_q is total time in queues, then

$$T_r = \sum t_{ri}$$
$$T_q = \sum t_{qi} \quad (2)$$

where t_{ri} and t_{qi} are riding time and queuing time at the ith ride.

TPQS uses a reservation center in which visitors can book their favorite rides in advance (Fig. 2). In the reservation center, each ride has a NFC card reader for reservation. The visitor can go to the reservation center to reserve favorite rides by sensing the NFC pass. The booking status is displayed at checking points. Visitors can check from the monitors or wait for notification. The system notifies the visitor in a reasonable time (say 3 minutes) before the ride is available. Notification can be done by means of sending short messages, LINE, or even e-mail to mobile phone, so the visitor can prepare and move toward the ride. If the visitor is absent to the ride, the reservation will be cancelled.

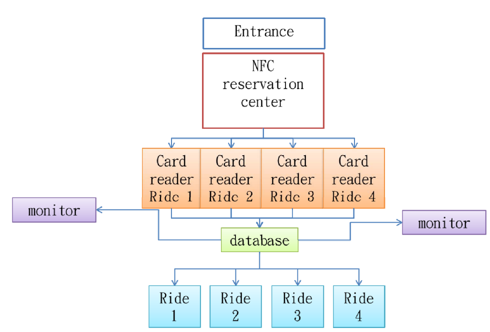

Figure 2. Structure of queuing system in the theme park.

When the visitor is playing at a certain ride, queuing for other rides are still in progress. If the next ride is available before the current ride is finished, the visitor simply re-book the cancelled ride or go for another reserved ride. The total queuing time is thus reduced, while the total riding time is the same that,

$$T_r = \sum t_{ri}$$
$$T_q = \sum t_{qi} - \sum t_{rj} \quad (3)$$

Where, t_{rj} is the riding time at the *j*th ride while queuing another ride.

The queuing time of a ride depends on its capacity, riding time, and popularity. The popularity level of a ride varies as the number of visitors changes every day. The differences of the popularity levels among the rides can be observed and recorded. In the queuing system, the popularity of each ride is defined as f_i at the *i*th ride. Then,

$$t_{qi} = \frac{N_T \times f_i}{n_i}(t_{ri} + e_i) \quad (4)$$

Where, N_T is the number of total visitors, n_i is the capacity of the ride *I*, and e_i is the access time of the ride.

IV. SIMULATION PROCEDURES AND RESULTS

A. Simulation Models

The first part of the simulation model consists of 5 cases with different sets of popularity factors. The popularity factors are arbitrarily selected in order to find the corresponding improvement rate of satisfaction value.

The second part of the simulation model consists of 5 cases with identical popularity factors but different total waiting time. This is to find the corresponding improvement rate of satisfaction value as well.

In the simulation models, the number of total visitors is defined with normal probability distribution. The open time of the theme park is from 9:00 am to 4:00 pm. The average number of customer is 78 for 6 entertainment facilities.

B. Simulation Procedures

The simulation procedures are the same as the first TPQS:

- Define input parameters: the frequency of the visitors going into the theme park.
- Define input parameters: riding time.
- Define input parameters: popularity of the rides.
- Connect 2 or more process lines: queuing for more than 1 ride at the same time.
- Start: finding the total queuing time and riding time.

In order to simplify the model, the initial assumptions are as follows:

- Visitors who are not on any rides remain in the theme park.
- Distances among rides are ignored.
- The visitors will not go to any ride before receiving notification.
- The visitors will not re-take the same ride.
- The visitors will leave the theme park after completing all the rides.

C. Simulation Results

Table 1 shows the parameters and results of the first part of the simulation.

Table 1. Simulation model 1

	Case 1	Case 2	Case 3	Case 4	Case 5
Ride 1	8	6	5	3	3
Ride 2	11	8	10	7	5
Ride 3	13	16	15	10	7
Ride 4	18	22	20	15	10
Ride 5	22	23	25	25	15
Ride 6	28	25	25	40	60
Total	100	100	100	100	100
Average	16.67	16.67	16.67	16.67	16.67
Standard deviation	6.82	7.39	7.45	12.53	19.75
total waiting time without Queuing System	0.3359	0.3425	0.3583	0.3696	0.3739
Satisfaction Value without Queuing System	1.7864	1.7517	1.6747	1.6236	1.6047
total waiting time with Queuing System	0.1003	0.086	0.1172	0.1675	0.1838
Satisfaction Value with Queuing System	5.9791	6.9767	5.1209	3.5829	3.2636
Increasing rate of Satisfaction Value	234.70%	298.28%	205.78%	120.68%	103.38%

The improvement rate is decreasing when the standard deviation of popularity factors is increasing. This suggests that when only a small number of facilities have very high popularity factors, the TPQS has least contribution. Fig.3 shows that there is a relative maximum at case 2. This is a possible peak value of the improvement rate of this experiment.

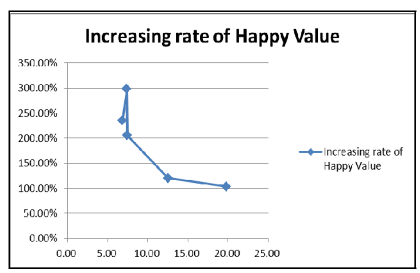

Figure 3. Model 1, the increasing rate of satisfaction value.

Table 2 shows the parameters and results of the second part of the simulation. The results indicate that the improvement rate reaches maximum when all the total waiting time are the same. There is a relative maximum of the improvement rate at case 3 which average waiting time is 0.092 hour, and the standard deviation of the waiting time is highest (Fig. 4).

D. Discussion

The simulation results suggest that TPQS and queuing behavior are quadratic or higher power of functions. In the first model, the possible maximum improvement rate at case

2 where half facilities have almost the same popularity while the others vary. The waiting times are similar without TPQS. When TPQS is introduced, the improvement rate is decreasing as an exponential function.

Table 1. Simulation model 2, the total waiting time.

Popularity factor	Case 1	Case 2	Case 3	Case 4	Case 5
0.05	0.05	0.05	0.03	0.06	0.05
0.08	0.05	0.03	0.05	0.08	0.05
0.12	0.05	0.07	0.07	0.04	0.1
0.2	0.05	0.15	0.1	0.15	0.1
0.25	0.05	0.06	0.15	0.12	0.15
0.3	0.05	0.03	0.15	0.13	0.15
Total	0.3	0.39	0.55	0.58	0.6
Average	0.05	0.065	0.092	0.097	0.1
Standard deviation	0.00	0.04	0.05	0.04	0.04
total waiting time without Queuing System	0.3119	0.3124	0.3314	0.3464	0.3083
Satisfaction Value without Queuing System	0.9619	1.2483	1.6598	1.6746	1.9459
total waiting time with Queuing System	0.0979	0.1576	0.1227	0.1328	0.1514
Satisfaction Value with Queuing System	3.0645	2.4752	4.4822	4.3662	3.9625
Increasing rate of Satisfaction Value	218.59%	98.29%	170.04%	160.73%	103.63%

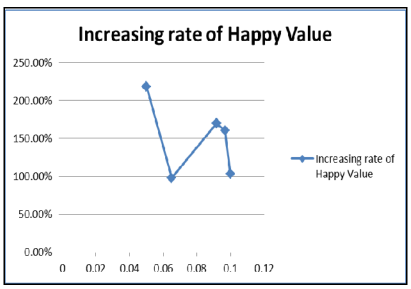

Figure 4. Model 2, the increasing rate of satisfaction value.

In the second model, the best interpretation is to eliminate case 1 since the standard deviation of waiting time is 0. Thus, the improvement rate has a maximum at case 3 where the standard deviation of waiting time is maximum.

All the results indicate that a TPQS provides significant contribution in saving queuing time.

I. CONCLUSION

A more complex TPQS has been designed and tested. According to the results of ARENA simulation, the waiting time has been significantly reduced and the customer satisfaction value increases. The results also suggest the TPQS performs a higher power or an exponential function. The research leads to a high degree of non-linear mathematical model. The future work also focus on implementation of a small queuing system in Tamkang University on Lanyang Campus

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