Agent-Based Simulation for Avoiding the Congestions of Tourists

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***Abstract*—In this paper, we develop an agent-based simulation model to avoid tourist concentration in a sightseeing area. Among main tourist destinations, the tourist concentration called "overtourism" becomes an issue for both of tourists and residents in the destinations. While spreading COVID-19 among sightseeing areas, tourist concentration should be avoided from the standpoint of the public health. We develop an agent-based simulation model to estimate the effectiveness of "congestion information at the destination" among tourists. The simulation results show that the congestion information is effective when only 30% of tourists follow the information to avoid the concentration in the major attractions in a sightseeing area.**

Keywords—Overtourism, congestion information, sightseeing, agent-based simulation

I. Introduction

"Overtourism" have attracted attentions from travelers and researchers recently. Cappocchi et al. [1] shows the word "overtourism" had emerged on the internet since 2017 by using Google Trends. Fig. 1 shows the results of Google Trends during January 1, 2016 to December 31, 2020 all over the world. Google Trends shows the relative scores of the number of searches during the target period. In Fig. 1, the week starting from October 20 gives the score 100, and scores of other weeks show relative values according to the week of October 20. Fig. 1 shows that the trend of using the term "overtourism" starts from September 2017 and have an increasing trend until October 2020. Since the end of 2020, the COVID-19 started to spread among the world, and a lot of countries prohibit international tours in order not to bring nor spread COVID-19 from/to other countries.

Before COVID-19, "overtourism" becomes issues for tourists and residents caused by congestions of tourists in a sightseeing area. For tourists, they cannot find enough accommodations at their destinations, and cannot enjoy strolling at the area due to a huge number of tourists. For residents, they face heavy traffic and long queues at any shops in their residential area. As one of the major tourist spots in the world, Kyoto City Tourism and Industry Bureau conducted tourist survey, and asked "what makes you disappoint in your trip?" They reported that "Too many tourists" (1st by Japanese tourists, 4th by foreign tourists), "Too complicated transportation systems" (2nd by Japanese, 2nd by foreigners), "Insufficient time" (1st by foreigners), and "Insufficient English guides" (3rd by foreigners). Too many tourists make themselves unsatisfied at their visits [2].

During COVID-19 era, it is essential matter for tourists and residents to reduce congestions in the sightseeing area in order not to spread COVID-19 among people in the area. In order to avoid the congestions in the sightseeing spot, the congestion information for each sightseeing spot can be distributed to tourists to decide whether they visit the place now or visit it later hours at the same day. By avoiding the congestion in the sightseeing place, tourists will enjoy strolling at the sightseeing spots and residents will take detours to avoid traffic and congestions around the spots.

To avoid congestions in the sightseeing area, Kyoto City Tourism and Industry Bureau has already tried to share the congestion information at the sightseeing spots in Kyoto City by the support of Kyoto University [3]. In their report, they investigate when tourists access webpages that share the congestion information. They found that webpages that introduce the sightseeing spots have many accesses before tourists visit the spots, but webpages that share the congestion information have accesses during visits of tourists. They found tourists information retrieving activities are transforming now, and those activities during tourists' visits should be further investigated. However, they have not yet investigated how tourists change their selection of sightseeing spots from the congestion information.

In this paper, we employ agent-based approach to see the effect of the congestion information to avoid the congestions at sightseeing areas. As a previous research using the congestion information for recreational attractions by agent-based simulation, Zheng et al. [3] conducted a simulation with information sharing among visitors using agent-based modeling. They conducted a simulation in a theme park that has several entrance gates and several attractions where agents should wait until the attractions become available. They introduced average waiting time (AWT), average moving time (AMT), and average unvalued time (AUVT = AWT + AMT)

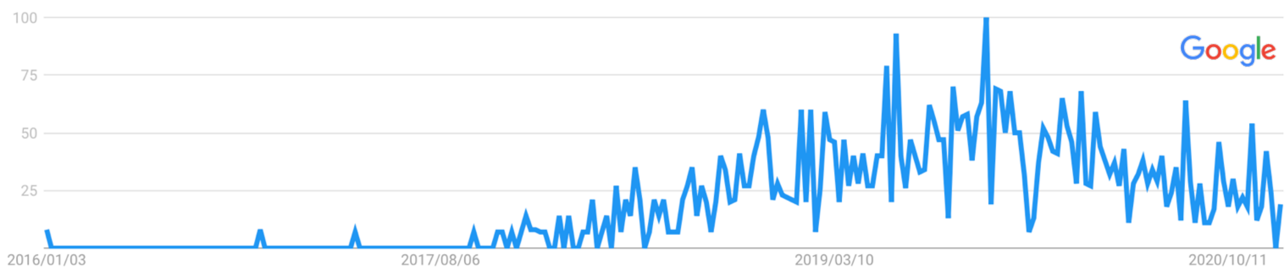


Fig. 1. Google Trends Result using the Keyword "Overtourism."

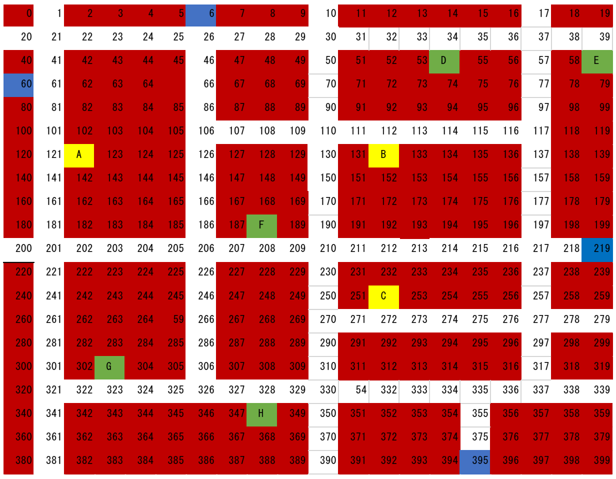


Fig. 2. Environmental model.

to compare three strategies: random strategy (agent visits attractions as they like), static strategy (agent visits the nearest attractions), and dynamic strategy (agent visits the nearest and available attractions based on the congestion information given to all agents). Their simulation results show that the dynamic strategy gives the minimum AUVT.

Chen et al. [4] also employs agent-based method to estimate the impact of walking speed on tourist carrying capacity. Tourist carrying capacity is a concept to avoid environmental disruption caused by tourists. They conclude that walking speed has a negative impact on tourist carrying capacity. They consider only the capacity of the sightseeing area but the satisfaction level of tourists or residents in the area. Scott et al. [5] conduct agent-based simulation for ski resorts. In their simulations, they observe the relations between climate change and the number of skiers. They compared three winters (Average, warm and cool) and two options of snowmaking schemes (Current and improved snowmaking). They point the congestion of skiers when many ski resorts cannot open due to the lack of snows in a warm winter. However, they do not examine scenarios such as how they can avoid the congestions in ski resorts. Their main concerns are the sustainability of ski resorts and ski cultures.

In this paper, we conduct an agent-based simulation model to avoid the congestion in a sightseeing area. We estimate how we can avoid the congestion by providing the congestion information to tourists. We consider scenarios where all, 70%, 50% and 30% of tourists respond to the congestion information to avoid the congestion in the sightseeing spots.

II. Sightseeing Spots Selection Model

A. Environmental Model

Our model consists of an environmental model and agent model. As for the environmental model, we consider a sightseeing area near Kyoto station in Japan. In Kyoto, we have a lot of sightseeing spots within walking distance. Tourists do not use transportations if their destinations are located within walking distance.

Fig. 2 shows the environmental model we employed in this paper. In this figure, we have four departure cells (Blue cell: 6, 60, 219, and 395) and eight destinations (Yellow cell: A, B, and C; Green cell: D, E, F, G, and H). Red cells indicate building cells where any tourist agent cannot enter. Agents can walk only on the white cells. If each cell is 100m square, the environmental model becomes 2km square. When agents can move 1 cell / step, we can consider that it takes 1.5 min / step. The three yellow destinations are attractive sightseeing spots. Thus, every tourist must visit those spots. The other five green destinations are not so popular. Every tourist will visit two of them according to their interest. Therefore, each agent visits five destinations in their one-day tour during 300 steps (approximately seven and half hours). Every tourist enjoy her/his visit for 15 steps at every sightseeing spot.

B. Congestion Information and Destination Selection

In this paper, we have 500 tourists to visit the same sightseeing area. As we have described, each tourist has five destinations. Among them, three destinations are visited by all tourists. Therefore 1/5 tourists may visit in the same order. If they visit the destination at the same time, 100 tourists will visit the same destination. As for the other five destinations, each tourist selects two destinations from the five candidates, then visit it as one of five destinations for him/her. Therefore, a destination is selected by the probability of 2/25 to visit. From this calculation, 40 tourists will visit at the same time for those five destinations.

In order to avoid the concentration even in the other five destinations, we share the congestion information if a destination has more than 35 tourists at the moment. When a tourist receives a congestion information, s/he tries to avoid visiting such a crowded sightseeing spot. S/he skips the crowded sightseeing spot but visit the next destination. S/he visit the skipped spot after the destination s/he visited earlier. If the next destination also has more than 35 tourists, s/he tries to visit the next one. If the final destination has more than 35 tourists, s/he visit it finally even if it has more than 35 tourists.

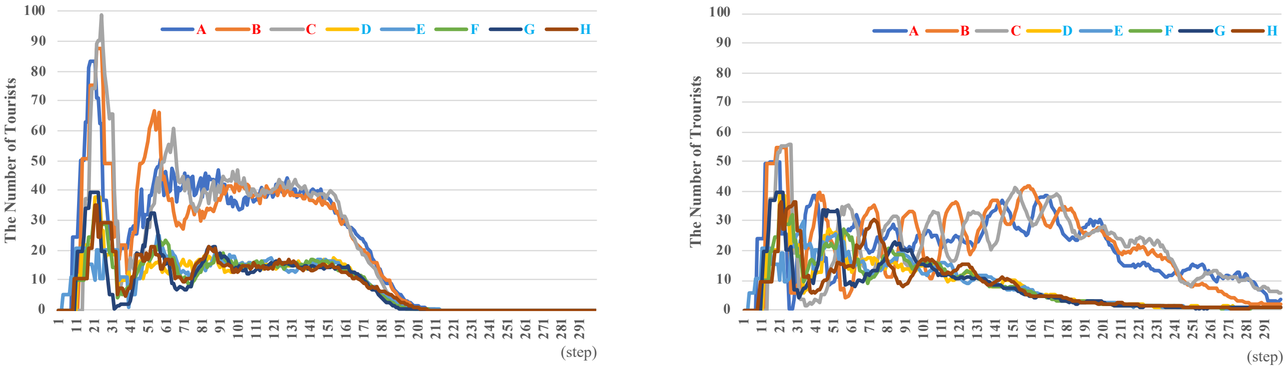
Each tourist selects a destination according to the congestion information at every step except just two steps before the next destination. That is, a tourist can change her/his mind at Cell 181 when s/he is going to Destination A, but s/he cannot change her/his mind at Cell 141 since s/he is about to reach Destination A.

We set a satisfaction level of a tourist according to the congestion level. If a tourist arrives at a destination with more than 35 tourists, s/he receives 30 points. If s/he arrives at a destination with less than 35 tourists s/he receives 80 points. If a tourist visits all five destinations less than 35 tourists, s/he receives 400 points from her/his visits. If all of her/his visits have more than 35 tourists, s/he receives only 150 points.

III. Effect of Congestion Information

A. Comparison of Using and Not Using the Information

We conducted 100 trials with different random factors to see the effect of congestion information. Fig. 3 shows the average number of tourists in eight sightseeing spots in the sightseeing area in Fig. 2. Fig. 3 (a) shows the number of tourists when no tourist uses the congestion information. Fig. 3 (b) shows the number of the tourists with the congestion information. From Fig. 3 (a), we can see that around Step 20, the numbers of tourists at Destination A, B and C are about to become 100 as we have shown in a simple calculation. The numbers of tourists at other destinations D, E, F, G and H are



(a) No tourists uses the congestion information

(b) All tourists use the congestion information

Fig. 3. The number of tourists at each destination.

TABLE I. The Average Number of Tourists in a Trial.

Congestion Information	Not Use	Use
The number of maximum tourists in Destination A, B or C	98	60
The number of maximum tourists in Destination D, E, F, G or H	41	42
The average satisfaction level over all tourists	307.3	375.5
The average number of tourists when each tourist visits at Destinations A, B and C	27.1	19.0
The average number of tourists when each tourist visits at Destinations D, E, F, G and H	6.8	7.6
The average number of steps over all tourists traveling in the sightseeing area	88.4	141.6
The number of tourists who cannot complete their one-day tour within 300 steps	0	42

about to become 40. Around Step 50, the next peak comes to every destination. Destinations A, B and C have 40 to 70 tourists and Destinations D, E, F, G and H have 20 to 30 tourists. At Step 70 or later, the number of tourists moderately decreases until the end of the simulation.

On the other hand, Fig 3 (b) shows the number of tourists when all tourists use the congestion information. Therefore, all tourists try to avoid congestion until they reach two steps before their destination. From Fig. 3 (b), we can see that the highest peak becomes less than 60 at Destinations A, B and C. Destinations D, E, F, G and H have constantly about 40 or less than 40 tourists.

TABLE I shows results of a trial among 100 trials. TABLE I shows the number of maximum tourists in Destination A, B or C, the number of maximum tourists in Destination D, E, F, G or H, the average satisfaction level over all tourists, the average number of tourists when each tourist visits at Destinations A, B and C, and that at Destination D, E, F, G and H, the average number of steps over all tourists traveling in the sightseeing area, and the number of tourists who cannot complete their one-day tour within 300 steps. From TABLE I, we can see that the number of maximum tourists in Destination A, B or C decreases 40% when all tourists use the congestion information. The average satisfaction level becomes near to 400 points with the use of the congestion information. However, the average number of steps all agents travel in the sightseeing area until 300 step becomes double in the case of using the congestion information. This is because tourists with the congestion information change their mind anytime on the way to the destination. Therefore, they sometime go back and forth before reaching a destination.

This also causes the number of tourists who cannot complete their one-day tour within 300 steps. When no tourist uses the congestion information, all tourists complete their day tour. On the other hand, 42 tourists can not complete their tour when they use the congestion information in a trial. From this result, we can see that providing the congestion information is better for tourists when they want to avoid the congestion at sightseeing spots. However, it makes their day tour longer or sometimes not completed in a day.

B. *When Not All Tourists Follow the Information*

In order to see results when not all tourists follow the congestion information, we conduct three cases when only 30%, 50%, or 70% tourists follow the congestion information. Figs. 3 to 5 show the number of tourists at each destination. From these figures, we can see that the first peak of the number of tourists at Destinations A, B and C becomes smaller when the rate of tourists who follow the congestion information becomes larger. On the other hand, the number of tourists who continue their day trip becomes larger when the rate of tourists who follow the congestion information becomes larger.

TABLE II shows the results of a trial among 100 trials in the three cases. In order to compare the three cases with the two cases in the last subsection, we add the simulation results of 0% and 100% in TABLE II. 0% and 100% tourists follow the congestion information correspond to “Not Use” and “Use”, respectively. From TABLE II, we can see that the average number of steps of tourists who follow the congestion information becomes larger when the rate of the tourists who follow the information becomes smaller. On the other hand, the number of steps of tourists who do not follow the information does not change whether the rate of the tourists who follow the information becomes smaller. The number of tourists at sightseeing spots becomes similar with any rate of tourists who follow the information. The number of tourists

TABLE II. The Average Number of Tourists in a Trial.

Rate of Tourists Who Follow the Congestion Information	0%	30%	50%	70%	100%
The average number of steps of tourists who follow the congestion information	N/A	137.9	129.6	120.1	141.6
The average number of steps of tourists who do not follow the congestion information	88.4	89.2	88.1	89.7	N/A
The average number of tourists when each tourist visits at Destinations A, B and C	27.1	21.3	21.1	20.5	19.0
The average number of tourists when each tourist visits at Destinations D, E, F, G and H	6.8	7.3	7.4	7.4	7.6
The number of tourists who cannot complete their one-day tour within 300 steps	0	3	17	26	42

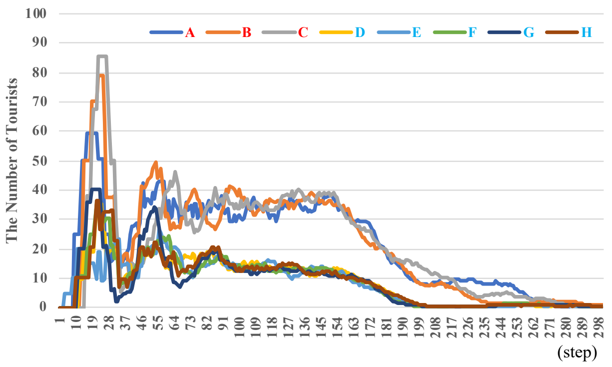


Fig. 4. The number of tourists when 30% tourists follows the information.

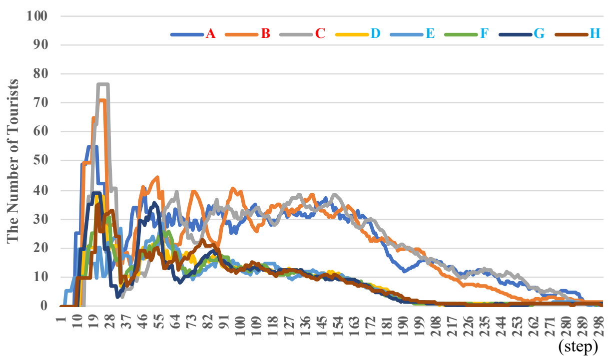


Fig. 5. The number of tourists when 50% tourists follows the information.

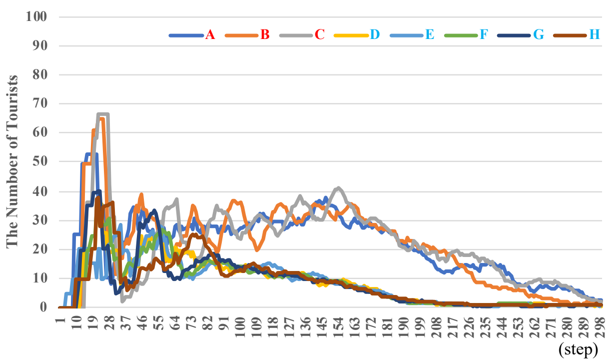


Fig. 6. The number of tourists when 70% tourists follows the information.

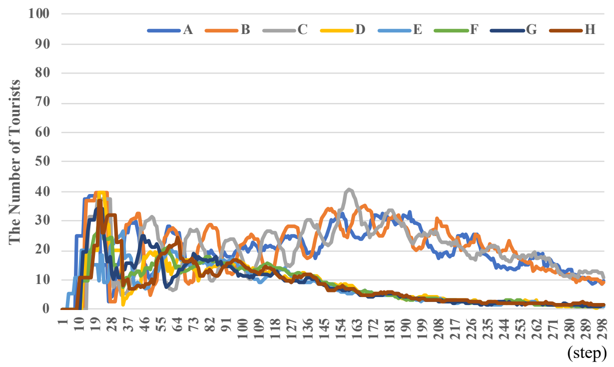


Fig. 7. The number of tourists when the information is sent more than 25.

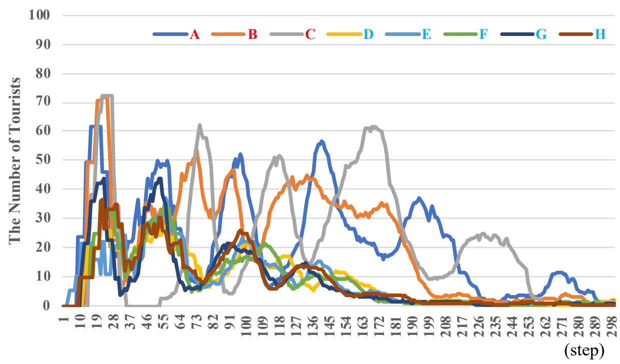


Fig. 8. The number of tourists when the information is sent more than 60.

who cannot complete their one-day tour within 300 steps becomes larger if the number of tourists who follow the information becomes larger. From these results, we can see that even if not all the tourists follow the congestion information, the average number of tourists at the sightseeing spots becomes not so different.

C. *When Congestion Information is Sent to Smaller or Larger Number of Tourists*

In order to see the difference between smaller and larger congestion information, we set different number of tourists at the same sightseeing spot. That is, the congestion information is sent to tourists when more than 25 tourists are visiting a sightseeing spot, or more than 60 tourists are visiting. Figs. 7 and 8 show the number of tourists at each destination. We can see that small fluctuations can be seen when the congestion

TABLE III. The Average Number of Tourists in a Trial.

The Number of Tourists When the Congestion Information Is Sent	25	35	60
The average number of steps of tourists who follow the congestion information	162.2	141.6	103.2
The average number of tourists when each tourist visits at Destinations A, B and C	16.3	19.0	24.8
The average number of tourists when each tourist visits at Destinations D, E, F, G and H	10.1	7.6	7.1
The number of tourists who cannot complete their one-day tour within 300 steps	64	42	4

information is sent more than 25 tourists. On the other hand, the large fluctuations are found in the case of 60 tourists.

TABLE III shows the simulation results in a trial when the congestion information is sent with smaller or larger number of tourists. In TABLE III, the case with 35 tourists is the same result of using the congestion information in TABLE I. From TABLE III, we can see that the average number of steps of tourists who follow the congestion information becomes larger when the information is sent to tourists when more than only 25 tourists visit the sightseeing spot. In that case, many tourists cannot complete their one day-tour since many tourists change their destinations according to the congestion information. From these results, we can see that too strict congestion information makes many tourists change their destinations, then the number of steps in a one-day tour becomes larger, and the number of tourists who cannot complete their one-day tour becomes larger.

IV. Conclusion

In this paper, we develop an agent-based simulation model to consider the effect of the congestion information in a sightseeing area. From the simulation results, we can see advantages and disadvantages of using the congestion information. Advantages of using the information is that we can reduce the number of tourists in a sightseeing spot when we employ the congestion information to avoid the congestion. On the other hand, the number of steps during a one-day tour becomes longer because tourists change their destinations even if they are on the way to the next destination.

As the further studies, we should examine other options how to change destinations of tourists when they receive the congestion information. Some tourists want to avoid the congestion but want to minimize the number of steps in their one-day tour. We need to incorporate an option to select the nearest destination from the current position of the tourist.

We should also consider that the congestion level on the way to destinations. In this study, we do not consider the congestion on the way to the destination. Some tourists do not want to be involved the congestion even on the way to destinations. We can also consider such a situation. Chen et al. [4] try to consider the congestion level during walking in a sightseeing spot. We can take into account such approaches in our study.

We can also consider the variety of tourists in our simulation model. That is, young tourists may walk between sightseeing spots much faster than older tourists. Such age composition of tourists can be considered to make our simulation more realistic.

Acknowledgment

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