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Study on Pedestrian Traffic Flow in Crowded Conditions Using Mobile Location Data

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Abstract

In recent years, in Japan, the number of incidents involving large crowds has been increasing for several reasons, including the increase in the number of such time-intensive events as sports events and concerts, the increase in the number of tourists, and the paralysis of traffic functions caused by natural disasters. However, the increasing sophistication of information and communication technologies and smart phones has increased the technological possibilities and improved crime prediction systems, leading to the development of pedestrian agent simulations and the analysis of crowd conditions using big data. However, there is still a lack of knowledge on crowd control at the micro level of events, such as fireworks displays and disasters. The purpose of this study was to gain new knowledge on how to understand and control crowd behavior at events by analyzing mobile location data obtained from smartphones.

KEYWORDS: crowd behavior, mobile location data, *K–V* scatter map

1. Introduction

In recent years, the number of crowd incidents has increased because of an increase in the number of time-intensive events, such as sports and concerts, as well as the paralysis of traffic functions during natural disasters. Around the world, there have also been such crimes as mobbing and molestation in crowds, such as the sexual assault at the Etoile Arc de Triomphe during the 2018 soccer World Cup celebrations and the light truck incident at Shibuya Halloween 2018.

However, because of the sophistication of information and communication technology, in many countries, pedestrian simulation and crowd analysis using big data have been conducted. In Japan, the prediction of crowd behavior by simulation[1)], the analysis of crowd wave phenomena[2)], simulations of GNSS availability for location estimation[3)], and map matching of pedestrian trajectories using GPS and PDR[4)] have been conducted, but there is still a lack of knowledge on the observation of crowd behavior in the pedestrian space and on crowd control and response in the event of a disaster.

Therefore, in this study, the target elements were classified as the direction of the crowd, walking speed, density, and spatial conditions. Psychological conditions were excluded. Mobile location data obtained from smartphones were used to gain basic knowledge about pedestrian traffic flow under crowding conditions during events.

2. Methods of analysis

2.1 Target events

The target events were Halloween in Shibuya and Luminarie in Kobe. By observing and analyzing events with different characteristics (Table 1), one can understand the characteristics of crowd behavior and differences in pedestrian traffic flow control methods.

2.2 Analysis methods and flow

The velocities and densities obtained from the field survey results and mobile location data were compared. “Crowding” was defined as a state of high density and reduced speed to understand the characteristics of pedestrian traffic flow that differ from event to event and crowding conditions under high density (Figure 1).

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Table 1. Characteristics of target events

Event	Shibuya Halloween	Kobe Luminarie
Target Location	“Shibuya Scramble Crossing ~Around Center Street”	“Motomachi Higashi Yuenchi”
Area covered	Approx.0.12 ㎢	Approx.0.5 ㎢
Number of mobile deta acquired	12,889 units	39,445 units
Number of participants [per day]	“No organizer, unknown. (Estimated 10 to 1 million people)”	“Approx.542,000
Spatial Conditions	Streets and Intersections	Streets and Squares
Crowd movement conditions	No guidance,only Center Street is one direction in congestion	One direction with guidance

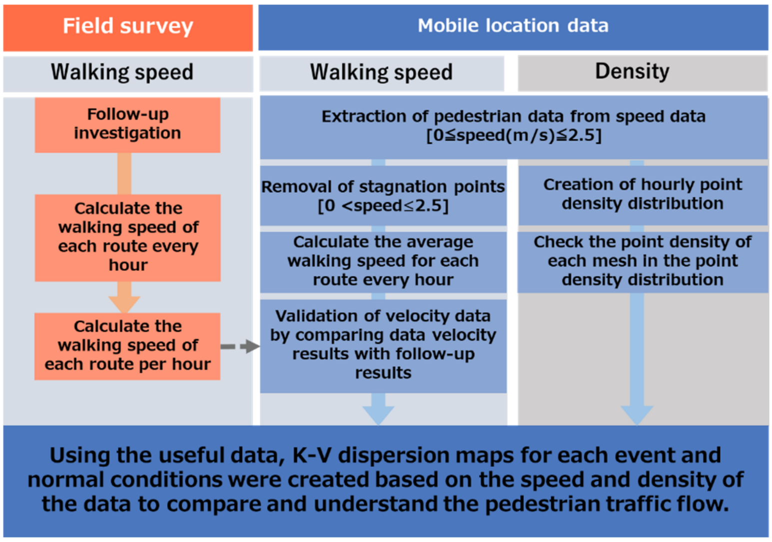


Fig. 1. Flow analysis

2.3 Outline of the field survey

A follow-up survey was conducted to understand the walking speed of people on the day of the event. In the follow-up survey, pedestrians were followed along the set course, and the speed of each route was measured every hour — five times for the Shibuya Halloween and twice for the Kobe luminarie. (Figaure 2,3)

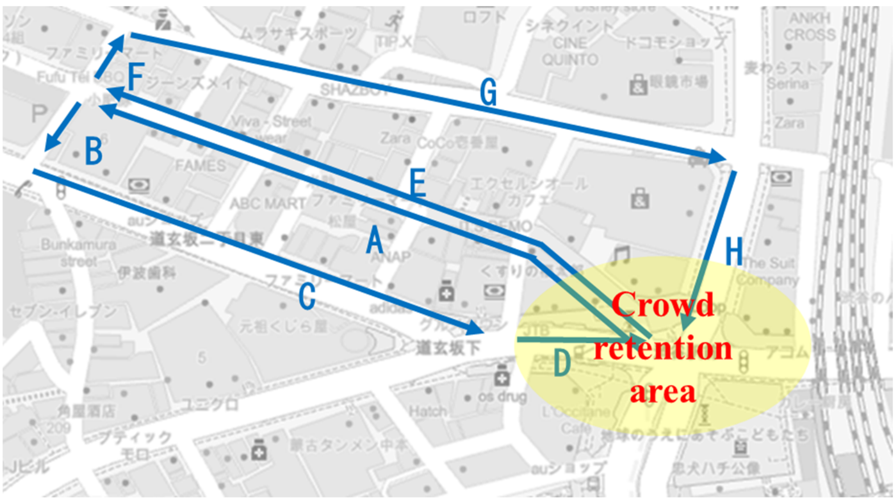


Fig. 2. Route map for Halloween in Shibuya

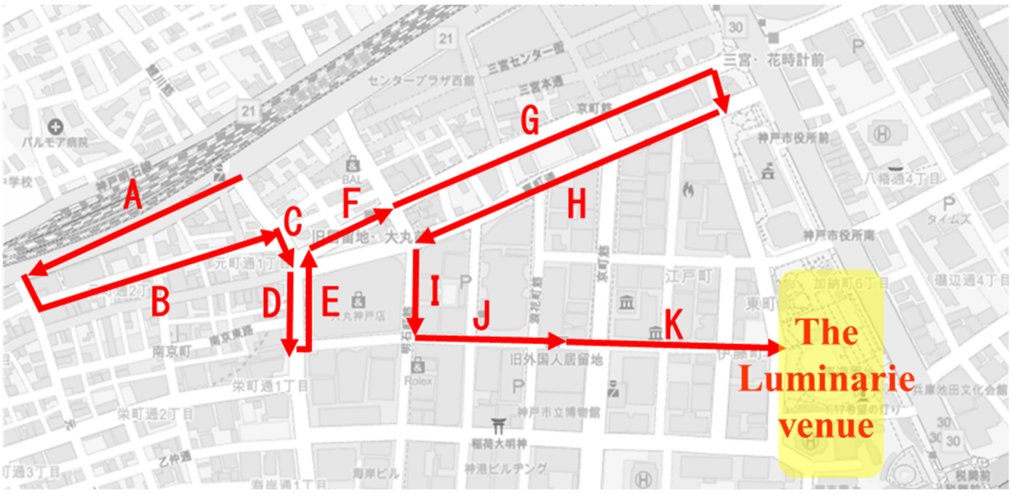


Fig. 3. Path of Kobe Luminarie

2.4 Mobile location data

The mobile location data used are the location information collected from the GPS of a smartphone with a specific app installed, with the age and gender of the user being kept secret, and provided by Agoop as point data. The information includes longitude and latitude, direction of movement, and speed.

2.4.1 Average transit speed analysis for each link path in the data

Pedestrian routes were set up for each event, and mobile location data at the time of the event were analyzed for the average hourly transit speed of each link using the Mobmap human flow analysis software.

2.4.2 Comparison of density and velocity relationships before and after the event

Using mobile location data observed on an hourly basis, point densities and velocities were aggregated hourly in 10-m meshes of the target site and compared before and after the event.

3. Results of the field survey and comparison of speed data

The results of the follow-up survey were compared with the mobile data, which were determined to be pedestrians based on the speed ($0 < \text{speed} \leq 2.5$) when passing through each route during the event. For Shibuya Halloween, the averages were similar except for route D.(Figure 4)

However, for the Kobe Luminarie, the average speed was higher for all routes in the follow-up survey results than for the data, and the average speed for Kobe Luminarie was higher than that for Shibuya Halloween. This is because the entire route of the Kobe Luminarie is unidirectional, and it is influenced by the spaciousness of the induction routes and the age range of the participants. Next, the intervals of variation were compared using Tables 2 and 3. In the Shibuya Halloween, the value of path A is small (Table 4). This may be because the movement of the crowd was unified to one way only for path A. In addition, the significant decrease in the standard deviation of path F after 7:00 p.m. was caused by the one-way flow of path A (E), which caused a backflow of participants who tried to reverse the flow of path A and a stagnation of participants who walked along path A near the start of path F.

As a result, the effect of the constant movement of the crowds was considered as a numerical value. In the Kobe Luminarie, the low values of J and K in Table 3 are considered to result from the effect of constant crowd movement at the highest density near the event destination. The results in Tables 2 and 3 show that the data had a large variation, even when crowd movements were unified, as in Kobe Luminarie.

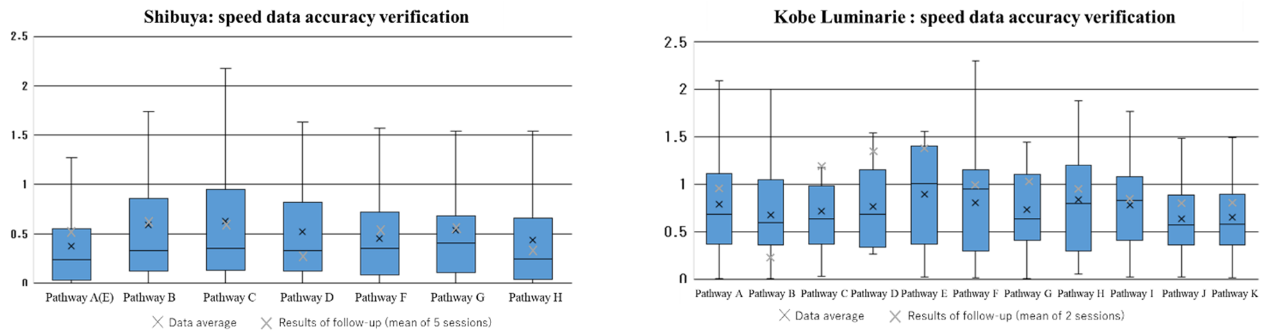


Fig. 4. Speed verification results for each link path at each event

Table 2. Standard deviation of Shibuya Halloween speed data by time and route

Standard deviation	Pathway A(E)	Pathway B	Pathway C	Pathway D	Pathway F	Pathway G	Pathway H
5:00 p.m.	0.476	0.819	0.697	0.452	1.105	0.793	0.808
6:00 p.m.	0.428	1.098	0.585	0.592	0.702	0.577	0.486
7:00 p.m.	0.363	0.443	0.55	0.528	0.183	0.565	0.454
8:00 p.m.	0.422	0.473	0.594	0.501	0.059	0.588	0.34
9:00 p.m.	0.269	0.136	0.729	0.684	0.059	0.494	0.649
10:00 p.m.	0.5	0.938	0.737	0.416	0.006	0.552	0.458
11:00 p.m.	0.329	0.479	0.372	0.215	0.331	0.496	0.405
Mean standard deviation	0.398	0.627	0.609	0.49	0.35	0.581	0.514

Table 3. Standard deviation of speed data by time and route in Kobe Luminarie

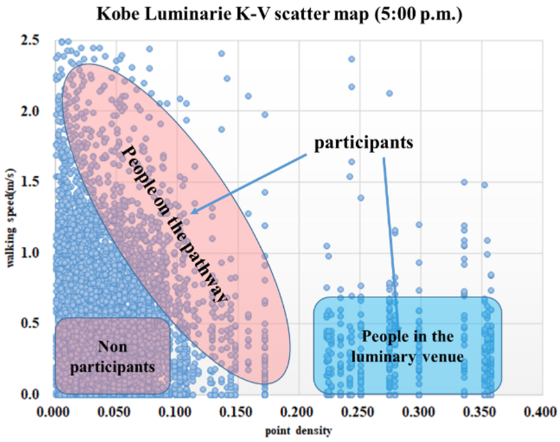
Standard deviation	Pathway A	Pathway B	Pathway C	Pathway D	Pathway E	Pathway F	Pathway G	Pathway H	Pathway I	Pathway J	Pathway K
6:00 p.m.	0.554	0.377	0.454	0.773	0.601	0.471	0.331	0.332	0.354	0.462	0.325
7:00 p.m.	0.472	0.334	0.404	0.447	0.469	0.588	0.426	0.545	0.387	0.299	0.282
8:00 p.m.	0.478	0.512	0.458			0.469	0.428	0.458	0.557	0.439	0.479
9:00 p.m.	0.557	0.454	0.679			0.371	0.211	0.412	0.465	0.402	0.387
Mean standard deviation	0.515	0.419	0.498	0.61	0.535	0.475	0.349	0.437	0.441	0.4	0.368

4. Comparison of pedestrian traffic flow analysis and *K–V* scatter plots for each event

The *K–V* scatter plots were used to compare the normal data and the data at the target event by event. In Kobe, the dots with $K > 3.0$ in Fig. 5 are the highest density symbols in Fig. 7, i.e., people in the luminary venue. Figure 7 shows the result of extracting the points with $K \leq 0.5$ and $V \leq 0.5$, as shown in Fig. 5. Because most of the points in Fig. 5 are not on the induction path, these points are mostly nonparticipants, while the points on the *K–V* line are mostly on the induction path and are considered to be points of the event participants.

Thus, it was possible to capture the strict division of event participants and nonparticipants by security on the *K–V* scatter diagram.

In the Shibuya area, points with $K \leq 1.5$ and $V \leq 0.5$ were extracted, and the above points were sparsely distributed throughout the entire area except for the high-density area (Fig. 6,8). In the normal case, the points $0 \leq K \leq 0.5$ and $0.5 \leq V \leq 2.5$ on the scatterplot flowed around the $0.5 \leq K \leq 1.5$ and $V \leq 0.5$ area. Therefore, it was found that most people walking at low speed, even at low density, during the Shibuya Halloween tended to congregate at places where there were crowds of people to a certain extent.



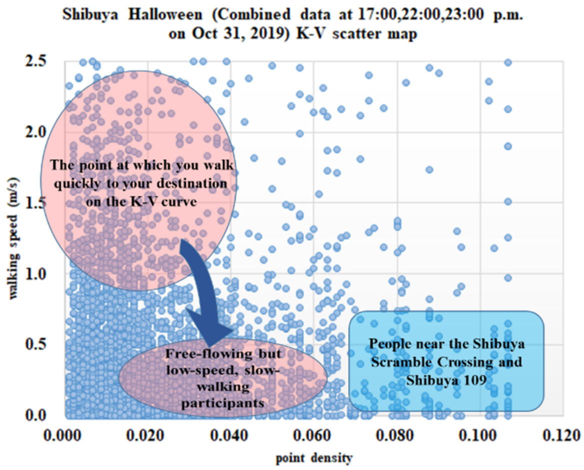


Fig. 5. Kobe Luminarie *K–V* scatter map

Fig. 6. Shibuya Halloween *K–V* scatter map ($K \leqq 3$)

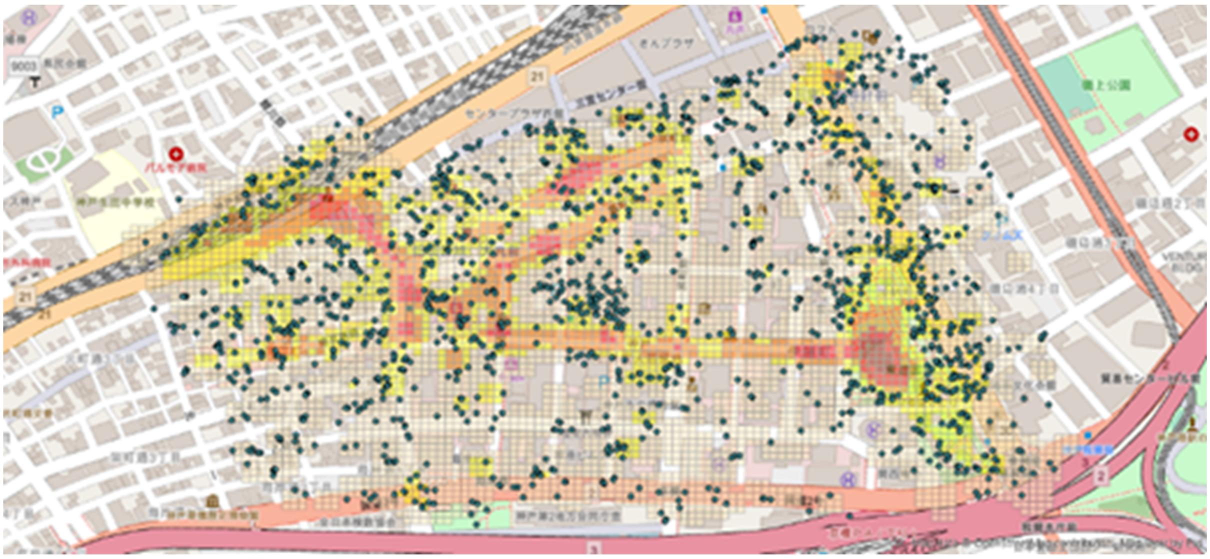


Fig. 7. Point extraction for Kobe Luminarie ($K \leq 0.5$ and $V \leq 0.5$)

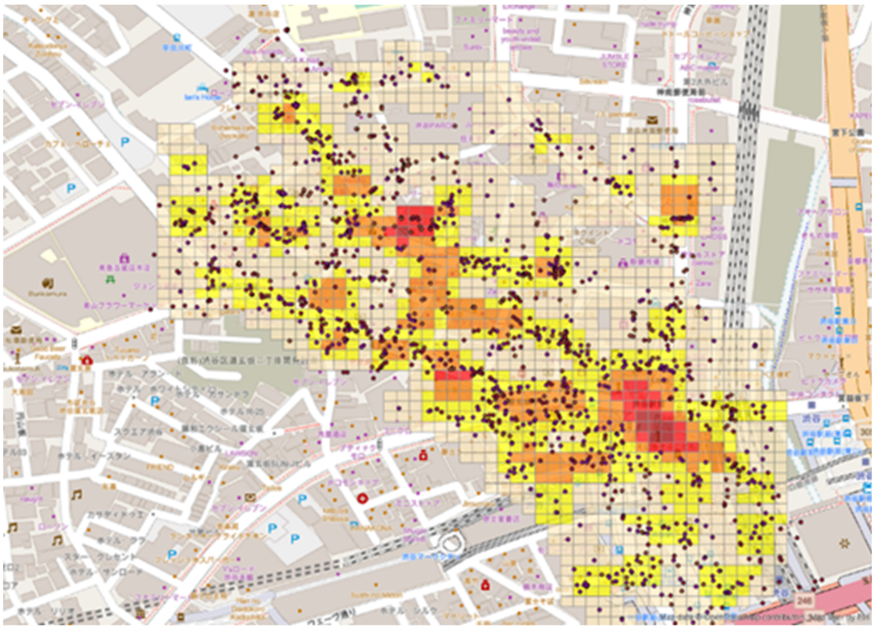


Fig. 8. Point extraction for Shibuya Halloween ($K \leq 1.5$ and $V \leq 0.5$)

5. Conclusions

The variability of the speed data was found to be relatively small when the movement of the crowd was unified or when retention was occurring. On the other hand, the variability of speed data in the whole data made us feel the limitation of the current accuracy. By creating the *K-V* scatter diagram, we found that many people walked at a lower speed at Shibuya Halloween than in normal times, and that people tended to gather at places with a certain amount of crowds. In Kobe Luminarie, the participants and non-participants were strictly separated by security. Thus, it was confirmed that it was possible to roughly understand the pedestrian traffic flow during the event.

In this study, we were able to capture the overall movement of people at the time of the event in an aggregate manner from the entire data, such as the variability of the entire data and the K-V scatter diagram, but we were not able to grasp the movement of each individual in detail. In the future, we would like to seek a method of analyzing pedestrian behavior and crowd behavior from mobile location data to better understand pedestrian traffic flow during events and disasters, and to gain new knowledge on how to control it.

6. References

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