Safe Route Navigation Using Traffic Volume Estimated by Noise Data

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***Abstract*—The focus of this research is on the new possibilities of map-based pedestrian navigation applications. Currently, many map-based pedestrian navigations can only display the shortest path. However, it is not always appropriate for typical users. We propose a map-based pedestrian navigation application which presents a path that can reduce the fear of crime for the pedestrians. In other words, we propose a safe route navigator. Our research question is whether it is useful for the user that the application shows a safe path. We have created a prototype application that suggests a safe path and we also evaluate the usefulness of the application. We consider that a busy road is typically a safe road; however, estimating human density to indicate busy road is not easy. We propose a method of using the environmental noise as an easy way to estimate human density. Compared to the human density, the noise level can be easily measured. Then, we show that the proposed application can reduce the user's fear of crime. This means that future map-based pedestrian navigation application should show not only the shortest route but also a safe route.**

Keywords-route navigation; map application; safety; noise level.

I. INTRODUCTION

In recent years, smart devices, such as smartphones have become widespread. Further, various applications for these devices have become available. A map-based pedestrian navigation application is one of such applications. Many of such applications also have a route navigation function, which is used to find a route to the destination. Such map applications often suggest the shortest path to the user. However, valuable paths other than the shortest routes exist. For example, in railway transfer guidance in Japan, a route with a low fare or a route with a small number of transfers is displayed in addition to the shortest route. The research by Quercia et al. [1] presents a route navigation for walking. It proposes a beautiful route, a quiet route, and a happy route. Each route made a different impressions on the users.

In this paper, we created a map-based pedestrian navigation application that proposes routes with attributes other than shortest distance like Figure 1. The attribute we focused on is “Safety”. In this paper, “Safety” means that the route is less susceptible to crime and does not take into account the dangers of traffic accidents. The research in [2] is as an example of a route guidance also focusing on “Safety”. The authors created a system that uses a database that records the locations where crimes actually occurred. By using this database, they search for path with fewer crimes, and propose them to users. However, it is not easy to create a database of how many crimes have occurred in the past for all roads. According to Ohno et al. [3], the crime rate is low in Japan and the total amount of crime data is small. Therefore, it is difficult to accurately evaluate safety by simply comparing the number of crimes on each road. For this reason, in Japan, such an evaluation is often based on fear of crime and not the actual number of crimes. This paper also does not focus on the actual number of crimes but, rather, evaluates the perception of the crime rate.

Figure 1. Safe Route Navigation

We conducted two experiments. Experiment 1 shows the relationship between noise level and traffic in Tokyo, where noise level means the loudness of environmental noise. We studied people living in Tokyo and investigated the relationship between the noise level and the traffic. As a result of this study, we found that traffic is busy in areas

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where noise level is high. This result means that human density can be measured more easily.

Experiment 2 shows that the traffic information estimated in Experiment 1 is applicable, and that the route guidance that presents a busy route is useful. In experiment 2, we used the results of Experiment 1 to estimate the human density and created a map application that suggests a path with high traffic. The experiment consists of two sub-experiments. In Experiment 2-1, we showed that the sense of security estimated by the map application matches users' perceptions. Thus, the traffic information estimated by using the noise level is useful. In Experiment 2-2, we explored whether the safe path presented by the proposed application is useful for users and demonstrated the utility of this.

The structure of this paper is as follows. In Section II, we compare the proposed approach with existing research. In Section III, we show the usefulness of this research using assumed use cases. In Section IV, we survey people living in Tokyo and confirm that there is much traffic in a noisy place. Based on what is shown in Section IV, we create a map application that proposes a path with much traffic as a safe route, and show that it is useful for users in Section V. In Section VI, we present the findings and future prospects obtained through this study.

II. BACKGROUND

When do people feel fear of crime while walking? According to Ferraro et al. [4] and Braungart et al. [5], people feel this fear when there are no people around, although there are differences depending on gender and age. In isolated areas, fear increases because no other individuals are nearby to help if a person becomes the target of a crime. In other words, a place where there is little sense of fear of crime is a place that is easily noticeable, that is, a place with busy traffic. The fear of crime can be alleviated by navigating through a busy place.

To find busy places, pedestrian traffic data is needed. It is used in many situations, such as when the government decides on a city plan. On the other hand, it is difficult to actually measure pedestrian traffic, and data cannot be easily collected. Therefore, methods for estimating pedestrian traffic rather than actually measuring it have been studied.

One example of these studies is a method using Global Positioning System (GPS) [6]. GPS is a system that detects the position of a person using artificial satellites and can accurately acquire data on the position of the person. There is already research on using GPS for other services [7]. In this research, there is a method of measuring how many people are on each road and estimating the traffic volume of pedestrians. However, in urban areas with many high-rise buildings, it is difficult to receive radio waves from artificial satellites, and GPS may not provide accurate position. We can detect the number of devices that have GPS functions by this method, but it is not possible to determine the exact number of people. In addition, it is not possible to distinguish between people in a car and pedestrians. Therefore, it is difficult to estimate an accurate pedestrian traffic volume.

Another method of estimating pedestrian traffic is to use images or videos [8]. In this method, pedestrian traffic is estimated by analyzing road images or videos. The methods presented in [9]-[11] estimate the density of crowds; thus, we can estimate the pedestrian density even when there is a large amount of traffic. However, it is necessary to install a camera on the road to collect images or videos. It is difficult to collect images or videos because data cannot be collected from places where cameras are not installed. Thus, while information on pedestrian traffic is useful, it is difficult to estimate it. Therefore, we considered a method for estimating pedestrian traffic more easily and that is, the method using noise level.

It is easy to collect data of the noise level. For example, a smartphone has a built-in microphone. By using this, we can easily record and measure the volume of noise anywhere. By mapping this data, it is possible to know how much noise is generated in each place.

There is already a method for mapping noise data to a map. NoiseSpy [12] proposes two methods for displaying noise data on a map. The first method is called journey-based visualization, which displays the noise level along a specific route on the map. The second is city-based visualization, which divides the map into squares of a certain size and displays how much noise is generated in each area by color. By using these methods, noise data can be mapped.

We thought that pedestrian traffic volume could be estimated from mapped noise data. Many of the causes of noise in an urban area can be attributed to people. In other words, it can be estimated that a place in the city with many people has much noise. We can evaluate the noise level of each route by mapping the noise. We propose a method for estimating pedestrian traffic more easily by finding the relationship between noise level and pedestrian traffic.

III. SCENARIO AND REQUIREMENT ANALYSIS

In this section, we consider the situation in which the application that suggests a safe route, as proposed in this research, and determine if this suggestion is useful.

A. Scenario

Ms. Miya is a female university student. She was working on research at the university on a weekday at 7 p.m. She was tired of working at the university and decided to continue her work somewhere else. She searched for a new place to work. She found a new cafe approximately 10 minutes by foot from the university. She tried to go there by searching for a route to the café by using a map-based pedestrian navigation application. However, the road to the cafe was dark and quiet. She was worried about walking alone on the road and decided not to go to the cafe.

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B. *Requirement Analysis*

The problem with this scenario is that the map-based pedestrian navigation application presented only the shortest route. If the application had presented a safe route, Ms. Miya would not have given up on going to the destination. Our application can present a safe route in addition to the shortest route. Therefore, it is possible to propose a route that allows users to reach the destination without fear of crime.

IV. EXPERIMENT 1

We conducted a survey to determine the relationship between noise data and pedestrian traffic in cities. The target city for the survey was Tokyo. To determine whether there are many people in a noisy place, we conducted a noise questionnaire for people living in Tokyo. We received 31 responses from people in their teens and 20s. Questionnaires used in the experiment are shown in Table 1. The results of the questionnaires are shown in Figure 2 and Figure 3.

TABLE I. QUESTIONS INCLUDED IN THE QUESTIONNARIE

Question number	Question
1	Where was the path noisy?
2	What was the source of noise?
3	At that time, how many people were there around you?

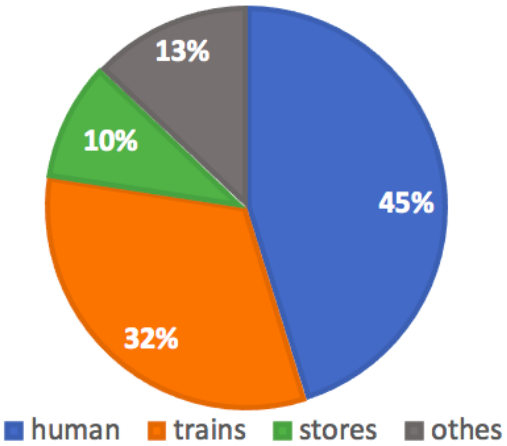

Figure 2. Results of the question 2

Figure 2 shows the responses to the question about the source of noise. The most common source of noise was from people, comprising 45 % of the total. The second most common cause was trains, comprising 32 % of the total. Other causes of noise included stores' advertisements, cars, factories, and large version. People were the most common cause of noise but made up less than half of the total noise.

Figure 3 shows how many people were around when the area was perceived as noisy. The largest number of respondents said that there were too many people to count, accounting for 61 % of the total. The second most common answer was approximately 10 people, making up 26 % of the total. The total of these two answers is 87 %. This result indicates that in more than 80 % of the places where noise occurred, there were more than 10 people in the surrounding area.

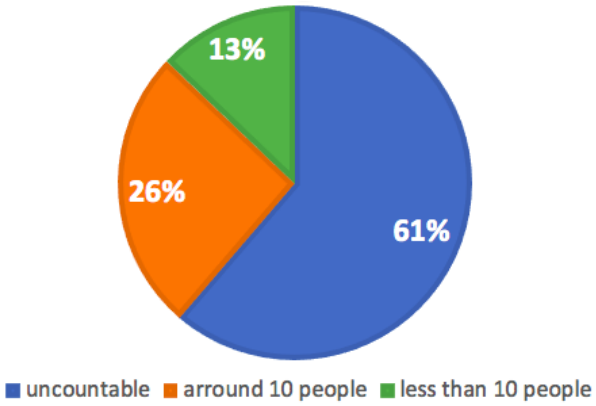

Figure 3. Results of the question 3

These results are summarized as follows. First, less than half of the urban noise was caused by people. On the other hand, it is clear that there are many people in areas that tend to be noisier. Therefore, it can be said that people do not cause much of the noise in the city, but pedestrian traffic is often found in a noisy place. In other words, we were able to show the relationship between noise level and pedestrian traffic, which is the purpose of this experiment.

V. EXPERIMENT 2

We created a map-based pedestrian navigation application that suggests routes that people can walk without fear of crime using pedestrian traffic estimates based on noise level. In this application, a place with much noise is treated as a busy place based on the result of Experiment 1. This application presents the user with a route through a noisy place, which is assumed to be a busy place and a place where one can walk without fear of crime. Figure 4 shows the processing flow of the application.

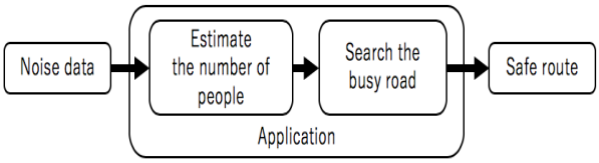

Figure 4. Processing flow of the map application

We conducted Experiment 2 in Takadanobaba in Tokyo shown in Figure 5. The size of the test area is approximately 200 m by 150 m. We divided the roads in the test area into 33 roads at each intersection. The noise was measured for each road and the pedestrian traffic volume was estimated. All

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measurements were taken between 7 p.m. and 8 p.m. Noise was measured using an iPhone. The application used for the measurement is a sound meter [13]. The measurement was performed at the midpoint of each road, and the average noise value for 30 seconds was calculated. The weather at the time of measurement at each point was cloudy and the wind speed was less than 5m; thus, we considered that the measurement value was not affected by the weather.

The experiment was divided into two parts. Experiment 2-1 presents the user with pictures of multiple roads that are judged to have different perceptions of safety depending on the application. We investigated whether there is actually a difference in the user's feeling of safety. In Experiment 2-2, the application presents the user with a fast route, a fast and safe route, and a safe route. We investigated whether the route indicated by this application is useful for users.

Figure 5. A map of evaluated area

The test subjects were 16 people in their 20s, of which 8 were male and 8 were female. Subjects are the same in Experiment 2-1 and Experiment 2-2.

A. *Map-based Pedestrian Navigation Application*

Our application presents the user with three routes: the shortest path, the shortest and safest path, and the safest path. We classified the road into three noise levels based on the noise measurements. Table 2 shows the noise level classification.

We set the coefficient *a* for each noise level and calculated the weighted distance L of each road based on this value and the actual road length l. The coefficient *a* increases as the noise decreases, which means that the weighted distance L increases as the road becomes quieter. In addition, by using the coefficient *n* that indicates how much emphasis is placed on security, it is now possible to search for routes that take both speed and safety into consideration and routes that take only safety into account. The coefficient *n* is 0 when searching for the shortest route, and increases as safety is emphasized. The formula used for the calculation is as follows. However, the route number is i and the noise level is j.

$$L_i = l_i\,(1 + a_j * n)$$

TABLE II. NOISE LEVEL CLASSIFICATION

Noise level	Volume	Number of roads classificated
Level 1	0-19Hz	11
Level 2	20-29Hz	10
Level 3	30-Hz	12

Our map application uses L to search the route from the current location to the destination. By searching for a route that minimizes L, it is possible to guide the route through a road with much noise (which also means that there is much traffic).

B. *Experiment 2-1*

The purpose of this experiment is to verify whether the degree of security estimated by the application is close to the user's perception. We presented three roads with different noise levels to the subjects and investigated how they felt on each road. The subjects were shown videos of three roads and asked about their impressions of each road. The videos were all approximately 15 seconds and were shot between 7 p.m. and 8 p.m.

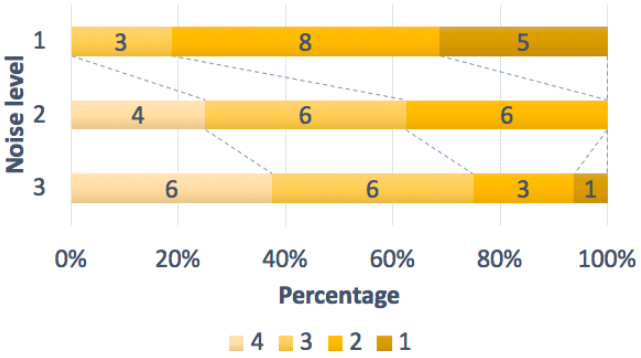

Figure 6. Result of Q.1, “Do you feel fear of crime if you go alone on this road?”

After showing the video to the subject, we asked the subject two questions. Figure 6 is the result of Q. 1, “Do you feel fear of crime if you walk alone on this road?” Answers are given on a four-level Likert scale, in which 4 is “I don't feel afraid” and 1 is “I feel afraid”. It can be seen that as the noise level decreases (i.e., the road is estimated to be less

busy), more subjects tend to fear crime. Figure 7 is the result of Q. 2, "Do you think you might walk alone on this road at the same time as this video?" Answers are given on a four-level Likert scale, in which 4 is “I think I will pass” and 1 is “I don’t think I will pass.” It can be seen that the lower the noise level is, the fewer subjects that want to follow the suggested route.

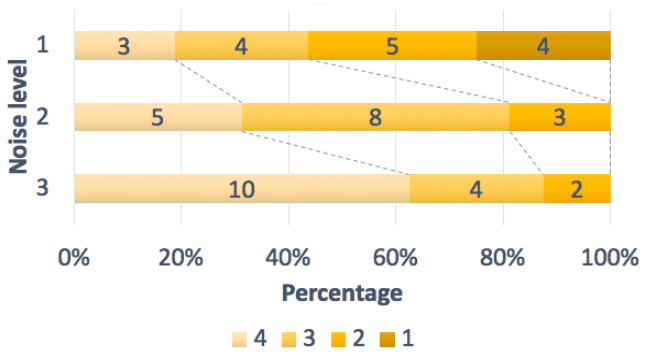

Figure 7. Result of Q.2, "Do you think you might walk alone on this road at the same time as this video?"

From these results, it can be seen that the subjects do not fear crime and do not hesitate to walk on the road that the application has estimated to be the safest (that is, the road where the noise level is high). On the other hand, on the road that the system estimates to be less safe, the subject tends to feel afraid of crime and want to avoid the road. From this result, it can be said that the degree of security estimated by this application is close to the user's feelings. This means that the purpose of this experiment has been confirmed.

Figure 8. The three routes suggested by our proposed application

C. *Experiment 2-2*

The purpose of this experiment is to make sure that the secure route proposed by the proposed application is beneficial to the user. Three routes searched by the application were presented to the subjects, and we investigated which route was selected. The three routes are a fast route, a fast and safe route, and a safe route. The three routes are shown in Figure 8.

We presented the scenario to each subject before starting the experiment. We examined which route each subject took when he/she was placed in the scenario situation. The scenario is as follows.

D. *Scenario*

You are working at a university doing research. Today is a weekday, and the current time is 7 p.m. After growing tired of working at the university, you decide to move to a coffee shop in Takadanobaba. Because you are worried about walking alone on the road at night, you search for a route you can walk with confidence for your safety using a map-based pedestrian navigation application.

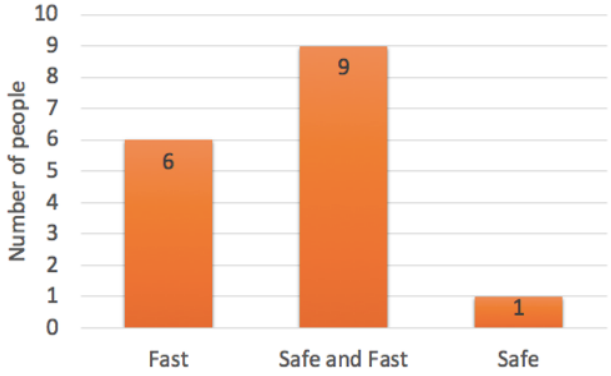

Figure 9. Result of Experiment 2-2

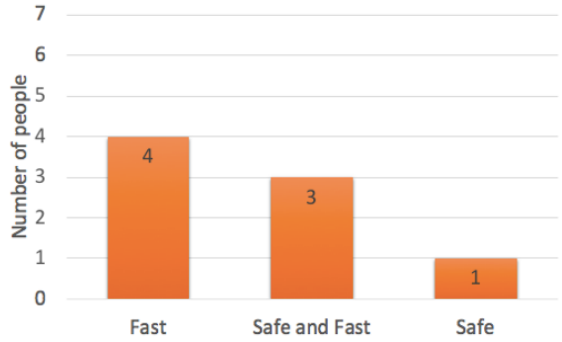

Figure 10. Result of Experiment 2-2 (male)

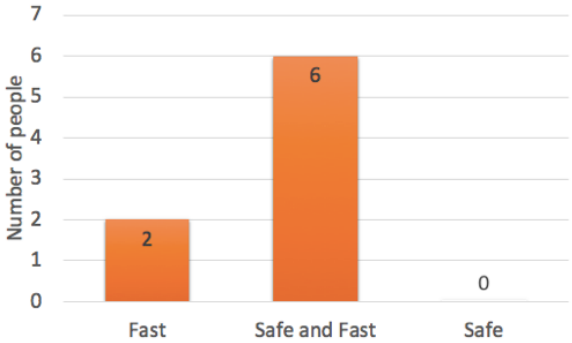

Figure 11. . Result of Experiment 2-2 (female)

E. Results and Considerations

The results of the experiment are shown in Figure 9. Ten people chose a fast and safe route or a safe route. This means that 10 people chose route options that are unique to this application. In addition, we asked subjects who chose the shortest route whether they would choose a different route if they were in a city with which they were not familiar or in a foreign country. Five subjects (out of 6) chose routes unique to this application depending on the situation. Thus, the application's unique routes are valuable for 15 out of 16 subjects. This means that the purpose of this experiment has been confirmed.

The results by gender are shown in Figure 10 and Figure 11. The application's unique routes were chosen by 4 of the males and 6 of the females. This finding indicates that the functionality of this map application is more valuable for females than for males.

VI. CONCLUSION

Through this research, we were able to show that a map-based pedestrian navigation application that presents a safe route is valuable. The application that we created changed the way a certain number of users evaluated routes and reduced fear of crime. It was also verified that noise level data can be used as a criterion for judging safe routes.

In the future, it is necessary to confirm that this application would be of value to many people. In Experiment 2, we investigated the usefulness of our application, but all subjects were in their 20s. It is necessary to determine what kind of result is produced for people from other generations. We should also evaluate the relationship between traffic and noise in different cities. In this study, only the Tokyo city was investigated, but it is necessary to confirm whether the relationship between the traffic and the noise exists in other cities.

We can also think of using a threshold on noisiness. With the route searching algorithm suggested in this paper, very quiet and dark street can be accepted. However, it is not desirable. By using threshold on noisiness, we will be able to avoid suggesting quiet and dark route completely.

We also have to consider a new way to create a data set for noise information. In Experiment 2, we created a data set manually, but in the future, we can easily collect a data and create a data set by using crowdsourcing. This will help us to easily introduce the proposed system to other cities.

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