Evacuation Route Recommendation System by DTN for Congestion Mitigation Using Evacuee Attributes

Makoto Misumi[1] Noriaki Kamiyama[1]
Faculty of Engineering, Fukuoka University[1]

1 Introduction

When a disaster happens, in order for victims to evacuate safely and quickly, not only information on shelters that can be shared before the occurrence of a disaster, but also information on the status of road failures in disaster areas is needed. Since information on road breakdown status can only be obtained after a disaster, it is necessary to collect information in the disaster area after the disaster and distribute it to the victims in the disaster area.

In the previous research [1] on evacuation route recommendation, the congestion caused by the concentration of evacuees on a specific route becomes a problem due to the recommendation to all evacuees of the route with the lowest cost obtained under the same parameters. To solve this problem, an evacuation route recommendation method has been proposed that includes congestion information in the cost [1]. In [1], the traffic congestion status is inferred from the exact location information of the evacuees.

In this paper, in order to alleviate the traffic congestion at the time of evacuation, we propose a method to set the possibility of passing for each attribute such as age and gender of each evacuee according to the degree of failure of the failure point, and find and recommend evacuation routes.

2 Proposed Method

In this study, for the purpose of alleviating traffic congestion at evacuation, we propose a system that presents different routes for each evacuee attribute, assuming that the degree of failure at passable failure point differs depending on the attribute of evacuee such as gender and age.

In Fig. 1 (a), the evacuation terminal does not have information on the failure point, and the failure point present on the route presented by the evacuation terminal is broken at such a degree that the evacuee can not pass it. In Fig. 1 (a) ①, the evacuee starts evacuation according to the route 1 presented by the system. The evacuee reaches the failure point at ②, determines that the failure point is so broken that he can not pass, and as shown in ③, takes a detour action and goes to a route different from the presentation route 1. Our proposed system monitors location information of evacuees using GPS, so it detects that evacuees have selected a route different from the presentation route 1 in ④. Then, the system presents a new route 2 that does not include the failure point. Furthermore, the system obtains failure point information from the difference between the presentation route 1 and the route actually traveled by the evacuetor without the operation of the evacueer, and registers the failure point in the evacuetor terminal. Evacuees evacuate according to the presentation route 2 in ⑤ and avoid the failure point and reach the destination. If the system determines that the terminal has the failure point information in advance and that the failure point is broken so that the evacuees can not pass through it, a route avoiding the failure point is presented as shown in Fig. 1 (c).

When the evacuee terminal does not have failure point information and the failure point included in the presentation route is passable for the evacuee, or the evacuee terminal has failure point information and the failure point included in the presentation route is passable for the evacuee, the situation in Figure 1 (b) is obtained. Evacuees start evacuation on route 1 presented by the system(①). The evacuees reach the failure point at ②, but the evacuees judge that they can pass and pass the route 1 as presented(③). In the situation shown in Fig. 1 (b), when the evacuee terminal has failure point information, the number of evacuees passing the failure point is incremented at the timing when the failure point is passed.

The proposed system uses the degree of failure of the failure point, but it is also necessary to collect such information after a disaster occurs. In the proposed system, the degree of failure at the failure point is estimated by the following procedure that does not require the operation by the evacuees. In this system, the evacuees terminal gets in advance the population ratio of each evacuee attribute in the target area and the upper limit value of the failure degree to which the evacuees of each attribute can pass. Moreover, this system presupposes the evacuee type registration of the evacuee's own to the evauee terminal in advance. When the evacuee reaches the failure point, if the evacuee decides that it can pass, it passes the failure point, and if it judges that the evacuee can not pass, it bypasses the failure point. This information is recorded at each evacuee terminal, and exchanged among a plurality of evacuees. By using the exchanged information and calculating at each evacuee terminal, the estimated value of the passability probability of each failure point can be obtained. Based on the population ratio for each type of evacuees in the target area, the upper limit value of the degree of failure that each evacuee type can pass, and the estimated value of the passability probability, the degree of failure of the failure point is estimated.

The estimated value P_{xn} of the passability probability of the failure point x at the evacuee terminal n is expressed by the following equation.

$$P_{xn} = \frac{C_{xn}}{S_{xn}} \quad (1)$$

Here, C_{xn} is the number of evacuees who succeeded in passing the failure point x, and S_{xn} is the number of evacuees who tried to pass the failure point x. The evacuee terminal n keeps in the terminal the estimated value P_{xn} of the passable probability and the sample number S_{xn} used for deriving the estimated value of the passable probability in the evacuee terminal, and exchanges these values with other terminals. The evacuee terminals manage the terminals whose failure point information has already been exchanged as a set $N_{\text{exchanged}}$. Each evacuee terminal periodically transmits its own failure point information, except when the evacuee terminal that sent the information is included in $N_{\text{exchanged}}$, When evacuee terminal n receives fail-

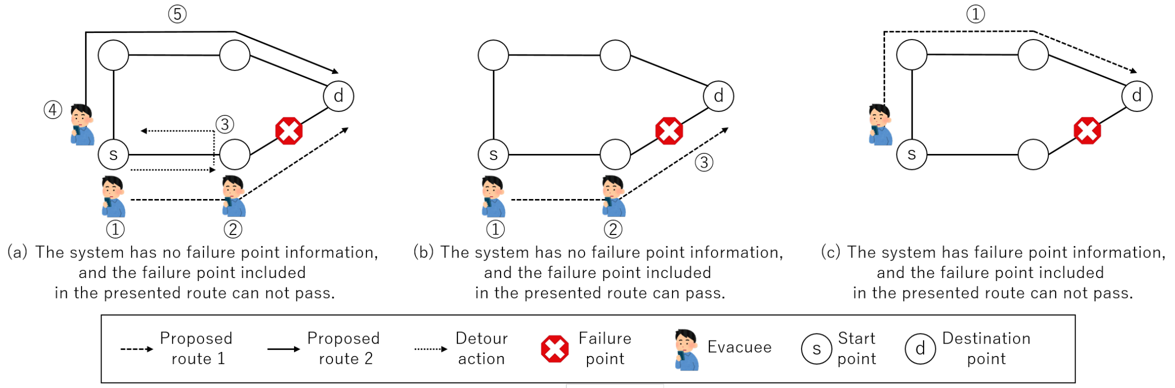

Fig. 1: Evacuation route presentation to evacuees by the proposed system

ure point information sent by another evacuee terminal, it updates its own P_{xn} and S_{xn} according to the following procedure. Here, when the passage probability that evacuee terminal n receives from evacuee terminal n_{peer} is $P_{xn_{\mathrm{peer}}}$ and the number of samples is $S_{xn_{\mathrm{peer}}}$, P_{xn} and S_{xn} of evacuee terminal n after these information exchanges are updated by the following equation.

$$P_{xn} \leftarrow \frac{P_{xn}S_{xn} + P_{xn_{\mathrm{peer}}}S_{xn_{\mathrm{peer}}}}{S_{xn} + S_{xn_{\mathrm{peer}}}} \quad (2)$$

$$S_{xn} \leftarrow S_{xn} + S_{xn_{\mathrm{peer}}} \quad (3)$$

The evacuee terminal n adds n_{peer} to $N_{\mathrm{exchanged}}$ as an information exchanged evacuee terminal after information exchange is completed. This process is repeated each time failure point information is received from a evacuee terminal not registered in $N_{\mathrm{exchanged}}$, thereby exchanging and updating failure point information.

The evacuee terminal searches for nearby terminals in the following procedure. The evacuee terminal n periodically transmits a neighbor evacuee terminal search beacon at an interval t_B. The neighbor evacuee terminal that receives the neighbor evacuee terminal search beacon returns a response to it. The evacuee terminal n receiving the response adds the neighboring node receiving the response within the response waiting time $t_{B_{\mathrm{wait}}}$ of the neighboring evacuee terminal search beacon to the evacuee terminal group $N_{\mathrm{in\text{-}range}}$ existing within its own communication range.

$N_{\mathrm{exchanged}}$ is a set of information exchanged evacuee terminals in each terminal. A evacuee terminal registered in $N_{\mathrm{exchanged}}$ is not selected as an information exchange target node n_{peer}, and therefore does not exchange information with the same evacuee terminal multiple times. On the other hand, even if the evacuee terminal has exchanged information once, when it moves out of the communication range after the information exchange and becomes within the communication range again after a certain time, it may have different failure point information than before. Therefore, in this method, those evacuee terminals are targeted for information exchange. Therefore, in order to realize them, update $N_{\mathrm{exchanged}}$ according to the following procedure.

- For each evacuee terminal in $N_{\mathrm{exchanged}}$, record the last time the neighbor search beacon response was received.
- From the last time the neighbor search beacon response was received, evacuee terminals that have passed over the lifetime $t_{D_{\mathrm{ttl}}}$ of the evacuee terminal out of the communication range are periodically deleted from $N_{\mathrm{exchanged}}$.

3 Evaluation

We model the proposed method to confirm the congestion reduction effect of the proposed method using road information of Kita Ward Osaka City, and compare density at evacuation by multi agent simulation.

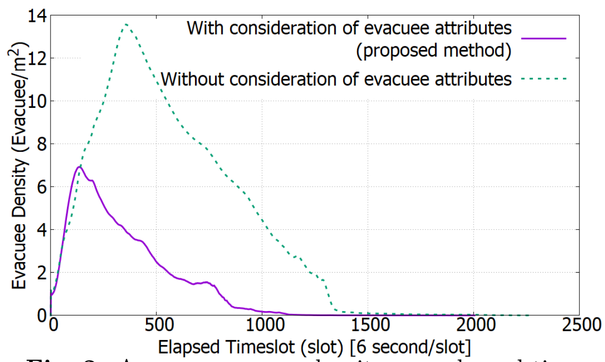

Fig. 2: Average evacuees density over elapsed time

Fig. 2 is a graph of the temporal change of the average evacuees density. In the method that does not consider the evacuees' attribute [2], the evacuee density rises to 14 people per unit area, which is high evacuee density for a long time. On the other hand, the maximum evacuee density of the proposed method considering evacuee type is small. Moreover, in the proposed method considering the evacuees' attribute, the traffic congestion is resolved in a shorter time.

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