A Route Recommendation System in Disaster-Struck Areas with Consideration for Preferences of Affected Drivers

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Abstract— **This paper proposes a route recommendation system in disaster-struck areas with consideration for the preferences of affected drivers. Although routes to a destination and traffic information such as congestion can be obtained easily, there are routes which disaster victims will wish to avoid. For example, when a tsunami warning has been made, it is necessary to avoid routes near the sea, and to take a safe route which is higher in elevation than the height of the tsunami. Accordingly, our proposed system searches for routes in consideration of the psychology of affected drivers. By searching for an appropriate route for affected drivers, it is expected that smooth road traffic can become a reality without causing road congestion.**

Keywords- traffic information; disaster prevention; route recommendation; navigation system

I. INTRODUCTION

This paper proposes a route recommendation system for disaster situations with consideration for the preferences of victims. There are routes which disaster victims will wish to avoid. For example, when a tsunami warning has been made, it is necessary to avoid routes near the sea, and to take a safe route which is higher in elevation than the height of the tsunami. It is possible to position this study as the field amalgamated by ITS and disaster prevention. The paper organized as follows. In this section we present the relationship between earthquakes and roads, and briefly introduces ITS. In the next section we present related work. System overview is presented in Section 3, and the results of the comparison with other systems are presented in Section 4. Section 5 presents a conclusion and future work.

A. Earthquakes and Road Traffic

Japan is a country of frequent earthquakes, with many earthquakes occurring every year. The Great Hanshin Awaji Earthquake of 1995 recorded a seismic intensity of 7.3 in Kobe, killing 6,434 people. The Great East Japan Earthquake in 2011 recorded a magnitude of 9.0. This earthquake was a plate earthquake, thus causing major damage by the resulting tsunami, which had a recorded maximum height of 15.8m in Iwate Prefecture. The disaster caused the confirmed deaths of 15,616 people, with a further 4,949 people recorded as missing. The tsunami reached 5 kilometers inland along the coastline and swept away houses, roads, railroads, bridges and even reinforced concrete buildings. Cars, large ships, and airplanes were also carried by the waves, becoming the cause of further damage to buildings.

Seismic intensity is classified as follows in Japan.

i. Seismic intensity of 1-2: the quake is perceptible by humans.
ii. Seismic intensity of 3-4: Buildings are shaken.
iii. Seismic intensity of 5-6: Buildings start collapse and landslides occur.
iv. Seismic intensity of 7+: Many buildings completely collapse and major damage occurs.

Earthquakes of a seismic intensity of 5 or greater have occurred more than 100 times in Japan since the year 2000. An earthquake damages buildings, traffic networks, and lifelines. Particularly, the traffic network is often greatly damaged due to earthquakes, which prevents the delivery of relief goods.

In 2004, the Mid Niigata Prefecture Earthquake occurred, causing railways, such as the Joetsu Shinkansen line, and roads to close. Among major roads, the Hokuriku Expressway, the Kan-etsu Expressway, and National Routes 8, 17, and 116 were closed, causing the transport of goods to be suspended. However, the road network played an important role in the transport of relief goods by ensuring access to alternative routes, as shown in Figure 1[1]. In this figure, the Kan-etsu Expressway (blue line) was out of use, and two detours (red lines) were alternatively used.

The same situation was found in the Tokachi-Oki Earthquake occurred in 2003, also causing major damage by tsunami [2].

A peculiar driver psychology can be observed in disaster-struck areas. During the Great East Japan Earthquake in 2011, many drivers avoided routes near the sea in fear of being killed by the approaching tsunami. As a result, heavy traffic occurred due to the increase in cars on mountain roads where traffic is usually light.

This paper proposes a route recommendation system in disaster-struck areas, targeting affected drivers with consideration for this kind of psychology of victims.

Figure 1. Ensuring alternative routes (map data provided by Yahoo Maps)

B. *Intelligent Transport Systems : ITS*

ITS have the purpose of improving the efficiency, safety and serviceability of automobile traffic. As ITS technology progresses, many benefits can be obtained in various areas. Among these, the field of automotive navigation systems is notable. Automotive navigation systems provide traffic information containing traffic congestion information, and search for the most suitable route to the destination. Such technology is already a feature of many people's daily lives.

However, there are only a few opportunities to apply this technology to traffic problems in disaster situations. These support by ITS elicit an effect to solve the problem in unusual situation. In the next section, such trials are introduced and problems to be solved about road traffic in disaster-struck areas are revealed.

II. RELATED WORK

Various studies have been conducted on navigation systems. Especially, the NAVITIME and MapFanWeb systems are very famous in Japan for providing traffic updates, enabling drivers to get the route to their destination easily. NAVITIME provided by NAVITIME JAPAN is the Total Navigation solution that allows users to plan travel routes from various transportation methods - including trains, subways, buses and taxis. MapFanWeb is same services, map retrieval, route research, transfer guidance.

These services, however, are useful in everyday use and special functions are required in disaster situations.

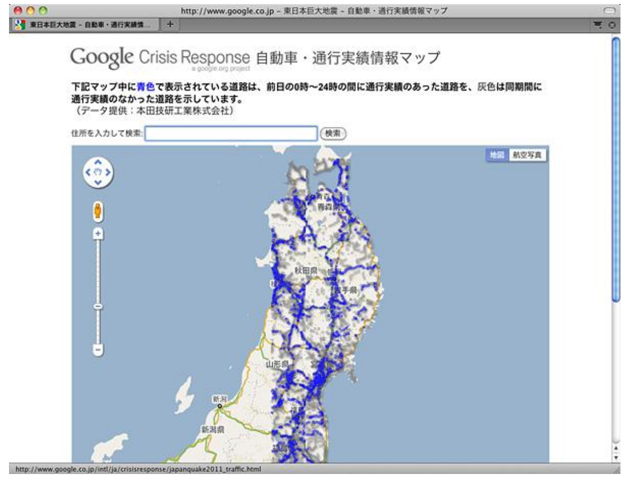

Figure 2. Google's Map of Automobile Traffic Performance

A. *Map of Automobile Traffic Performance*

Google provided maps of Automobile Traffic Performance during the 2011 earthquake and tsunami disaster [3] (Figure 2). Using these maps, many drivers were able to travel easily in the disaster area. This service displays roads which were accessible between 0:00 and 24:00 of the previous day in blue, and roads which were inaccessible during the same time period in gray. The service is renewed every 24 hours.

B. *Probe Car System*

Probe car systems, which regard individual vehicles as moving sensors and provide traffic, weather information, etc. generated from vehicles, are attracting much attention. Among the systems realized are primarily probe traffic congestion information systems based on vehicle positions, time stamps, etc. [4]. For example, such systems can obtain local weather information from combination of the GPS data and activation of windshield wipers. These systems are also able to get traffic congestion information by using the information of the car's speed. While having the advantage of collecting local data, probe car systems have the disadvantage of only being able to collect data when the car is actually running.

C. *Route Preference During Disasters*

Figure 3 shows a map of Tagajo, Miyagi Prefecture, which was hit by the tsunami in the Great East Japan Earthquake of 2011. National Route 45 and Prefectural Roads 23 and 10, principle roads in Miyagi, all became inaccessible due to tsunami damage (circled in red on Figure 3). These roads were restored after one month, but many drivers, afraid of further tsunami damage, continued to take the Rifu Bypass Highway (circled in blue on Figure 3) which is 3 kilometers inland instead of the coastal roads. As a result, major traffic congestion occurred on the highway due to the increase in cars.

Figure 3. Map of Tagajo (map data provided by Google Maps)

Even when drivers in disaster situations use navigation systems to search for their destination, navigation cannot fulfill its role, if there are roads rendered inaccessible by damage. Thus, it is expected that the drivers in the disaster situations uses the navigation systems by combining the information about road condition they know. To solve this problem, in this paper, we propose a navigation system that reflects the results of road condition detection. Furthermore, the system recommends roads based on the psychological analysis of drivers in disaster situations. That is, roads which is preferred by the drivers are predicted by the systems and proposed to the drivers.

III. SYSTEM OVERVIEW

This study proposes a navigation system which combines the results of road condition detection.

A. *Fundamental Policy of Proposed System*

i. Ignore inaccessible roads when searching for the route to destination.

Ordinarily, when a route to destination is searched for in a navigation system, it recommends the route in consideration of shortest journey time and traffic conditions, but this is for non-disaster situations. In fact, there is no guarantee that the roads can be used normally after a disaster. Maps of performance of automobile traffic display such information, as stated above. In this study, the proposed system searches for the route to a destination containing no inaccessible roads.

ii. Recommend appropriate routes according to the type of disaster.

There are various types of disaster (landslides, tsunami, floods, etc.), and drivers may need to use different roads according to the type of disaster. For example, when a landslide occurs, this system displays safe roads, ignoring roads near mountains and other places where landslides are likely to happen. When a tsunami occurs, this system displays safe roads which are higher in elevation than the predicted height of the tsunami. Thus, this system selects the route in consideration of elevation and distance from the sea and mountains. Because of this, it is expected that the driver can arrive to the destination safety. Further, if there are any roads that the driver does not want to take, the system can search for the route after the driver has deselected such roads.

iii. Display the optimal alternative route for the driver

If all drivers take the route recommended by the system to avoid the tsunami, too many cars will concentrate on the road and there will be danger of traffic congestion. However, traffic congestion must be avoided in order to ensure smooth access for emergency vehicles. Therefore, it is necessary to propose a route which enables emergency vehicles to arrive at their destination safely, and as quickly as possible.

Also, as cars exist in different sizes (large, medium, and small), in order for each size to drive safely, it is important to ensure sufficient road width in the route to the destination. For example, when the system proposes a safe road to drivers of large cars, they may not be able to pass if the road is too narrow, which would waste time unnecessarily. Thus, avoidance of traffic congestion and realization of smooth road traffic can be attained by proposing the optimal route separately to drivers of each size of vehicle.

B. *Use of Floating Car Data*

Floating car data are driving data used by the Internavi-a Floating Car System provided by the Honda Motor Company to drivers in Japan [5]. Internavi recommends routes and allows display of the newest road information by using detailed road information from cars equipped with the system, in addition to information about trunk roads and highways via VICS. Furthermore, it is possible to generate traffic information from floating car data. It can be expected that smooth road traffic which avoids congestion can be realized by using floating car data.

C. *Details of System*

The proposed system is implemented in a Windows environment, using Java as the development language and JavaScript to display the route on a map (provided by Google Maps). Although the system can be applied to any location, we used the area shown in Figure 4 as a model area to investigate the necessary functions of the system.

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We can retrieve the route to the destination in the target area. In this system, the user selects a point of departure, destination, and the disaster (tsunami, landslide, or flood) that the user needs to avoid, and the system proposes the optimal route in consideration of these terms.

For example, if the selected disaster is a tsunami, the system will propose a route which has sufficient distance from the coastline. To be specific, the system targets routes which are predicted not to be damaged by the tsunami on the hazard map provided by the Ministry of Land, Infrastructure, Transport and Tourism. Furthermore, the system proposes the shortest route among the roads unaffected by tsunami, because if the proposed route is too far from the coastline, the driver will take too much time.

The information related to the proposed route is recorded as XML data, and the system displays the safe route on a Google Map based on this XML data.

If there are any roads that the user wants to avoid, the system will propose a route excluding these. For example, the system proposes a route which will not be affected by tsunami according to the hazard map, but the user is worried that this road may be dangerous. In such cases, the user can deselect the route they do not want to use, and search for the route again in consideration of this.

Figure 4. Target area, Yokkaichi. (map data provided by Google Maps)

All intersections within the target area are assigned a number, and the road is modeled as connecting these intersections. Suppose the target area in Figure 5, composed of 5 intersections and 5 roads. Intersection 2 is linked to Intersections 1 and 3. Each intersection has data of the longitude and latitude. The intersections where cars can pass safely are recorded as XML data.

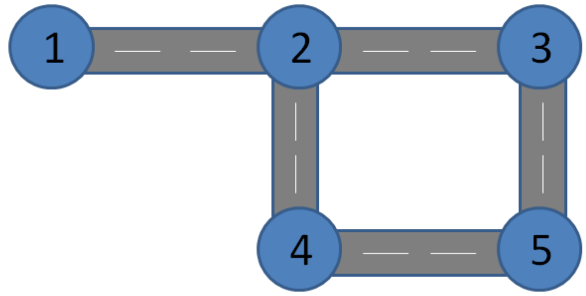

Figure 5. Example of road formation.

This system consists of 5 Java classes. XML data is produced by executing these, and displayed on a Google Map using JavaScript. A diagram of the system process is shown in Figure 6.

D. System Target Area

Although the proposed system can target any area, in the evaluation of this paper, we targets part of Yokkaichi, Mie Prefecture, as follows. The area is 7 kilometers from north to south, where north is the point where National Route 23 and a Prefectural Road 502 cross, and south is the point where National Route 23 and Prefectural Road 401 cross. This system targets national roads and prefectural roads in this area, shown in yellow on Figure 4.

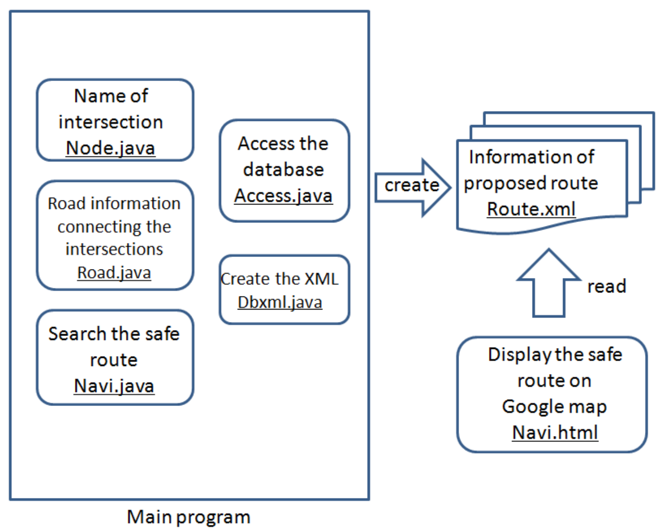

Figure 6. System process.

Tokai, Tonankai, and Nankai earthquakes occur periodically every 100-150 years, so it is predicted that one will strike without fail in the first half of this century. Regarding the Tokai earthquake, it it possible that one may happen at any moment, as none have occurred since 1854. Furthermore, these earthquakes have often occurred at the same time or in close succession. There are predictions of major damage due to these earthquakes in Yokkaichi. This

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area has the sea in the east, so there is a danger of tsunami damage similar to the Great East Japan Earthquake.

IV. Results of Comparison with Other Systems

A. Results of Each Navigation System

The same departure and destination were set in NAVITIME, MapFanWeb, and the proposed system. Figure 7 shows the route recommendation results by these systems. A recommendation result by NAVITIME is indicated in blue, MapFanWeb in red, and the proposed system in green. NAVITIME and MapFanWeb recommended National Route 23, along the sea, while the proposed system selected National Route 1, which is further inland than National Route 23.

Figure 7. Recommendation results (map data provided by Google Maps).

B. Comparision with Hazard Map

A hazard map is a map that highlights areas that are affected by or vulnerable to a particular hazard. They are typically created for natural hazards such as earthquakes, volcano eruptions, landslides, flooding, and tsunami. Hazard maps help prevent serious damage and deaths, and help victims to take refuge quickly and precisely. Figure 8 shows a hazard map of Yokkaichi [6]. This map data provided by the Ministry of Land, Infrastructure, Transport and Tourism.

Figure 8. Hazard map of Yokkaichi(map data provided by the Ministry of Land, Infrastructure, Transport and Tourism)

The proposed route of NAVITIME and MapFanWeb passed through the area which is colored yellow on the hazard map. This area will be affected by tsunami. However, one of our system only passes the uncolored area, so it may be said that drivers will be more likely to reach their destination safely in comparison to the other recommended routes.

National Route 1 is recommended as an alternative route instead of National Route 23, in the route proposed by our system.

When the authors confirmed our system’s recommendation with a student from Yokkaichi, we were told that National Route 1 has two lanes each way and a wide lane, meaning it will be easy to drive, so it is no problem as an alternative route. However it is prone to heavy traffic on a routine basis, so if traffic from National Route 23 is diverted to National Route 1, it has the potential to cause a traffic jam. Thus, we received advice that our system should disperse cars to several other safe roads.

V. Conclusion and Future Work

In this paper, we proposed a route recommendation system for disaster situations which considers the preferences of victims. We demonstrated the effectiveness of our system, which proposes a safe alternative route, avoiding places known to be dangerous according to a hazard map.

The proposed system uses a hazard map provided by the Ministry of Land, Infrastructure, Transport and Tourism to target roads which will not be affected by disasters. However it is not always true that the effects of a disaster will spread exactly as indicated on a hazard map. Accordingly, some effects may occur in places which are predicted not to be affected on the hazard map after an actual disaster. In order to avoid such problems, a system which constantly renews information relating to traffic flow, as in Google's map of performance of automobile traffic described above, will be necessary.

In additional, the proposed system does not consider the amount of traffic, including traffic jams, that will be generated by diverting a large number of cars to alternative routes. Thus, there is a possibility that traffic jams will occur if all drivers take the route recommended by this system. Therefore, an area for improvement would be to ensure that the system recommends the route in response to the amount of traffic, and attempts to avoid traffic jams.

In the future, we aim to improve the system so that it can recommend a route in consideration of the amount of real-time traffic, and renew real-time road information regarding routes which have recently become inaccessible due to disaster or construction works.

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