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FUNDAMENTAL STUDY ON THE DEVELOPMENT OF ALGORITHM FOR ROAD DAMAGE ESTIMATION DUE TO NATURAL DISASTERS USING PROBE-CAR DRIVING DATA

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ABSTRACT

In order to bring out the realization of effective disaster response activities by collecting road damage information as early as possible after a disaster occurs, the authors propose the adoption of road damage estimation system using probe-cars. In this system, when a probe-car enters the hazardous area when an earthquake occurs, for example, sensors equipped with in the car starts to detect anomalous driving data. Analyzing these data, road damage such as road closure due to slope failure can be estimated and it is sent to the server computer of road damage estimation system operated by a road administrator. In order to verify a possibility to develop such a system, it is necessary to construct the algorithm, which can be applied to road damage estimation using actual driving data. In this paper, driving experiments are carried out to measure driving data which represent the two typical anomalous driving, such as (1) opposing lane driving, (2) turning around, both of which are conducted to avoid failed earth. Then, a simple algorithm is developed using the data. The road damage estimation simulation is developed by applying the algorithm. Numerical values governing parameters for road damage estimation are determined by driving experiments with four different drivers and two different types of cars. In conclusion, the authors summarizes a prospective to establish effective disaster response using information sharing of road damage information among not only a road administrator but various public agencies relating to disaster management using an information sharing system and general drivers using a car navigation system.

Introduction

Road damage information is one of the most important issues for disaster responses in a natural disaster. It is also, however, one of the most unavailable information. Due to both a long road extension and a multilayered structure of road administrators, not only a collection but

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uniform management of road information during a disaster is difficult. Then, the authors proposed the map of vehicular swept path which is road routes probe-vehicles actually have drove. The Niigata-ken Chuetsu-oki earthquake of 2006 confirmed its effectiveness [Hada, Y, Kodama, N., Suzuki, T., Suetomi, I. and Meguro, K., 2007]. The proposed map was delivered by the authors to the disaster countermeasure office of Kashiwazaki City where a severe damage was occurred due to the earthquake [Suzuki, T., Hada Y., Shimora, H., 2007]. It is a matter of course that the map of vehicular swept path is important, but road damage information is still required for the purpose of early recovery. Therefore, the authors propose the road damage estimation system using probe-car which enables us early collection and aggregation of road damage information and information sharing among stakeholders [Suzuki, T.,et al., 2008].

As a first stage of its development, the algorithm estimating road damage from anomalous vehicle driving due to slope failure, using the measuring instrument composed of GPS, gyrocompass, accelerometers equivalent to those equipped with in an in-vehicle unit for ordinary car navigation systems. In this paper, the development of road damage information system is reported, focusing on driving experiments conducted to develop the algorithm for road damage estimation.

Concept of Road Damage Information System

Fig.1 illustrates a schematic representation for the road damage information system that the authors have proposed. The authors suppose that a road administrator manages and operates the road damage information server. A road administrator, a prefectural government, for example, provides prefectural employees or consignors with in-vehicle units. In the proposed system, hazardous areas of earth failure specified by a prefectural government are registered previously on the units as the geographical information. When a vehicle enters such zone, an analysis using

Figure 1: Schematic representation of the proposed road damage information system.

the road damage estimation algorithm for anomalous driving is started, depending on the road damage situation. Then, the information of detected road damage estimation is sent to the system server through a communication tool. For example, Yamanashi Prefecture, Japan specifies over 4000 hazardous areas composed of mountain streams inducing mud flow, steep sloping lands, and landslide areas and they are published on the home page.

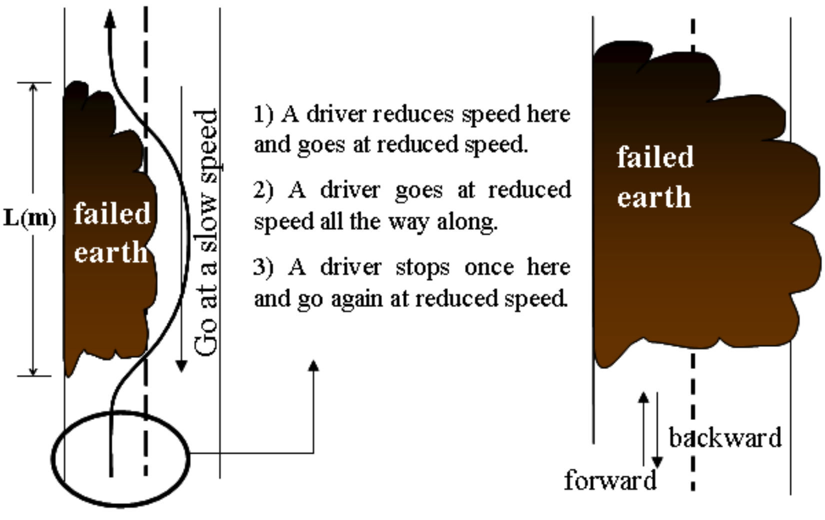
By using the road damage estimation, a road administrator easily can set the route for road patrol and can arrive at a damaged site, which enables not only early affirmation of road damage but early countermeasures such as closure to vehicle traffic or restoration works. Since the road damage information confirmed by a road administrator mentioned above is specified its location by latitude and longitude, it can be widely shared through public institutions in charge of disaster management such as local governments, fire departments, police, or public utility.

Information sharing database shown in the lower right in Fig.1 is the database in which different organizations can share information using the MISP protocol proposed by the authors [Suzuki, T., 2009]. This study is located in the lower left in the figure.

Execution of Driving Experiment

Cases and Methods of Experiment

Experiments were carried out for two types of diving patterns according to the damage situation. One is an opposite lane driving on double lane and another is a turning around. Fig.2 illustrates two types of driving pattern. In case of opposite lane driving, in front of failed earth, a driver reduces speed, go at reduced speed, or stops once and go again at reduced speed, respectively. L is the extension of failed earth and is set 5, 10, and 15 meters, respectively. In case of turning around, on the other hand, a driver stops once in front of failed earth, then back away for about 10 meters. In order to examine difference among individuals and types of vehicles, the driving experiment was conducted with four different drivers using two types of vehicles. The interval for driving experiment is 1000 meter long. Two points were set as a damaged area in the interval. No.1 point is on a straight line and No.2 point is on a curving line, respectively.



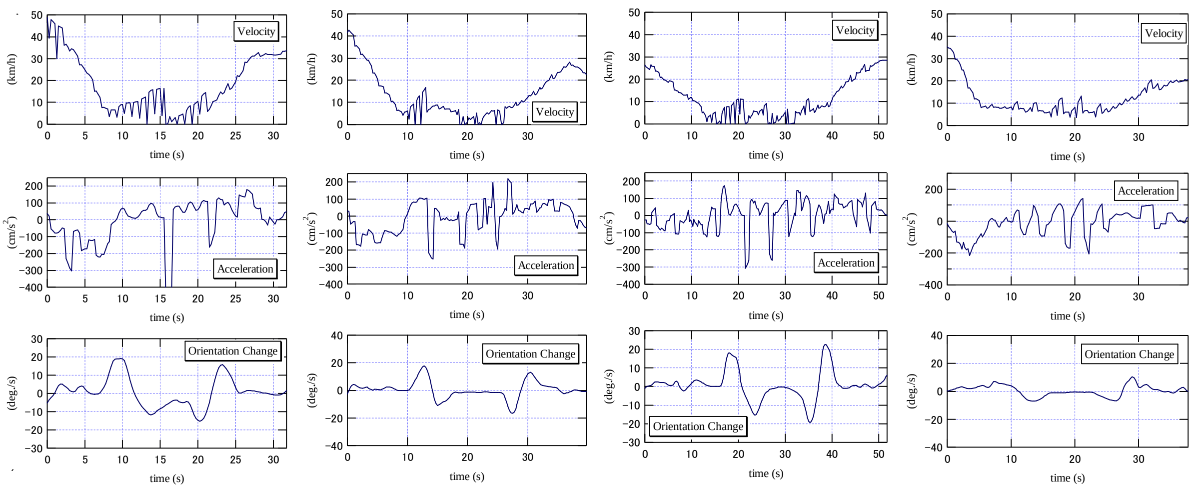
(a) opposite lane driving (b) turning around

Figure 2. Two types of driving patterns conducted in the experiment.

Results of Experiment

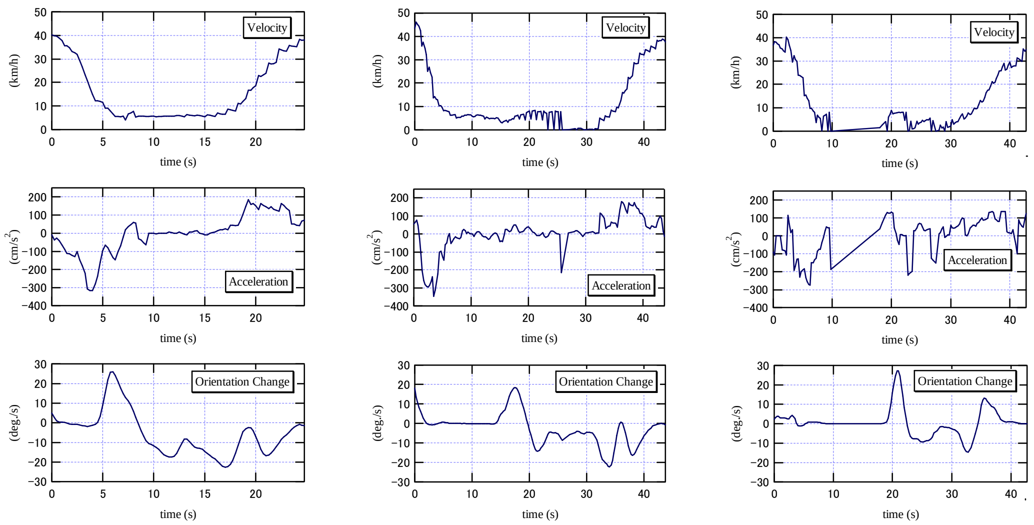
The in-vehicle unit used in the experiment equips GPS, gyrocompass and accelerometer, and not only global position, azimuth direction and acceleration, but velocity, change in velocity or orientation change (degree/second) can be measured. Fig.3 shows a part of experimental results, in which time histories of driving data in case of opposite lane driving at No.1 point are summarized in terms of velocity, change in velocity (acceleration) and orientation change. Four sets of these data are classified as each driver, A, B, C and D. In this case, drivers reduce speed in front of the failed earth and pass the opposite lane at reduced speed.

As shown in the figure, the velocity decreases to the value lower than 10 km/h by reducing



(a) Driver A (b) Driver B (c) Driver C (d) Driver D

Figure 3. Time histories of driving data in case of opposite lane driving at No.1 point when L = 10 meters, summarized in terms of velocity, change in velocity (acceleration) and orientation change



(a) Reduce speed (b) Slow speed all the way (c) Stop before proceeding slowly

Figure 4. Comparison of driving data in terms of speed in front of failed earth

speed in front of the failed earth before a driver turns a steeling wheel to an opposite lane. In the acceleration history, negative peak of acceleration exceeding -100 cm/s^2 can be seen at this stage. Since a driver turns a steering wheel at reduced speed, a notable peak with a value about 10 degrees/s in the time history of orientation change appears after the time that the negative acceleration peak appears. Passing through failed earth, a driver turns back a steeling wheel to an ordinary lane. Then, a negative peak in orientation change with a value about –10 degrees/s appears. After that, a driver gains the speed over 10 km/h as shown in the figure. Though the above-mentioned values are different from each other depending on an individual driver, the tendency is coincident with each other, independently of a type of vehicles and a driver.

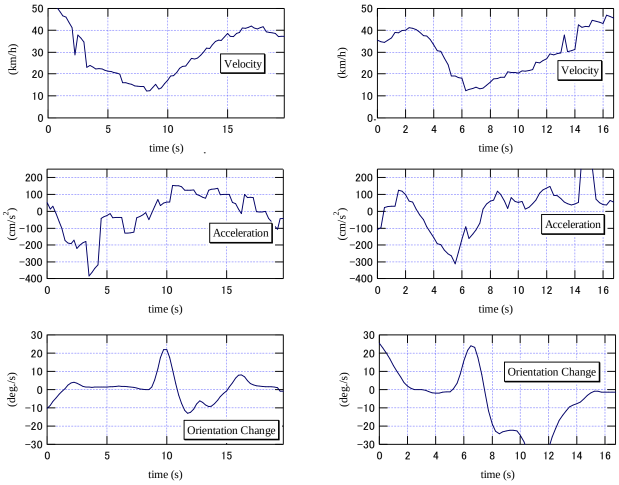


Figure 5. Time histories of driving data in case of opposite lane driving by passing

Fig.4 illustrates the comparison of opposite lane driving with L = 5 meters among three cases. In this data, a driver is fixed to driver A. Though the time of negative peak occurrence in acceleration may be a little earlier when L = 5 meters than when L = 10 meters, the tendency described above is not different even in the three cases. Data measured in the driving experiment were summarized in the same manner.

Fig.5 illustrates time histories of driving data in case of opposite lane driving by passing. The data for diver A at No.1 and No.2 points are summarized in the figure. As shown in the figure, the velocity decreases in front of a parked vehicle, but it was not reduced down to 10 km/h.

Development of Algorithm and Simulation on Road Damage Estimation

Described above, in case of opposite lane driving, anomalous driving can be characterized by the time histories of velocity, acceleration and orientation change. Thus, the algorithm for road damage estimation can be developed under the conditions in the followings:

(1) A start-up of the road damage estimation system is made, triggering the early earthquake warning or J-ALERT (Japan quick alerting system on meteorological, volcanic and earthquake disaster).
(2) The analysis using the road damage estimation algorithm is conducted only when a probe-car enters the hazardous area.
(3) In opposite lane driving, the velocity decreases to the speed lower than V (km/h) and in the vicinity,
(4) A negative acceleration peak with a peak value lower than $-a_{max}$ (cm/s^2) appears. Then,
(5) Keeping the velocity lower than V (km/h), two peaks with peak values higher than d_1 (deg./s) and lower than $-d_2$ (deg./s) appear successively and after that,
(6) The velocity comes back to the speed higher than V (km/h).

In case of turning around driving, a vehicle stops once and backs away the same road, it is easy to detect turning around. In order to determine parameters mentioned above, the examination on driving data measured in the experiment was carried out. Then, it was confirmed that anomalous driving was detected in case of opposite lane driving, when the following parameters were adopted; V=10 (km/h), -amax=-100(cm/s^2), t=5s, d_1=7 (deg./s) and $-d_2$=-7 (deg./s), respectively.

The authors developed a real-time road damage estimation system adopting the algorithm with the above-mentioned parameters. Fig.6 shows a screen shot of the developed system. The system works in a mobile computer directly connected with the in-vehicle unit. Hazardous areas are registered and plotted by grey polygons in the figure.

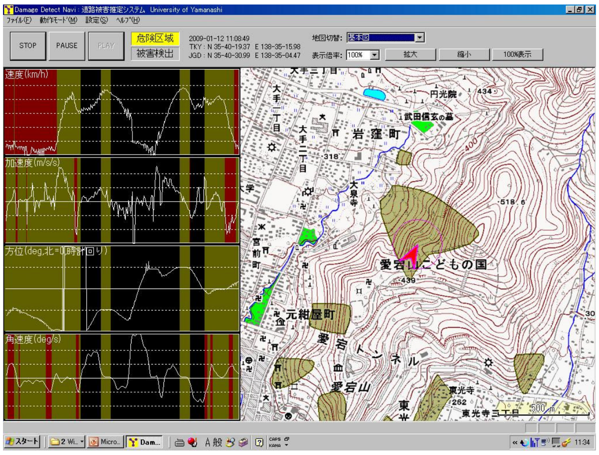


Figure 6. A screen shot of the road damage estimation system

Concluding Remarks

In this paper, driving experiments were carried out to measure driving data which represent two typical anomalous driving, such as (1) opposing lane driving, (2) turning around, both of which are conducted to avoid failed earth. Then, a simple algorithm was developed using the data. The road damage estimation system was developed by applying the algorithm. Numerical values governing parameters for road damage estimation were determined by driving experiments with four different drivers and two different types of cars. In order to realize road damage estimation by probe-cars, algorithms to estimate anomalous driving of a variety of damage is necessary.

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