System for Generating and Providing Semi-dynamic Traffic Information for Automated Vehicles

Shigeki NISHIMURA*, Kentaro TAKAKI, Kenichi MASUDA, Shoichi TANADA, and Akira SUWA

Level 3 or higher autonomous vehicles, which themselves control all aspects of driving, require lane-specific traffic information for safe and smooth driving. While this information is expected to be generated using probe data sent from vehicles, there are still problems such as the insufficient positioning accuracy of probe data for identifying the driving lane and the low penetration rate of probe vehicles. To overcome these problems, we have developed a system for generating lane-specific traffic information. The system uses images sent from on-vehicle front view cameras, which are in widespread use today, to identify the driving lane and the propagation model of traffic congestion to supplement the probe data.

Keywords: autonomous driving, semi-dynamic traffic information, probe data

1. Introduction

Autonomous vehicles are expected not only to reduce traffic accidents, enhance ride comfort, and reduce the environmental burden by mitigating traffic congestion, but also to support the movement of the elderly and other transportation disadvantaged people and to solve various social problems such as revitalization of local cities. The level of autonomy is defined by the number of functions that are automated and the areas in which the vehicle can be driven autonomously.(1) Level 2 and lower autonomous vehicles require the driver to be involved in all or part of the aspects of driving. In contrast, level 3 and higher autonomous vehicles are equipped with an autonomous driving system that takes charge of all aspects of driving.

Control of autonomous vehicles involves the following planning processes:

1) Route planning to determine the route to the destination
2) Path planning to mainly determine the lane in which the autonomous vehicle should run, the points at which the vehicle should change lanes, and the way to avoid contact with other vehicles and pedestrians
3) Drive planning to control the vehicle to follow the planned route

Level 3 and higher autonomous vehicles are required to perform all the above three planning processes. To ensure safe and smooth driving of the vehicle, it is preferable to perform path planning that not only takes into account other vehicles, pedestrians, and traffic signals near the vehicle but also predicts lane-specific semi-dynamic traffic information on congestion or other incidents having occurred several minutes before or at a point several kilometers ahead. Other vehicles, pedestrians, and traffic signals near the vehicle can be detected by a camera, Lidar, millimeter-wave radar, or other suitable sensor mounted on the vehicle. However, it is impossible for an on-vehicle sensor to acquire semi-dynamic traffic information on an incident that has occurred several kilometers ahead. For the vehicle to recognize such semi-dynamic traffic information, it must receive information from the outside.

This paper describes our study on the use of probe data*1 to generate lane-specific information on the travel speed of an autonomous vehicle, one of semi-dynamic information. Car navigation systems and navigation applications on smartphones are in widespread use today. When using the probe data that can be acquired by these devices (hereafter simply referred to as "probe data" unless it needs to be discriminated from other data) to generate information on lane-specific vehicle speed, the following problems occur:

1) Positioning accuracy of the probe data is insufficient to identify the travel lane.
2) Penetration rate of vehicles equipped with a device that can acquire and upload probe data is low. Accordingly, the volume of probe data acquired today is insufficient.

As a means of solving the first problem, we have developed a new system that generates lane-specific traffic information by using images sent from on-vehicle front view cameras, which have recently become widely used. To overcome the second problem, we have also developed a method that enable to generate highly-accurate information by introducing an estimation based on a traffic congestion propagation model.

2. Travel Speed Information

Travel speed information is one of many pieces of fundamental semi-dynamic traffic information that represent the traffic conditions on roads. Travel speed is used not only for path planning but also to generate information on congested sections that is important for path planning. An example of the use of information on travel speed and congested sections is shown in Fig. 1.

Travel speed information or travel time information is conventionally generated using probe data and is used mainly for route planning in car navigation systems. It is unnecessary for route planning to be conscious of the difference between travel lanes. In addition, information

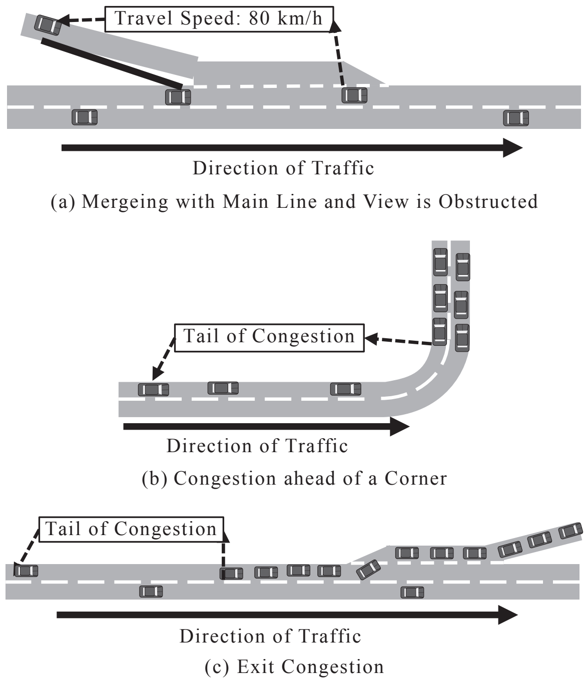

Fig. 1. Examples of use of information on travel speed and congested sections

between branching points, such as intersections, can be used without any problem. Accordingly, information is generated and provided for each road link. In contrast, for autonomous vehicles, which are required to use travel speed information for path planning, it becomes necessary to generate and provide not only lane-specific information in the transverse direction of the road but also short section-specific information in the longitudinal direction of the road (see Fig. 2).

The following two types of input information can be used to generate the travel speed information. One is the information transmitted by vehicle detectors mounted road side and the other is probe data that are collected by vehicles being driven on the roads and transmitted to the server. The advantage of a vehicle detector is that it can measure the travel speed of all vehicles passing through the sensing region. From another standpoint, the detector cannot acquire any information from outside its sensing region. To generate lane-specific highly-accurate semi-dynamic traffic information for autonomous vehicle applications using vehicle detectors, we need to mount a large number of detectors and this requires high installation costs. In contrast, a vehicle equipped with a device that can acquire and transmit probe data can acquire all the pieces of information on all the roads on which the vehicle travels. Since a probe vehicle eliminates the need to install any equipment or device in the road, probe data is superior to vehicle detectors in reducing the traffic information acquisition cost.

3. Generation of Lane-specific Travel Speed Information

Figure 3 shows schematically the system we have developed to generate lane-specific travel speed information. This system performs processes (a), (b), and (c). In process (a), the system checks if the probe data sent from a vehicle traveling in a road contain data on different speed zones. If so, the system groups the probe data into respective speed zones. At this point, it is impossible to know the correspondence between each probe data group and the travel lane. In process (b), the system uses machine learning technology to recognize the travel lane of the vehicle from images sent from some of the front view cameras mounted on probe vehicles. In process (c), the system matches the vehicle, whose travel lane has been recognized in process (b), with the probe data groups that have been classified in process (a) to determine the correspondence of each probe data group to a specific travel lane. In this manner, the newly developed system can generate travel speed information for each lane from the probe data in each group.

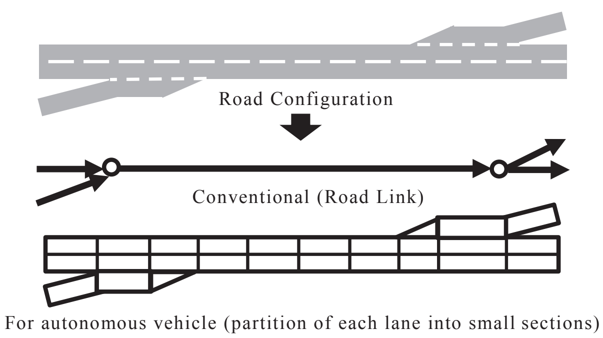

Fig. 2. Unit for generating and providing travel speed information

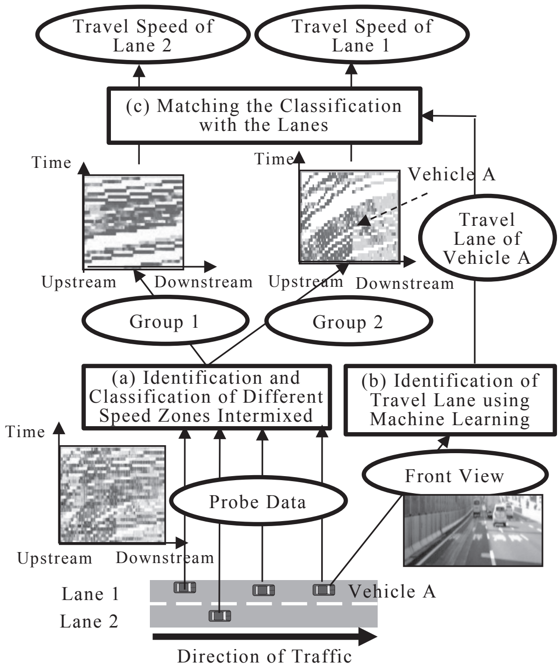

Fig. 3. System for generating lane-specific travel speed information

To verify the effectiveness of the new system, we evaluated the capabilities of the system to i) identify probe data contained in different speed zones and classify these data into groups and ii) identify the travel lane of the vehicle from images sent by on-vehicle front view cameras.

In the first evaluation test, we extracted samples from a population containing probe data obtained during traffic congestion and with no congestion, and checked if the system was able to identify and classify the samples. The test results given in Table 1 confirm that the new system can accurately classify probe data.

In the second evaluation test, we checked if the system can correctly identify the extracted samples when different speed zones are intermixed. This check was performed for populations of probe data obtained both during congestion and with no congestion. The test results are shown in Table 2. This table confirms that the system is also capable of identifying the samples with high accuracy.

To evaluate the capability of the system to identify the travel lane of the vehicle, we trained an identification procedure and then evaluated its capability using the images captured by on-vehicle front cameras when the vehicles traveled on two-lane, three-lane, and four-lane roads. The identification accuracy rates of the system measured when the vehicle traveled in each of the lanes are shown in Table 3. This table shows that the system can identify the travel lane of the vehicle with a relatively high accuracy.

Table 1. Identification and classification accuracy rates when different speed zones are intermixed

Number of Samples	Accuracy Rate
Less than 5	89%
5 or more	100%

Table 2. Identification accuracy rates when eifferent speed zones are not intermixed

Number of Samples	Population	Accuracy Rate
Less than 5	No Congestion	100%
Less than 5	Congestion	100%
5 or more	No Congestion	100%
5 or more	Congestion	100%

Table 3. Travel lane identification result

Travel Lane	Accuracy Rate
1	99%
2	88%
3	95%
4	93%

4. Improving the Accuracy of Travel Speed by Estimating the Propagation of Traffic Congestion

The most common method for generating the travel speed information from probe data on a real-time basis is to average the travel speeds of vehicles that have been obtained during a given time period. However, if probe data cannot be acquired for several minutes when the traffic congestion is expanding or contracting, a change in the traffic conditions after acquisition of the probe data leads to an error with this method. Since probe data for respective lanes are summarized in the generation of lane-specific traffic information, the effect of the above problem is larger than with conventional information generation for each road link.

To overcome the above problem, we have developed a system that can generate travel speed information by identifying the expansion or contraction of traffic congestion from probe data and then predicting the propagation of the congestion. The functions of this system are outlined below and are shown schematically in Fig. 4.

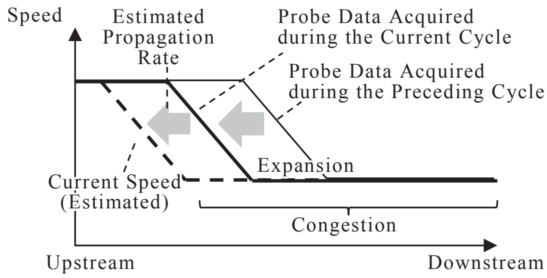

Fig. 4. Generation of travel speed information by estimating the propagation of traffic congestion

(1) This system compares the spatiotemporal locus of travel obtained from the probe data acquired during the preceding cycle with the locus of travel obtained from the probe data acquired during the current cycle, and identifies the expansion or contraction of traffic congestion and calculates its propagation rate.
(2) Using the propagation rate calculated in the above step and the locus of travel obtained from the probe data acquired during the current cycle, this system estimates the current locus of travel and generates travel speed information.

We evaluated the accuracy of travel speed information generated by the system using probe data. In practice, we compared the new system and the conventional system in terms of errors in the travel speed. The conventional system determines the travel speed by averaging the speeds of individual vehicles that were obtained from the probe data, as has already been described. The errors were determined from the data acquired during traffic congestion occurring in the zone between Ebina junction and Yokohama

Machida interchange on the Tokyo-Nagoya Expressway and the zone between Nishinomiya Kita interchange and Chugoku Ikeda interchange on the Chugoku Expressway. The results given in Table 4 show the new system can reduce the travel speed error compared with the conventional system. Figure 5 shows an example of a comparison between the travel speeds generated by the above two systems. This figure confirms that the new system efficiently estimates the propagation of traffic congestion to the upstream and thus enhances the accuracy of travel speed information.

Table 4. Errors in travel speed information generated during traffic congestion (Unit: km/h)

System	Tokyo-Nagoya Expressway	Chugoku Expressway
Conventional	14.6	18.3
New	12.5	14.1

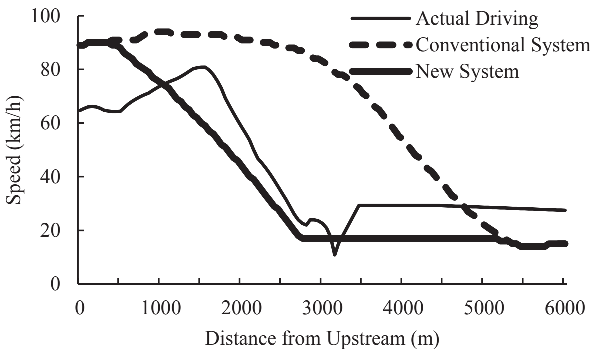

Fig. 5. Evaluation results for travel speed information generation systems

5. Conclusion

This paper outlines a new system that can generate high-accuracy lane-specific travel speed information using probe data for level 3 and higher autonomous vehicles, together with an evaluation of its performance. We will continue our evaluation of this system in the field and improve the information generation accuracy before putting it into use.

Technical Term

＊1 Probe data: Information acquired by a vehicle, such as its location, speed, and ID and time.

Reference

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Contributors The lead author is indicated by an asterisk (＊).

S. NISHIMURA*
• Senior Assistant Manager, Information Network R&D Center

K. TAKAKI
• Information Network R&D Center

K. MASUDA
• Information Network R&D Center

S. TANADA
• Group Manager, Sumitomo Electric System Sloutions Co., Ltd.

A. SUWA
• Advanced Automotive Systems R&D Center