Detection of Congested Intersections Using Car-Probe Data

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Traffic congestion occurs at intersections with fixed time signal control without vehicle detection sensors. This is partly because the signal control parameters have failed to respond to changes in traffic demand. Therefore, we have developed a technique to detect and analyze congested intersections where the situation will be improved by retiming the signal control parameters. Using this technique, we confirmed that it is possible to identify congested intersections without vehicle detection sensors and analyze traffic conditions.

Keywords: traffic signal control, car-probe data, congested intersection

1. Introduction

Traffic signal control (hereinafter referred to as "signal control") is performed to achieve a safe and smooth traffic flow. Signal control parameters, such as optimal cycle time*1 and split*2 of traffic lights, are calculated in real time depending on the traffic conditions, which are measured by vehicle sensors installed on roads. Thus, signal control has contributed to mitigating congestion*3 and reducing traveling time.[1]-[4]

However, it is difficult to install vehicle sensors at all intersections due to the installation and maintenance costs involved. Many intersections are operated based on fixed signal control parameters, which are preset depending on the day of the week and time slot.

Such intersections are often operated with signal control parameters that have become inappropriate for the actual traffic conditions due to changes in the traffic conditions over the years, resulting in congestion.

Recently, a large amount of car-probe data*4 has been collected around the world in line with the widespread use of smartphones equipped with GPS technology. The use of car-probe data has made it possible to determine the driving conditions of vehicles even on roads without vehicle sensors.[5]

At Sumitomo Electric Industries, Ltd., we have been conducted research and development on traffic systems that use such car-probe data.[6],[7] We have developed a technology to collectively detect "intersections congested on one side (Fig. 1)," which are attributed to signal control parameters inappropriate for the actual traffic conditions, by using car-probe data.

"Congestion on one side" refers to congestion only in a certain direction because the green light time for the direction is too short at an intersection. Namely, at an intersection congested on one side, congestion could be effectively mitigated by adjusting the signal control to an appropriate split.

If such intersections can be collectively detected within each area, the signal control parameters can be efficiently adjusted without installing vehicle sensors or investigating the traffic conditions on site.

This paper reports our new technology for detecting intersections congested on one side and the detection results.

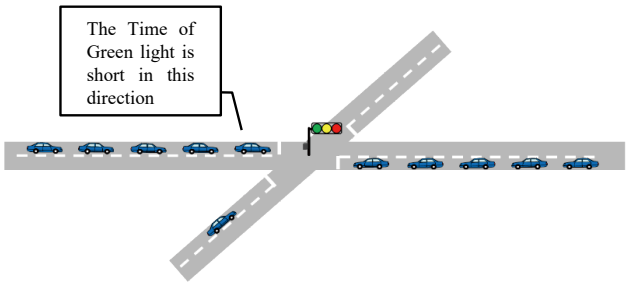

Fig. 1. Overview of an intersection congested on one side

2. Data Used in This Research

2-1 Car-probe data

In this research we used the car-probe data which are offered by TomTom,[8] a global traffic information vender, to determine the driving conditions of vehicles on roads.

In these data, road sections spanning several hundred meters to several kilometers as defined by a global standard are divided into multiple sections to provide information. The average speed and average traveling time of vehicles can be obtained as data for each section.

It should be noted that all information is statistically processed so that individuals are not identified.

2-2 Map data

In this research we used OpenStreetMap[9] (hereinafter referred to as "OSM") as the map data. OSM is open source map data that can be freely used and edited free of charge for both commercial and non-commercial purposes.

The basic map data, such as road connections and traffic light locations, can be obtained in the same format for each country.

3. Detection of Intersections Congested on One Side

3-1 Overall configuration

Our new technology for detecting congestion on one side consists of three processes: 1) a process to generate data of intersections and their approaches*5 based on map data, 2) a process to generate the congestion information of approaches of intersections based on the average vehicle speed, which is included in the car-probe data, and 3) a process to determine whether an intersection is congested on one side based on the congestion information of each approach at intersections (Fig. 2).

All information generated in each process is stored in the location information database and can be used for analysis of the intersection congestion conditions.

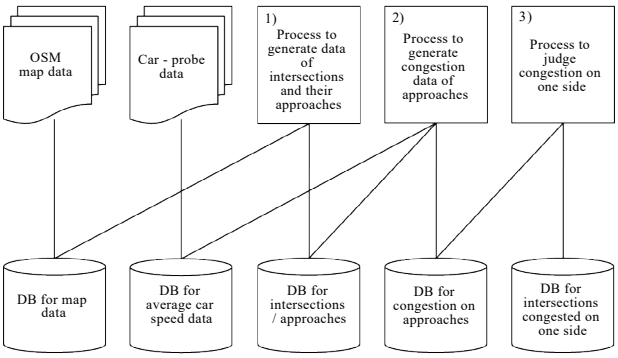

Fig. 2. Configuration of technology for detecting intersections congested on one side

3-2 Generation of information of intersections and their approaches

Intersection setting information, which defines intersection locations and approaches that connect with such intersections, is required to determine congestion at intersections.

In general, such information is set and managed by local traffic administrators. It is not necessarily digitized and may be difficult to obtain.

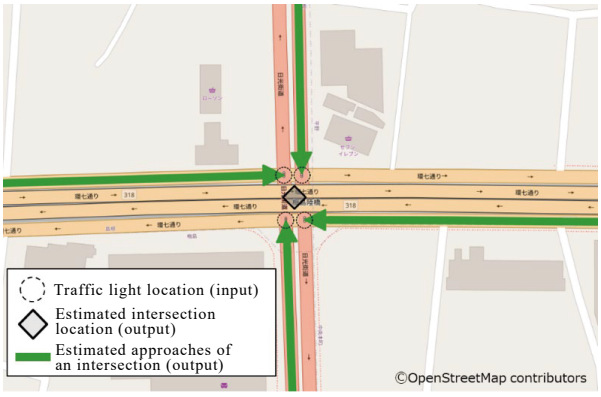

Fig. 3. Generation of the intersection setting information

Our new technology made it possible to collectively generate such information by using map data. The intersection setting information was uniquely generated by estimating the intersection locations and approaches that connect with such intersections based on the traffic light location information, which is included in OSM (Fig. 3).

This function makes it possible to collectively determine congestion at intersections for each area, even for regions where the intersection setting information is unavailable, from a remote location.

3-3 Generation of congestion information for approaches and judgment of one-sided congestion

This technology estimates the congestion section length (hereinafter referred to as “congestion length”) for each approach based on the average speed information of vehicles driving on the approaches of an intersection, which is obtained from the car-probe data.

A continuous section where the vehicles’ average speed is low toward the upstream direction from an intersection location is regarded as a congested section. The length of the section is regarded as the congestion length (Fig. 4).

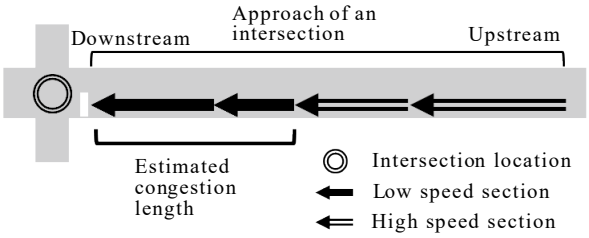

Fig. 4. Estimation of approach congestion lengths

The congestion length of all approaches of an intersection is estimated, and the maximum congestion length on the opposite approach is regarded as the congestion length in this direction. An intersection which is congested only in one intersecting direction is detected as an intersection congested on one side (Fig. 5).

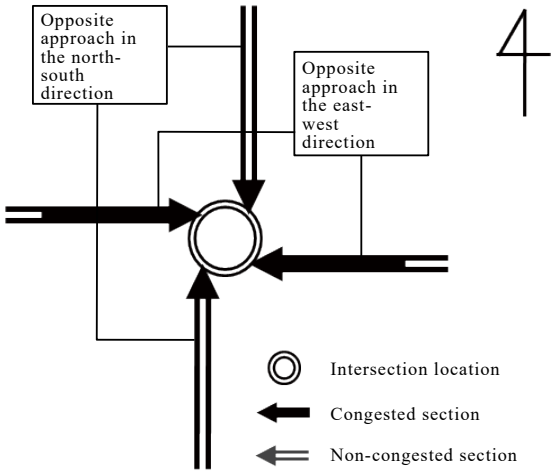

Fig. 5. Detection of intersections congested on one side

4. Evaluation of Performance to Detect Intersections Congested on One Side

Our new technology for detecting intersections congested on one side was applied to the entire Tokyo area, and the detection results were verified using the car-probe data obtained from July 19 to July 21, 2021.

Of 12,052 intersections in total generated by OSM, 1,498 intersections (about 12%) were detected as intersections congested on one side. Intersections congested on one side detected in Tokyo are plotted in Fig. 6.

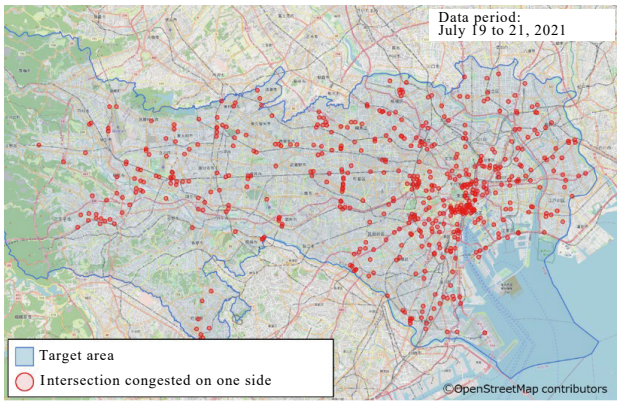

Fig. 6. Results of extraction of intersections congested on one side

Figure 7 shows the congestion conditions on one day at one of intersections congested on one side detected in Fig. 6.

The detection results indicate that approaches in the east-west direction were congested at this intersection during the peak time slot in the morning and that the approaches in the north-south direction were not congested. This is confirmed to be an intersection congested on one side.

We visited the intersection congested on one side, whose congestion conditions are indicated in Fig. 7, and confirmed the peak traffic conditions in the morning.

We found that vehicle sensors were not installed at this intersection, the approaches in the east-west direction were congested, and that approaches in the north-south direction were not congested. Thus, we confirmed that the detection results based on the car-probe data matched the on-site traffic conditions.

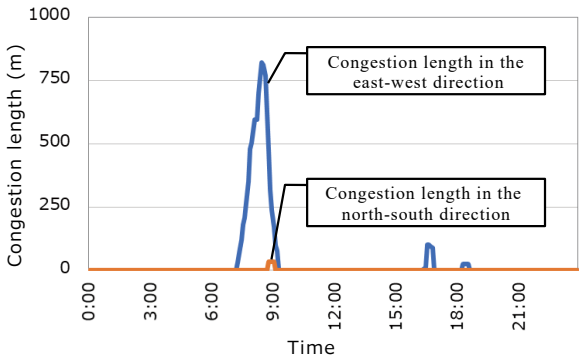

Fig. 7. Congestion conditions at an intersection congested on one side

Vehicle traffic was heavy on the approaches in the east-west direction. Vehicles, which could not pass the intersection during one green light period, had to wait in lines beyond an upstream intersection (Fig. 8 (a)).

In contrast, the vehicle traffic was light on the approaches in the north-south direction. The green light was uselessly lit when there were no vehicles passing the intersection (Fig. 8 (b)). It was found that the signal control parameters were inappropriate for the actual traffic conditions.

These results indicate the possibility that this technology may enable detection of intersections where the signal control parameters are inappropriate for the actual traffic conditions based on car-probe data.

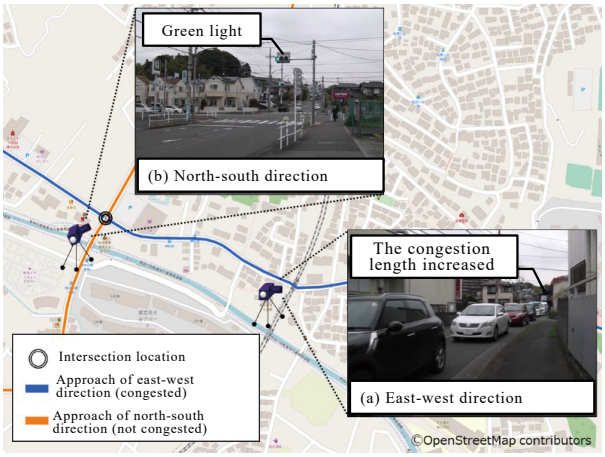

Fig. 8. On-site confirmation of an intersection congested on one side

5. Conclusion

This paper discussed a technology for collectively detecting intersections congested on one side, which are attributed to signal control parameters inappropriate for the actual traffic conditions, within each area by using car-probe data.

We also verified the detection results on site and found that the results of detection based on car-probe data matched the traffic conditions on site. We confirmed that the technology can detect intersections congested on one side.

This technology is expected to enable remote determination of the congestion conditions at intersections and increase the efficiency of adjusting the signal control parameters at intersections where vehicle sensors have not been installed. We will make efforts to upgrade the functionality and put the system to practical application.

6. Acknowledgements

We used data offered by TomTom in developing this technology. We would like to express our thanks to the company.

Technical Terms

∗1 Cycle time: Time required for a traffic light to complete a cycle.

∗2 Split: Ratio of the green light time allocated to each direction of an intersection.

∗3 Congestion: Vehicles waiting in lines which stops without being able to pass an intersection on a green light.

∗4 Car-probe data: Driving trajectory information of vehicles collected from smartphones equipped with GPS technology.

∗5 Approach: A road which is connected to an intersection and on which vehicles drive to enter an intersection.

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