Relative Zone Classification in V2X by HDL Technology

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Abstract

In the midst of a phase of major change said to occur once in a century throughout the automotive industry, technological development in the Connected, Autonomous, Shared & Services, Electric (CASE) domains has been accelerating in recent years. Vehicle to everything (V2X) is a key technology for connecting the ego vehicle to remote vehicles and infrastructure, and there is growing anticipation for it as a technology to improve recognition performance for Advanced Driver Assistance Systems/Autonomous Driving (ADAS/AD) aimed at safety and security, and to smoothly implement cooperative control between vehicles. Studies and development are actively being conducted globally, mainly in Europe and the United States—in Japan too, institutional frameworks and feasibility studies are being implemented, and verification tests on expressways are also underway.

Mitsubishi Electric Mobility Corporation (MELMB) has developed a V2X technology to achieve safer and more secure ADAS applications (such as collision warnings) by improving the estimation accuracy for the relative positional relationship with remote vehicles based on position information of the ego vehicle and remote vehicles, thereby enhancing the warning accuracy for collision risk. This technology uses highly accurate position information and map information—features of High Definition Locator (HDL) technology—to more accurately recognize the situation of remote vehicles around the ego vehicle and achieve relative zone classification and warning accuracy.

1. Introduction

ADAS and autonomous driving systems have been installed in various vehicles in recent years. The main vehicle control is based on detection results from vehicle sensors such as cameras and millimeter-wave radar, and ranges and use cases that are difficult for sensors to detect, such as when objects obstruct the view or in blind spots, need to be considered. To address these issues, using V2X to connect outside the vehicle makes it possible to identify vehicle behavior in advance between the ego vehicle and remote vehicles, powered two wheelers (PWTs), infrastructure such as traffic signals (roadside units RSUs), and pedestrians, and to provide collision-risk warnings. The result is increased safety, convenience, and comfort, and effects such as reducing traffic accidents, alleviating congestion, and reducing environmental impact are anticipated.

One technical challenge for V2X is when understanding vehicle behavior mutually and issuing collision-risk warnings—the relative positional relationship between the ego vehicle and remote vehicles need to be identified with a high level of accuracy, from the geographic coordinates and status of remote vehicles. In this regard, for the ego vehicle, high positioning accuracy and reliability can be maintained through map matching using Global Navigation Satellite System (GNSS), sensor information, and map information via the High Definition Locator; however, for position information received from remote vehicles, the reliability of position accuracy cannot necessarily be considered high because it depends on those vehicles' positioning accuracy and reliability. Therefore, technology to improve the accuracy of position estimation for remote vehicles is required.

This paper outlines MELMB's initiatives toward technology for improving the estimation accuracy of relative zones with remote vehicles by using highly accurate position information and map information, which are features of HDL technology, in order to improve these issues.

2. Initiatives with V2X Development Using HDL Technology

2.1 Issues with conventional V2X technology

With V2X technology, the ego vehicle and remote vehicles transmit position information such as latitude/longitude and altitude mutually. The system estimates the relative position between the ego vehicle and remote vehicles in real time, using the received position information of remote vehicles. In addition to relative position estimation, the system then determines whether to provide information, caution, or warnings to the driver depending on the use case by performing a risk assessment of hazards such as collisions based on the ego vehicle's and remote vehicles' headings, speed, distances to an arbitrary destination point, and estimated times of arrival.

Challenges with V2X technology include difficulty estimating accurate position using only the position information transmitted from remote vehicles, and difficulty estimating whether remote vehicles exist on a road related to the ego vehicle or in the driving lane. Therefore, technology is required to improve the accuracy of position estimation for remote vehicles; however, with position estimation based on remote vehicles' route history, which has been used in the past, accurate estimation is not always possible depending on the accuracy of the remote vehicles' position information and the geometry of the road being driven on.

Possible problems that may arise include cases where there is no actual possibility of a collision between the ego vehicle and remote vehicles, yet the system performs a risk assessment and notifies the driver of false alarms (false positives), and conversely, cases of incorrect detection (false negatives) where the system estimates that there is no possibility of a collision, but a collision risk does actually exist.

Such false alarms and missed detections could make it impossible to provide a safe system for vehicle drivers and traffic. To reduce these factors and achieve highly reliable V2X technology, highly accurate estimation of the positions of remote vehicles is required. Thus at MELMB, we implemented map matching for remote vehicles and developed relative zone classification technology that uses it, as shown in Fig. 1.

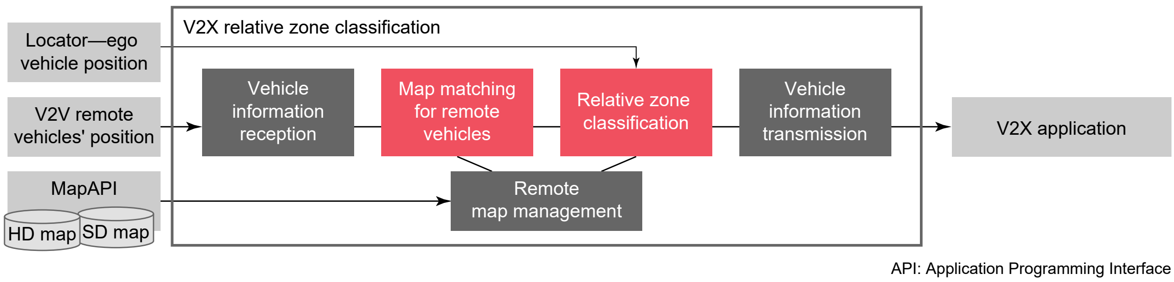


Fig. 1 System architecture of V2X relative zone classification using HDL technology

In this paper, Section 2.2 outlines improving position estimation through map matching for remote vehicles using HDL technology, and Section 2.3 outlines a method for relative zone classification between the ego vehicle and remote vehicles using HDL technology. Section 2.4 also outlines the evaluation results regarding V2X relative zone classification using HDL technology.

2.2 Map matching for remote vehicles using HDL technology

With the High Definition Locator, high-accuracy positioning is performed through GNSS positioning and Dead Reckoning (DR); furthermore, because lane level information is maintained in a high-definition map ("HD map"), it is possible to identify the driving lane on a lane level basis, and related forward and surrounding maps also become available for use. It also features a map used in conventional navigation systems (hereinafter referred to as an "SD map"), which is used during driving on urban roads. The HD map is mainly used on limited-access roads (e.g. motorway/highway) (Fig. 2).

	HD Map		SD Map	
Information granularity	Lane level		Road level	
Map accuracy	50cm or less		5 ~ 10m	
Target roads	Limited-access roads (e.g. motorway/ highway)		All roads	

Fig. 2 Data content of HD maps and SD maps

With conventional map matching using map information, the nearest neighbor point on the map to the positioning location was used as the map-matched position. However, depending on road geometry and positioning errors, the calculated position often differs from the actual driving position. Accordingly, with MELMB's HDL technology, candidate positions are set as points on roads within a prescribed range centered on the ego vehicle's positioning location that satisfy the conditions of the ego-vehicle heading. In addition, when the ego vehicle is driving and position updates occur, the travel distance is calculated from vehicle speed information, making it possible to stabilize map matching accuracy associated with ego-vehicle movement. By also applying this technology to remote vehicle information in V2X technology, it becomes possible for remote vehicles to achieve map matching accuracy equivalent to that of the ego vehicle when using HD maps and SD maps (Fig. 3).

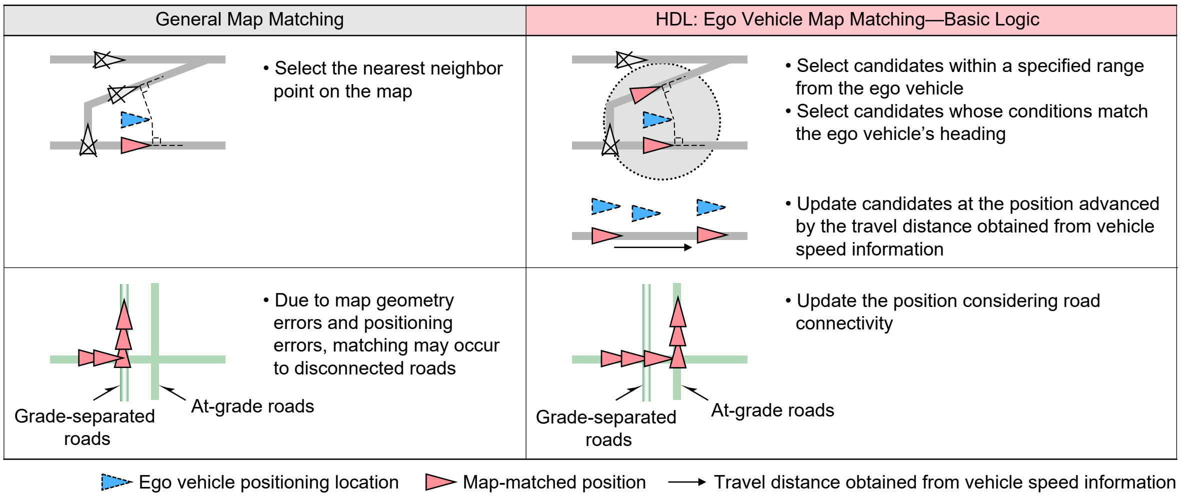


Fig. 3 Map matching methodology for HDL technology

2.3 Relative zone classification logic using HDL technology

Relative zone classification is the process of determining the relative position of remote vehicles with respect to the ego vehicle. When conventional methods do not use map information, a predicted route history is calculated based on the received position information of remote vehicles, and position estimation is performed such as whether they are located in front of or behind the ego vehicle. In this case, there are situations where relative zone estimation based on route history cannot be performed accurately amongst complex road geometries such as interchanges, merges, and splits. There are also cases where it is not possible to accurately estimate whether there is a possibility of a collision with remote vehicles approaching from the ego vehicle's oncoming direction, or whether it is simply a vehicle traveling in the opposite lane (Fig. 4).

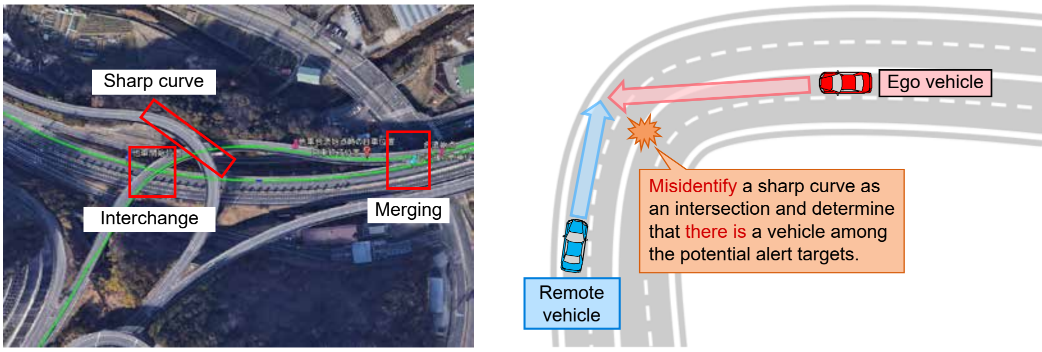


Fig. 4 Examples of complex road geometries and challenges in relative zone classification without maps

At MELMB, V2X technology leverages highly accurate map-matching results for the ego vehicle using a High Definition Locator. HDL technology is also leveraged to improve the accuracy of relative zone classification for remote vehicles, enabling classification at the lane level for HD maps and at the road level for SD maps. With HDL technology, as shown in the path model in Fig. 5, roads ahead of or behind the ego-vehicle position and the roads connected to them are detected, and information on related roads is handled by modeling road network connectivity. With V2X technology, as shown in the recognition model, roads are modeled in the same manner as the path model, and remote vehicles are matched to that road model. This enables classification of candidate roads related to the ego vehicle, classification of whether remote vehicles are present among them, and estimation of relative zones. As a result, in cases where map information is not used, there will be many remote-vehicle candidates among potential alert targets as shown in Fig. 6; however, applying the recognition model using map information makes it possible to filter out remote-vehicle candidates that are not potential alert targets. This makes it possible to accurately determine the relative zones of remote vehicles even for various road shapes and oncoming direction, and helps reduce the computation workload associated with handling information on numerous remote vehicles.

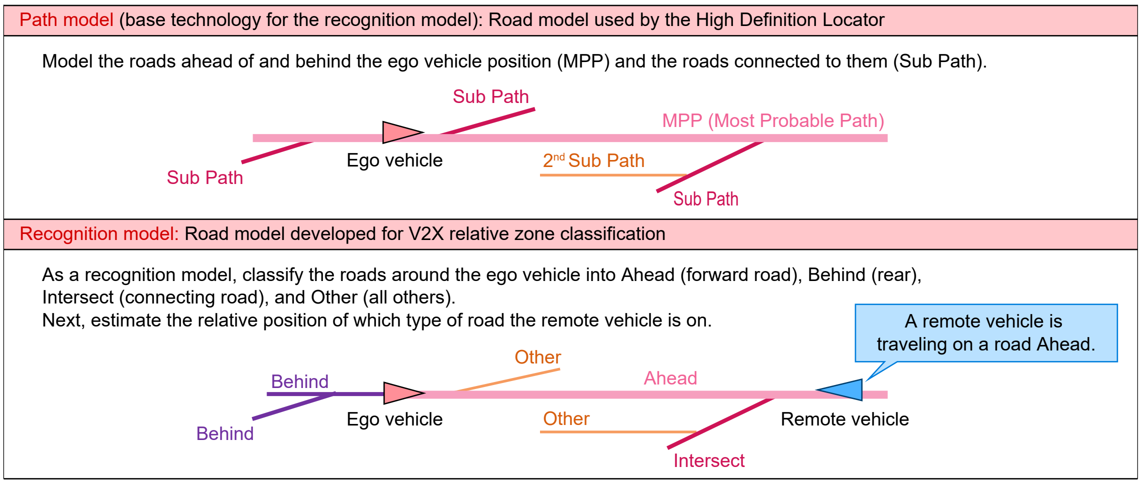


Fig. 5 Recognition model for V2X systems utilizing HDL technology

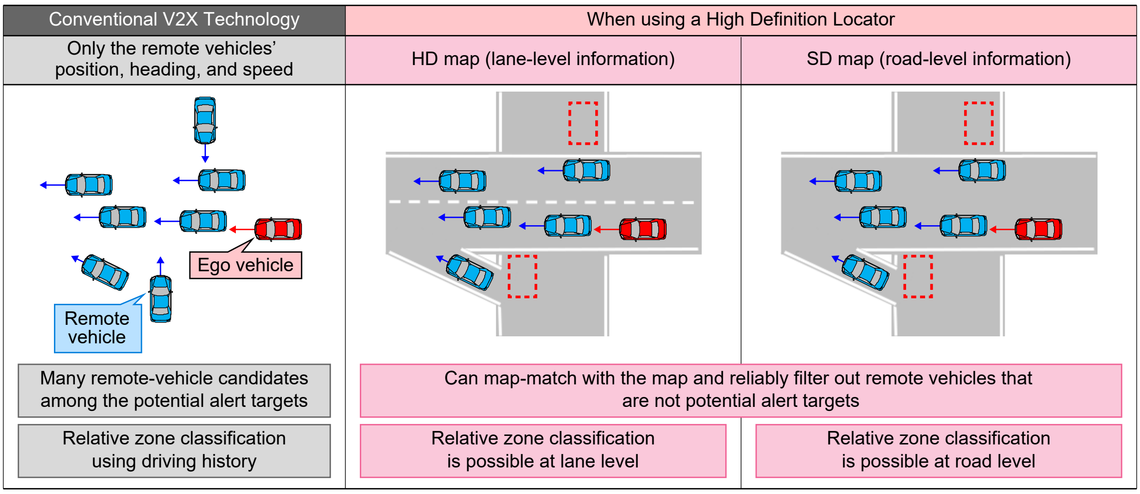
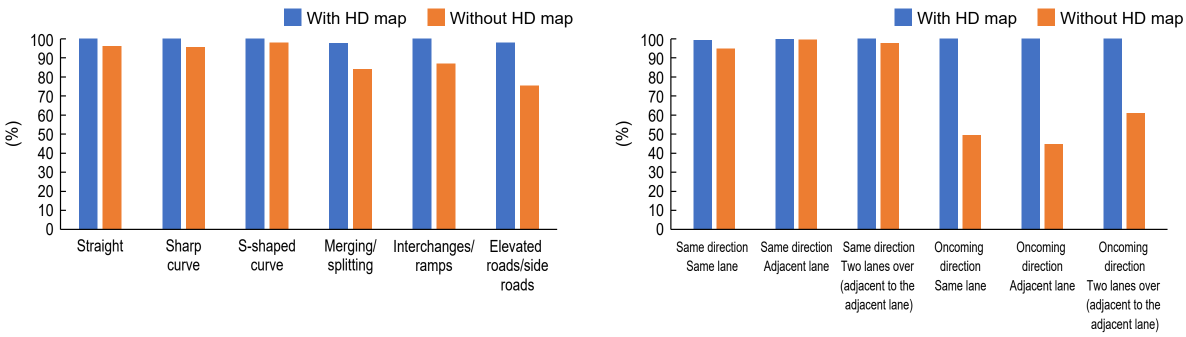


Fig. 6 Filtering effect on remote vehicles using HDL technology

2.4 Experimental evaluation

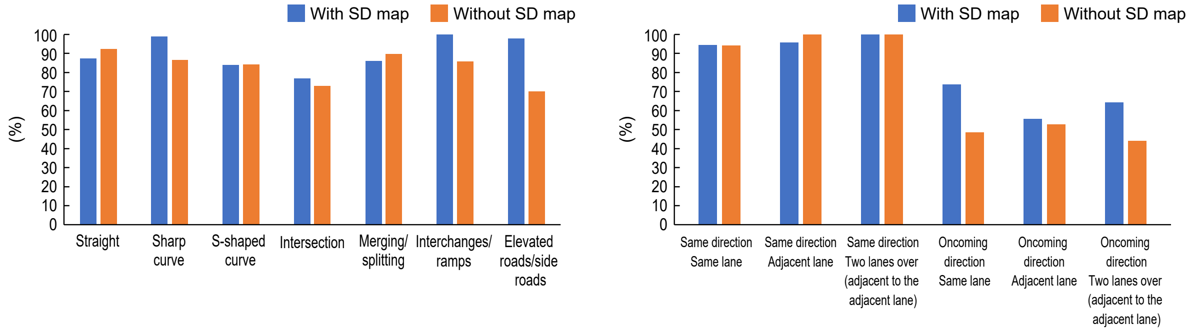
MELMB developed a simulation environment and conducted simulations based on driving scenarios combining road shapes (straight roads, sharp curves, S-shaped curves, merging/splitting, interchanges, etc.), positional relationships between the ego vehicle and remote vehicles (same direction, oncoming direction, etc.), and driving methods (following the road, turning right/left, etc.), and assessed performance to determine whether the expected classification was achieved. Figure 7 shows the comparative results of relative position classification between the case using an HD map with HDL technology and the case not using map information. By using HD maps, it was found that accurate relative zone classification is possible for patterns of each road shape and positional relationship—especially in cases of merging/splitting, interchanges, and elevated roads/side roads—and similar improvement effects were also observed for roads in the same direction and oncoming direction. Using HDL technology can be said to deliver improvements in the accuracy of relative zone classification for remote vehicles with V2X technology. When using an SD map and when not using a map, the comparative results are also shown in Fig. 8. Improvement effects were observed for sharp curves, intersections, interchanges, elevated roads/side roads, and oncoming direction, but the anticipated improvement effects were not obtained for straight roads, merging/splitting, and the same direction (adjacent lanes). This is because there are points that should be improved in the processing when using SD maps; going forward, we plan to conduct performance evaluations again under an improved environment and verify the improvement effects. The same lane and adjacent lanes for oncoming direction also contain less detailed map data compared with HD maps. As such, in order to obtain improvement effects equivalent to those of HD maps, we will further study SD-map-specific techniques in the future, such as determining road shapes and connectivity relationships.



Accuracy comparison: with vs. without HD map (by road feature)

Accuracy comparison: with vs. without HD map (by driving direction)

Fig. 7 Results of relative zone classification with HD maps



Accuracy comparison: with vs. without SD map (by road feature)

Accuracy comparison: with vs. without SD map (by driving direction)

Fig. 8 Results of relative zone classification with SD maps

3. Conclusion

We outlined MELMB's initiatives regarding the application of HDL technology to V2X technology. We verified that by performing map matching for remote vehicles and relative zone classification using this technology, it is possible—compared with traditional cases where map information is not used—to achieve effective improvement in classification accuracy for road shapes and driving patterns for relative zone classification, which is a challenge with V2X technology. HD maps also mainly target limited-access roads (e.g. motorway/highway), and SD maps are used for urban roads; however, improvements are being made in relative zone classification for each road shape, connectivity relationships, and driving patterns in order to obtain effects equivalent to those of HD maps. Going forward, we will contribute to achieving a safe and secure transportation society by addressing further performance improvements with SD maps(*) and advancing support for PTW and pedestrians.

* In partnership with map suppliers (e.g. HERE Technologies, etc.)

References

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(2) Ishigami, T., et al.: High Accuracy Vehicle Locator Using Centimeter Level Augmentation Service, Mitsubishi Denki Giho, 95, No. 7, 425–428 (2021)