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Driving Trajectory of Autonomous Driving Based on HD Map

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Calculating a target driving trajectory which vehicle actuators should follow is essential for an autonomous driving system. For this, some earlier studies proposed methods where it can be obtained by numerical optimization which minimizes a cost functional including a deviation penalty from a reference line of a target driving lane.

On the other hand, there are a number of advanced driver assistance systems made into products which utilize a high definition map (HD map). HD map contains topological information like relations between adjacent lanes and road features including lane markers and road boundaries, which enables an autonomous driving system to “look-ahead” even in hard situations for ego sensors to recognize.

A reference line is often referred to as a “centerline”, and a number of methods have been proposed to calculate it from lane markers on both sides which essentially derives a geometrical “center” of lane markers. But to serve autonomous driving for various situations, we have to consider road geometries where both side lane markers are not painted and also branch and merge lanes, which is not a “centerline” anymore.

Therefore we developed a method that creates desired reference lines from an HD map using lane links, lane markers and road boundaries information. The method first categorizes lanes into three major cases; a lane where you should just normally keep lane center, a lane with a branch or merge and lanes that branches or merges to multiple lanes simultaneously.

As for the first case, the lane is divided into three kinds of regions; where both side of lane markers exist, where only one side of a lane marker exists, and where no lane marker but only road boundaries exists. For the first region (alpha), reference lines are created by calculating the geometrical center. For the second region (beta), reference lines are created by offsetting a lane marker with an amount obtained by linear interpolation so that it smoothly connects to reference lines of adjacent regions. For the third region (gamma), either side of the road boundary is offsetted instead of a lane marker (Fig.1).

As for the second case, a reference line is basically created by offsetting a lane marker which travels along branching or merging direction, except for a special case where a branch is parallel type and a lane marker of a tapered section has large direction change so that it is inappropriate to drive along the lane marker.

As for the third case, especially for the branch case, a reference line of the outer branch is calculated in a similar manner as the second case, but a reference line of the inner branch is calculated by offsetting a lane marker to be crossed with the signed amount obtained by cubic polynomial interpolation.

The method was applied to actual highway roads of Japan and the United States and was capable of creating smooth reference lines including complex road environments (Fig. 2).

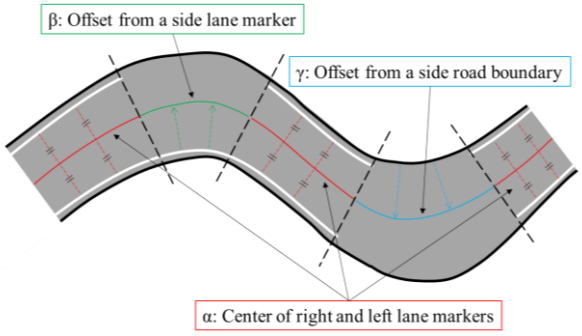

Fig.1 A reference line creation for a normal lane

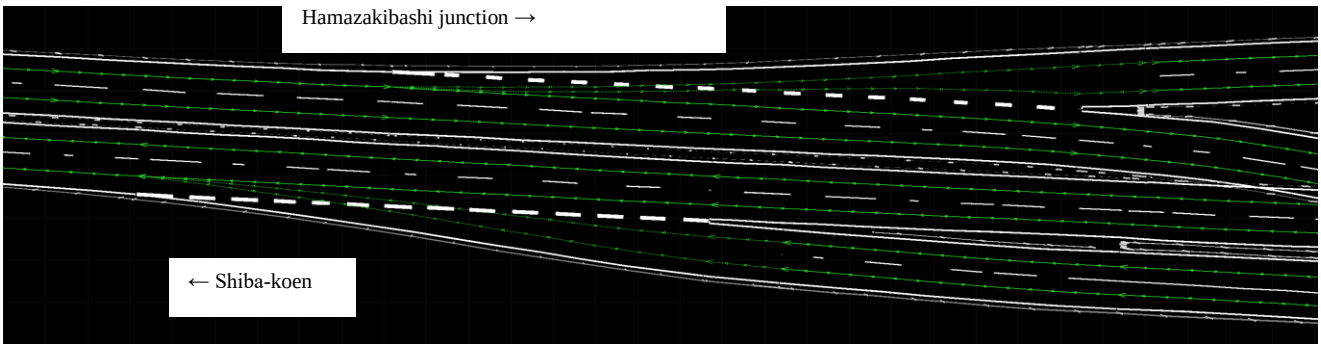

Fig.2 Reference lines (green) creation result around Hamazakibashi junction at Tokyo Metropolitan Expressway
(Road features are by courtesy of ZENRIN and Dynamic Map Platform)