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Road Data as Prior Knowledge for Highly Automated Driving

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Abstract

Vehicles need to recognize and record the roadway and the associated driving area elements with the help of sensors (stereo cameras, radar, lidar, laser scanners etc.) in highly automated driving processes; this information then needs to be converted into a digital 3D model in real time. The vehicle can then locate and orient itself and move in a so-called obstacle-free and restricted 3D area. Localizing the vehicle precisely in the surroundings is often difficult for several reasons: The volume of data needing to be processed in real time, the accuracy of the object recognition process and the multiple disturbances like the weather, daytime and nighttime or the traffic situation etc. To gradually solve the object recognition problems in real time when relying on the available sensors and disturbances, the vehicle should have a detailed prior knowledge of the traffic infrastructure on the planned route before the journey starts; this can take place through highly developed maps (HD maps with separate layers) within its navigation system. The localization of the vehicle can take place faster and more accurately as it compares the prior knowledge and the knowledge obtained from its surroundings. When selecting a route, the prior knowledge about the existing roads is then directly retrievable and can considerably accelerate the localization process in the surroundings; and it can particularly make things safer if any problems occur. The digital data on roads and surroundings can also be used to calculate recommended speeds and the necessary distances between vehicles and for highly automated driving. There are separately layers inside of the HD maps for the digital geometric data and the kinematic parameters.

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Keywords: automated driving; road data; critical velocity; prior knowledge

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1. The Problem

Vehicles need to recognize and record the roadway and the associated driving area elements with the help of sensors (stereo cameras, radar, lidar, laser scanners etc.) in highly automated driving processes; this information then needs to be converted into a digital 3D model in real time. The vehicle can then locate and orient itself and move in a so-called obstacle-free and restricted 3D area. Localizing the vehicle precisely in the surroundings is often difficult for several reasons: The volume of data needing to be processed in real time, the accuracy of the object recognition process and the multiple disturbances like the weather, daytime and nighttime or the traffic situation etc. To gradually solve the object recognition problems in real time when relying on the available sensors and disturbances, the vehicle should have a detailed prior knowledge of the traffic infrastructure on the planned route before the journey starts; this can take place through highly developed maps within its navigation system. The localization of the vehicle can take place faster and more accurately as it compares the prior knowledge and the knowledge obtained from its surroundings.

In addition to precisely localizing the vehicle, kinematic and vehicle handling parameters derived from the road geometry can be made available to the vehicle for the automated driving process. Some of the reference variables here are e.g. the recommended speed for a bend or the necessary distance for any emergency braking maneuvers that might be required.

Once a route has been selected and the speed profile for the section of road where the vehicle is traveling has been specified, the automated vehicle can then handle the longitudinal control process itself by relying on the geometrical parameters on the horizontal projection. The recommended speed for driving along a bend is largely dependent on the equilibrium of forces in the vehicle's handling. On straights, on the other hand, the speed is normally determined by the vehicle's engine power and the maximum speed allowed by the current road traffic regulations.

2. Highly Automated Driving

2.1. Summary

The longitudinal and lateral control of the vehicle (acceleration or braking or overtaking or making a turn) is increasingly transferred from the driver to the vehicle control systems. It is possible to classify five fundamentally different development stages for automated driving (Fig. 1). While driving a vehicle without the intervention of any vehicle control systems (normal driving) is gradually disappearing, assistance systems are increasingly helping it on the three levels of stabilization (ABS, ESP), driving (ACC, LCA) and navigation (routing systems). By introducing new kinds of sensor technologies, the vehicle can take over the longitudinal and cross slopes (gradient and camber) for a certain time and the driver then monitors the driving process. However, the aim is to guarantee fully automated driving through using suitable vehicle control systems that have a high degree of reliability; the driver then only has to take over control in exceptional situations – or not at all.

2.2. 3D Model

In order to be able to solve the object recognition problems by relying on the sensor technologies that are available and the disturbances (weather, vision), the vehicle should have a detailed prior knowledge of the traffic infrastructure on the planned route; this can take place with the help of extended digital maps in the navigation system. It is possible to provide faster and more precise localization in the 3D environment by comparing the prior knowledge and the information that the vehicle gathers in real time.

The special road data requirements for highly automated driving have been analyzed within a research project [1]; at the same time, a fundamental methodology for logging, processing and preparing road data has been suggested for further developments. By introducing special features for different degrees of detail on the roadway and the associated elements that characterize the driving area, it is possible to establish a standard data structure with as-