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V2V-Communication, LiDAR System and Positioning Sensors for Future Fusion Algorithms in Connected Vehicles

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Abstract

The automotive industry is changing from conventional driving into connected and later on autonomous driving. The fundamental principle of this alteration is communication and exchange of data between vehicles and other kind of traffic objects, for example traffic lights. The knowing about basic conditions from all traffic objects within a close proximity can ensure a more precise reaction of Advanced Driver Assistant Systems (ADAS). Thereby Vehicle-to-Vehicle (V2V) technology contributes to increase traffic safety. This paper describes an investigation of V2V communication based on commercial On-Board-Units (OBU). These units, integrated in two test-vehicles, transmit and receive data based on the IEEE 802.11p standard (ETSI ITS-G5). The messages include basic conditions like position, motion vector and vehicle configuration parameters. Those information ensure a relative positioning which is also implemented in the paper on hand. The calculations provide the prerequisites for additional autonomous vehicle system applications like autonomous braking or steering maneuver. To improve precision and reliability of ADAS, statements about integrity are inevitable. These can be achieved by a fusion of different sensor information. Therefore the paper also presents possibilities to ensure an accurate localization and object detection, regarding a Light Detection and Ranging (LiDAR) System (Velodyne VLP-16) and an Differential Global Positioning System (DGPS) approach. The interaction of communication, sensor fusion algorithms and integrity considerations form the basis for autonomous driving.

Keywords:
Autonomous Driving; Connected Vehicle; V2V-Communication; IEEE 802.11p; Relative Positioning; Object Detection; Sensor Fusion

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1. Introduction

The increasing automation of the driving functions places high demands on the vehicle, the environment and the driver. In order to navigate track selective, the vehicle needs to know its exact position. Conventional Global Positioning Systems (GPS) do not reach the required accuracies in the centimeter range. Solutions are based on DGPS approaches or use software technologies like Software Defined Radio (SDR). Cooperatively, the position can be determined by the perception of the environment using highly accurate digital maps. The challenge of recognizing objects in the foveal and peripheral field of view places a high degree of integrity on the sensors and data processing. The different geometric shapes of objects, their surface properties and their movement behavior require specific sensors corresponding to the application. Additional transmission characteristics of the atmosphere influence the accuracy of these sensors in a negative manner. The fusion of the information is the state of the art approach and is applicable for each individual vehicle. The provision of sensor data goes beyond the vehicle - with ad-hoc wireless networks such as WLANp or G5.
The paper on hand discusses three different sensor information. The positioning section describes possibilities to increase the own positioning accuracy. The LiDAR sensor, based on a Velodyne VLP-16, provides highly resoluted 3-D point data and is basicly used for object recognition and tracking. The sensor needs a line of sight to objects which should be recognized and tracked. But reality, especially urban traffic looks different. Shadowing by other cars and infrastructure causes a reduction of information. For this reason we are going to aggregate information provided by the V2V communication.

2. Related Work

There is a multitude of research activities focus on automated and intelligent vehicles and especially on communication in Intelligent Traffic Systems (ITS). As mentioned before neither communication in ITS nor high accurate localization by itself can realize connected and autonomous driving. For this reason, the following review includes both of these subjects.

Because of V2V communication provides a high potential for increasing traffic safety, the current literature deals especially with the application of these units for ITS. One of the most important aspects when V2V communication is regarded as a sensor system is the real time ability. Molisch et al. (2009) gives an overview of channel characteristics including transmission reliability and latency for different environment scenarios. Communication requirements to be met such as end-to-end latency are listed in Hobert et al. (2015).

Cooperative approaches which exploit the communication between vehicles are proposed in Obst et al. (2012) and Rohani et al. (2016). Both of them have implemented a DGPS method that increases position accuracy by exchanging GPS raw measurement between traffic objects. Another relevant work is presented by Alam and Dempster (2013), where different conventional and modern cooperative positioning systems are discussed.

A basic investigation about the combination of Global Navigation Satellite System (GNSS) positioning and a LiDAR system can be found in Kim et al. (2015). In this paper, a multi-channel LiDAR sensor is used to build a global map including curb information of the road based on the logged point clouds. However, the authors already pointed out to intensify investigations to improve 3-D reconstruction and particularly to enhance the fusion with a cooperative positioning method. For detection, segmentation and classification of the LiDAR point clouds, an approach is presented by Babahajiani et al. (2016).

3. Fundamentals

3.1. V2X-Communication and ETSI ITS G5

In the context of Vehicle-to-Anything (V2X) communication, different communication technologies are provided to cover different requirements concerning flexibility, dynamics, reliability, area coverage, latency, data rate, security aspects and other performance parameters. An European communication structure is described by the European Telecommunications and Standards Institute (ETSI) ITS with an associated reference architecture. Based on the IEEE