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# Autonomous Vehicle Function Experiments with Low-Cost Environment Sensors

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**Abstract**

The paper presents the development of an experimental vehicle framework for testing autonomous vehicle functions. The development of system serves primarily the education and the scientific work of the students. It is a good experience for the students on any level of mechatronic education because of its diverse possibilities for mechanical engineering, embedded systems, or control design. Overall system architecture, sensors, actuators and control solutions are outlined in this paper along with the development of a low-cost 3-D LIDAR sensor and some Simultaneous Localization and Mapping (SLAM) experiments.


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*Keywords:* autonomous vehicle, SLAM, LIDAR, ultrasonic sensor

## 1. Introduction

In 2013 our department has started to develop an experimental vehicle framework for testing autonomous vehicle functions, see Aradi et al. (2014). Our system serves two purposes: research and education.

In the 80s embedded systems began to appear in automotive industry and progress in achievable computational performance opened up the possibility to design advanced driver assistance systems with continuously increasing performance. These solutions utilizes the high integration of mechanics, vehicle dynamics, modern control theory and machine intelligence forming a complex mechatronics system.

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Nowadays the automotive industry, supplemented by several IT companies are facing towards full driving automation. The term ”autonomous car” became popular amongst journalist, though its exact meaning is not well-defined. Though the automotive industry uses it more carefully, in 2014 SAE International and National Highway Traffic Safety Administration (NHTSA) have defined in detail the driving automation levels from ‘Level 0 - No Driving Automation’ to ‘Level 6 – Full Driving Automation’. In 2016 NHTSA has adopted (see SAE 2016.) these six levels of automation, thus now the SAE J3016 Recommended Practice (see SAE J3016 2016.) contains the standard definitions related to driving automation systems.

These new engineering fields can also pose challenges for higher education, see Bécsi et al. (2014.). Developing ADAS systems or automated driving systems needs complex knowledge, since it is a multidisciplinary area of IT, electrical and mechanical engineering. In recent years we have gained positive experiences with our experimental vehicle in the vehicle engineer education. Thus we have seen worth to continue the development.

In the first part of the paper the vehicle framework, the sensor architecture, the on-board communication system and the control system is shortly outlined. After that the development of low-cost 3-D LIDAR sensor is detailed. The concept is built on a special LED-based light detection and ranging device which is capable to measure with 16 channel in a 2D plane. Rotating mechanism with electronic control unit and CAN interface was developed and the prototype was built by 3D printed parts, assembled and installed on the vehicle framework.

Finally the experiments with a special SLAM-based vehicle function development the so-called “home zone assist” is presented.

## 2. Vehicle Framework

The first version of the vehicle framework was detailed in Aradi et al. (2014). In this section we present the improved second version highlighting the differences compared to the first version.

### *2.1. The vehicle frame*

As mentioned above the main purpose of the development to build a low-cost vehicle framework which is capable to model a real vehicle. Considering the options a commercial go-cart frame (see Fig. 1.) with hydraulic disc brakes, rigid rear axles, and chain drive has been chosen. Compared to the first version, instead of the rigid axle a differential gear with two axle shafts has been built into the driveline.

Fig. 1. The basis of the vehicle framework

### *2.2. Sensors*

The second version of our vehicle framework is equipped with near all of the sensor types that can be found on a modern, premium passenger car. A Bosch mono camera (MPC1) is installed on a stand, which provides information about the lanes and the moving objects. A Bosch medium-range radar (MRR1 Plus) can be found front of the vehicle, which data can be used in safety critical applications. For near-range detection a Bosch Park Pilot system is used with twelve ultrasonic sensors. The vehicle dynamics is measured with an ESP sensor and wheel speed sensors. And last, a 3D LIDAR is used for the SLAM-based applications, which will be detailed in the later section sand which was the main improvement of the vehicle framework compared to the previous version.