Development of an Autonomous Vehicle for High-Speed Navigation and Obstacle Avoidance

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Abstract. This paper introduces the autonomous vehicle named Pharos that participated in 2010 Autonomous Vehicle Competition organized by Hyundai-Kia Automotive Group. Pharos was developed for high-speed on/off-road unmanned driving avoiding diverse patterns of obstacles. For the high speed travelling up to 60 Km/h, long range terrain perception, real-time path planning and high speed vehicle motion control algorithms are developed. This paper describes the major hardware and software components of our vehicle.

1 Introduction

The first autonomous vehicle competition in South Korea organized by Hyundai-Kia Automotive Group took place on November, 2010 [11]. The mission of the competition was unmanned travelling of about 4 Km on/off road, passing 7 different patterns of obstacles. Missions also included lane keeping and stopping within 1 m of cross-walk. Out of eleven universities from South Korea, participating in the competition, "Pharos" has taken 4th place. It finished the course in 8 min 52 sec clearing all the missions except cross-walk stopping, which gave 5 min penalty.

Recently there have been many research activities in autonomous vehicle area. Especially, DARPA Grand Challenge [1], [8] and Urban Challenge [10] have made a big progress in the area of autonomous vehicles. However, there are still many open issues for high speed unmanned driving such as long range terrain perception [9], real-time obstacle avoidance and trajectory planning [3], [6], and high speed vehicle motion control [5] et al.

In this paper autonomous vehicle based on real Sport Utility Vehicle (SUV) is introduced, motivated by the competition. The main challenging issue in the development of the vehicle was to build a reliable system, able to travel at high speed up to 60 Km/h through on-road and unstructured off-road while avoiding different types of obstacles. To satisfy these requirements, new methods were developed and extended based on existing methods in the field of autonomous navigation, such as long-range obstacle detection and mapping, real-time collision avoidance and trajectory planning, and stable vehicle control on slippery and rugged terrain.
2 Hardware Design

Pharos’ hardware design consists of several blocks, which are roof platform, which holds sensors, steering and braking actuators, power and data processing systems, and wiring.

Actuation is done by rotating the steering wheel with a controlled motor. A geared DC motor is attached to the steering column. After analysing required torque and rotational speed the choice was given to Smart motor from Animatic Co. with 1:4 gear ratio to control the steering wheel.

Fig. 2 shows the assembled 3D CAD model of the steering actuation mechanism. one-to-one pulley powered transmission mechanism was used, and steering angle sensor was moved to the motor output axis to measure the absolute steering angle.

Braking is actuated by the same type motor with gear, which pushes the brake pedal. Throttle is controlled through internal vehicle electronic system. Vehicle data, such as steering angle, vehicle speed, APS signal, etc are fed to the computing system through CAN interface.

Shown in the Fig. 1 is the custom-made roof platform, holding four SICK laser scanners are installed there. All scanners are facing forward along the driving direction of the vehicle, but with slightly different tilting. A single CMOS camera is installed on the roof for cross-walk detection. GPS receiver, DGPS RF modem and a radio antenna for E-stop (emergency stop system) are also installed on the roof platform. The E-stop system was provided by the organizers of the competition to allow the following patrol car safely stop an autonomous vehicle. Three physical E-stop buttons are also available on both sides of the vehicle and in the rear side.

Pharos’ controllers and communication system are located inside of the trunk. Six Compact PCI computers, NI-CompactRIO, two Gigabit Ethernet switches and various signal converters are installed in a rack. Custom-made power system with backup batteries is installed underneath of the rack to supply power. A six degree-of-freedom inertial measurement unit is attached close to the gravity center of vehicle.