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Development of Intelligent Electric Vehicle for Study of Unmanned Autonomous Driving Algorithm

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Abstract

World-class automakers such as BMW, Audi, GM and even IT Company Google are giving much effort in developing unmanned autonomous vehicles. As it can be seen from IEEE report that 3 of every 4 vehicles in 2040 will be unmanned, the studies on future unmanned vehicles have become very important issues these days. This report proposes an intelligent electric vehicle, developed for unmanned autonomous driving algorithm study. This intelligent electric vehicle directly controls traditional steering device and acceleration/brake pedals through electrical signals with electronic actuators which were equipped at each component. Also, various sensors were utilized to recognize surrounding situations, obstacles, and road boundary instead of human. The obtained sensor data and vehicle state are used for performing of unmanned autonomous driving, evaluating the performance of intelligent vehicles.

Keywords: Electric Drive, EV, Intelligent, NEV (neighbourhood EV)

1 Introduction

Future automobile market will be led by eco-friendly, highly safe automobile technology. The fuel efficiency and safety of the vehicle have depended on the driving habit of the driver, but once the current ADAS (Advanced Driving Assist System) technology is commercialized, furthermore, as the unmanned autonomous driving vehicle technology advances, the vehicle will control itself to prevent traffic accidents and enable high-efficiency eco-friendly driving.

To commercialize unmanned autonomous vehicle technology, technologies from various areas should be integrated. Various sensors should be able to recognize the circumstances around the vehicle, and based on this information, the vehicle should be able to control itself for a safe driving to the destination. Also, since the sensors used for these unmanned autonomous

driving vehicles are very expensive, it is essential to design a system that can minimize the number of sensors by using the sensors appropriately and organizing efficiently. This report proposes the intelligent electric vehicle platform, developed for researching unmanned autonomous driving vehicle technology. And unmanned autonomous driving algorithm is implemented to verify the performance of this intelligent electric vehicle platform.

2 Vehicle Platform Composition

2.1 Concept and Design

Table 1 shows the specification of the electrical vehicle platform for unmanned autonomous driving. The driving motor is 7kW Induction Motor, and the power source is 72V battery pack. For motor controller, Gen4 model of SEVCON was used.

Table 1 : Vehicle Specification

Length	2880 mm
Width	1683 mm
Height	1450 mm
Wheel Base	2150 mm
Tread (Front)	1420 mm
Tread (Rear)	1420 mm
Weight	980 kg
Top Speed	40 kph
Driving Range	60km
Traction Motor	7kW Induction type
Battery	72V Battery pack

Figure 2 shows the concept design for initial unmanned vehicle platform development. In case of common unmanned vehicles, the driver-operated components were indirectly controlled by using mechanical devices for the unmanned driving, but this vehicle is a platform only for unmanned autonomous driving. Brake and acceleration pedal and steering wheel has been removed to secure over 10% of space compared to conventional vehicles. Each actuator can be controlled with signals.

2.2 Concept and Design



Figure 1: Sungkyunkwan University's UEV

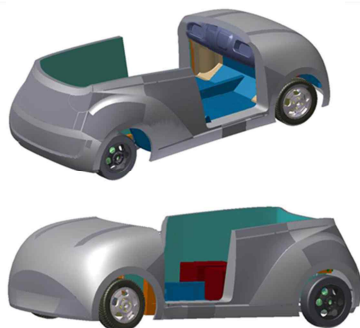


Figure 2: Conceptual Design

2.2.1 VCU System Architecture

VCU is the controller that controls the vehicle behavior, and Single board Rio of NI was loaded. It carries RS232c and CAN communication module, and has Digital I/O and Analog I/O channels. VCU controls each actuator and subordinate controller according to the longitudinal/lateral orders from PCU (Perception Control Unit), which estimates the vehicle state and plans path. Also, it sends feedback of vehicle operation state to PCU.

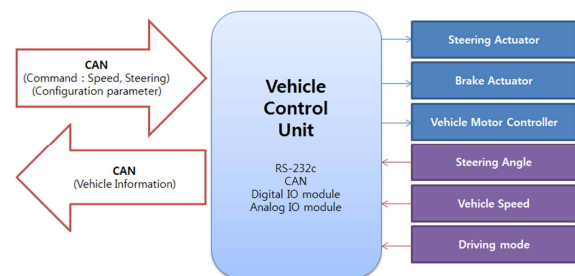


Figure 3: VCU System Architecture

2.2.2 Steering Control

For steering control, Steering module of electric power steering type was used. 24V 420W servo motor was used for operation, and EPS can be controlled by RS-232c. Also, it has a sensor that can measure the angle of steering wheel, which can be communicated through CAN.



Figure 4: Steering System using EPS

2.2.3 Brake Control

For brake control, linear actuator was designed in front of the hydraulic cylinder. 24V 200W SMART motor of Moog Animatics was used, and 60:1 decelerator was connected to the servo motor output axis to deliver sufficient torque to the brake cylinder. Screw-type slider of link structure and universal joint was used to deliver brake torque in the design. The brake servo motor also can be controlled through CAN communication. Effective stroke length is 2cm.

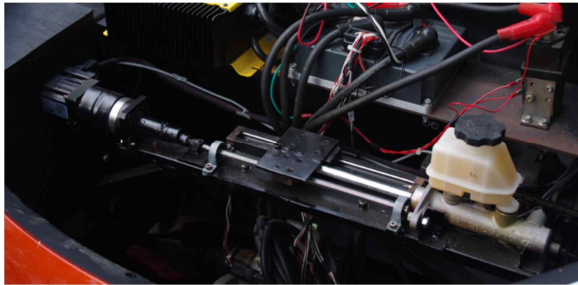


Figure 5: Brake Actuator System

2.2.4 Acceleration Control

Acceleration control was implemented by sending an electrical signal directly to the motor controller instead of the existing acceleration pedal. Analog voltage between 0-5V is applied to control the operation of traction motor. Also, CAN communication terminal of motor controller is used for real-time feedback of current motor RPM information. This was used for longitudinal control of the intelligent electric vehicle.

2.3 Sensor and PCU for Unmanned Autonomous Driving

2.3.1 Sensor Fusion System Architecture

Various sensors are used for unmanned autonomous driving, and there is much difference in the performance of unmanned vehicle depending on how the low data from sensors are utilized. Figure 6. Shows the architecture of surrounding environment recognition controller and sensors used in intelligent electric vehicle. PXI system of NI was used to construct this, and LIDAR sensors, DGPS, Vision Camera and AHRS sensor were used.

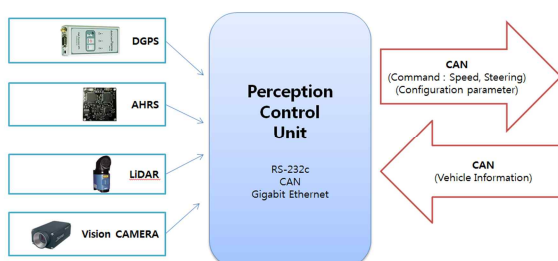


Figure 6: PCU System Architecture

As in Figure 7, it is necessary to have each algorithm to overcome various circumstances for performing of unmanned autonomous driving;

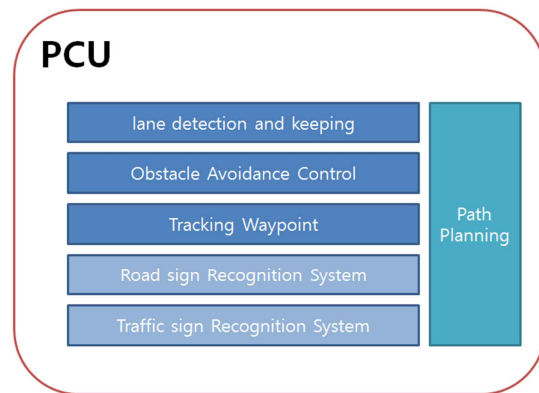


Figure 7 Autonomous Driving Algorithms

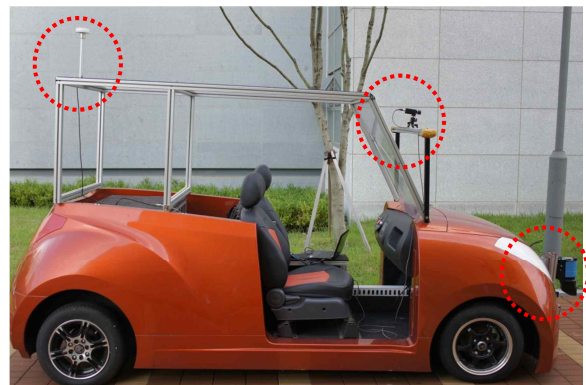


Figure 8: Sensors on SKKU UEV

the information received through PCU from each sensor is integrated to generate the path, which is then delivered to VCU to control the intelligent electric vehicle.

2.3.2 Lane Detection and Keeping

The lane is the most basic element among various features on the road, and it is detected using vision camera for unmanned autonomous driving. This report integrated two algorithms of image information to increase the lane detection rate. Lane information obtained by extracting lane edges through Canny filter and lane information detected from color information were used at the same time.

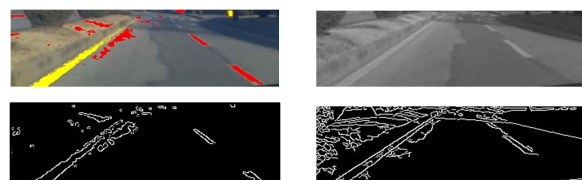


Figure 9: Pre-processing for Lane Detection

Then those images were applied with Hough transform to detect line components. Hough transform provides parameters of those line components(r , θ). After finding out valid data, lane can be detected.

$$r(\theta) = x_0 \cos \theta + y_0 \sin \theta \quad (1)$$

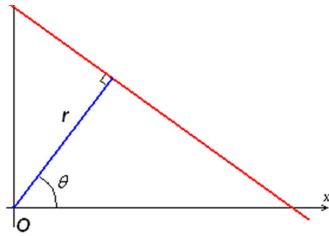


Figure 10: Hough Transform

2.3.3 Obstacle Avoidance Algorithm

It is necessary to develop an algorithm to detect and avoid obstacles such as road structures, other vehicles, or pedestrians. Laser scanner (LiDAR) can be used to detect an object in front of the vehicle and obtain distance (l) and angle (θ) information. Distance information per $\Delta\theta$ section and obstacle existence probability density was made into a histogram. Using this information the vector field histogram (VFH) algorithm was applied for the obstacle avoidance.

SICK LiDAR is used to get the distance and angle of barriers and VFH algorithm was constructed using by LabVIEW Robotoics Module.

2.3.4 Tracking Waypoint

DGPS is used for the unmanned autonomous driving vehicle to find the destination. The target points are taken as waypoints and compared to current position, received from DGPS, for driving. DGPS module used in this study has error within 0.7m, and it is possible to make reception at the period of 1Hz. Also, Attitude and Heading Reference System (AHRS) sensor gives the direction of heading. Autonomous Driving algorithm has implemented by using the direction of heading and coordinates of waypoints and current position.

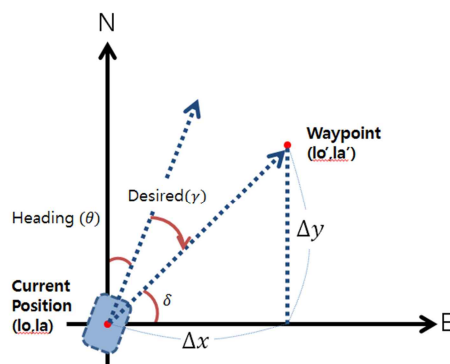


Figure 11: Waypoint Tracking

Longitude variation per 1m: $D_o = 111.2$ km

Latitude variation per 1m: $D_a = \frac{2\pi R_c}{360}$ km

Equatorial radius: 6378km

Polar radius: 6350km

$$R_c = \sqrt{\frac{(R_e R_p)^2}{R_p^2 + R_e^2 \tan^2 \theta}} \quad (2)$$

$$\Delta x = (l'_a - l_a) \times D_a \quad (3)$$

$$\Delta y = (l'_o - l_o) \times D_o \quad (4)$$

$$\text{Distance} = \sqrt{\Delta x^2 + \Delta y^2} \quad (5)$$

$$\delta = \tan^{-1}\left(\frac{\Delta x}{\Delta y}\right) \quad (6)$$

3 Vehicle Test

3.1 Obstacle Avoidance Driving Test

Obstacle avoidance driving test was performed. Some traffic cones were used as figure 12. Obstacles were detected using by LiDAR, The vehicle avoided them by using Vector Field Histogram Algorithm.

Figure 14 shows how make a desired steering angle to moving into largest gap.



Figure 12: Obstacles using Traffic Cone

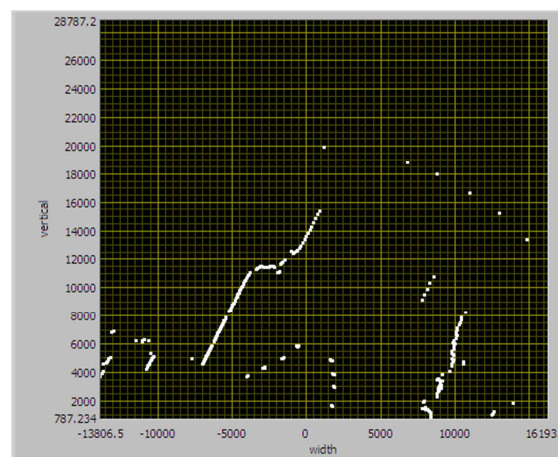


Figure 13: Raw data from LiDAR

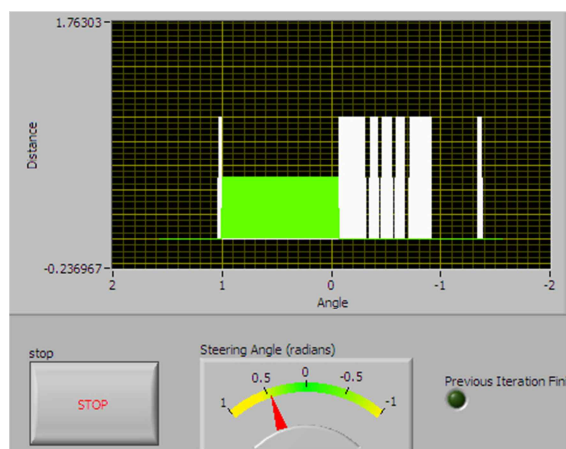


Figure 14: Vector Field Histogram and Desired Steering angle

3.2 GPS Navigation Test with Lane Keeping System

Autonomous driving test was performed; DGPS, AHRS, Camera was used to follow waypoints and keep the lane. The test was conducted 290m on-road course, which contains straight and curve section, recording the distance in 8-10km/h speed.



Figure 15: Lane Detection and Keeping

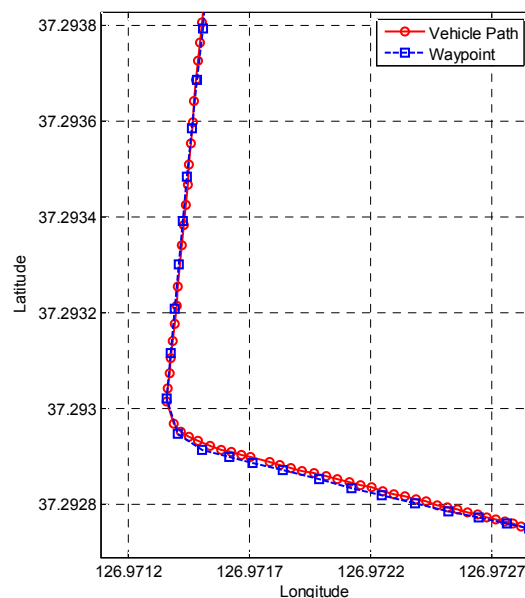


Figure 16: Vehicle Path and Waypoint

4 Conclusion and Future Plans

An intelligent electric vehicle was developed for development of unmanned autonomous driving algorithm. Also, through the developed intelligent electric vehicle platform, the performance of autonomous driving algorithm was evaluated and tested.

Through actual vehicle test, unmanned autonomous driving algorithms such as Lane Detection and Keeping, Obstacle Avoidance, Waypoint Tracking were verified, and it was found to be very effective in performing each independent algorithm.

Unlike unmanned vehicle which is remodeled an existing vehicle, it is possible to use the intelligent electric vehicle platform for application of more effective and diverse algorithms and sensors in construction of sensor, controller, and actuator.

In future, a stronger controller shall be designed to apply to actual road driving and not independent and limited circumstances, and cooperative control between algorithms and parallel computing will be used to implement integrative algorithm.

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