Journal of Engineering and Applied Sciences 12 (Special Issue 11): 9216-9219, 2017
ISSN: 1816-949X

Control System Design of Autonomous Vehicle Through Real-Time Information Convergence

Hyun Seob Cho
Department of Electronic Engineering, Chungwoon University, 22100 Incheon, South Korea

Abstract: Recently, the automobile industry is pursuing the functionality and robustness of the entire system while applying various technologies such as electronic equipment, computer and control. The autonomous navigation system recognizes the position autonomously through the GPS and the sensors and cameras installed in the vehicle and allows the driver to run on the road without driving himself. The key technology of autonomous vehicles is to implement an optimal control system through real-time information fusion in the presence of different sampling, time delay and unspecified disturbance. In this study, a robust controller is designed by distributed image processing algorithm using dynamic motion of vehicle for each sensor and data fusion using these results. In addition, the autonomous vehicle control system is applied to real-time optimization based control and prediction method and the proposed control system is verified through application to simulation vehicle.

Key words: Autonomous car, self-driving, image processing, convergence, driving environment, recognition

INTRODUCTION

It is called autonomous driving technology that oneself to the destination even if it does not operate the steering wheel, the accelerator pedal and the brake manually. Unlike an unmanned automobile that can be driven without a person it is mixed in everyday life. In order to realize the autonomous driving function of the automobile it is required to have a driving environment recognition system which is robust and superior in performance to the conventional intelligent automobile recognition system. In particular, cameras and laser radar sensors are a typical sensor for driving environment recognition which provides information on the characteristics and distances of objects. A single sensor-based recognition system has been actively studied. An autonomous vehicle uses various sensors such as a camera a laser radar sensor and a GPS to recognize a vehicle, a lane and an obstacle. In order to process such sensor information, various technologies such as signal processing, object recognition and tracking technology are required and there is a limitation in recognition performance with only one sensor. Especially, the camera is affected by driving environment such as illumination and the laser radar also provides correct distance information in general but it is vulnerable to external environment such as weather. In this study, we propose a new fusion technique to improve the robustness of recognition system by fusing various sensor information. Generally, the distance information of the laser radar sensor is widely used for recognition of road structure, vehicles, pedestrians, etc. and the image information of the camera is used for recognition of driving environment such as lane, crosswalk and sign. However, a single sensor-based recognition system is not suitable for autonomous navigation because of the high detection rate or non-detection rate due to sensor characteristics and driving environment. Therefore, in order to overcome the limitation of recognition system based on single sensor it is essential to develop an information fusion recognition system using camera, laser radar and GPS (Jung *et al*., 2009). In this study, autonomous vehicles that carry out robust lane recognition and pedestrian recognition through information fusion of video and laser radar we designed a control system of autonomous vehicle through real-time information convergence. The driving environment recognition technology designed through this study was applied to simulated autonomous vehicles and verified reliability and stability through various driving tests.

System structure: The autonomous navigation system designed and implemented in this study is composed of a PC part that manages the state and control of the model car in a remote place and a model car part equipped with a real-time information fusion module for the protocol. The camera sensor and the real-time information fusion module send and receive data to the assigned dedicated base station (Elfes, 1989; Jung *et al*., 2009). The reason for separating the intermediary paper into the dual

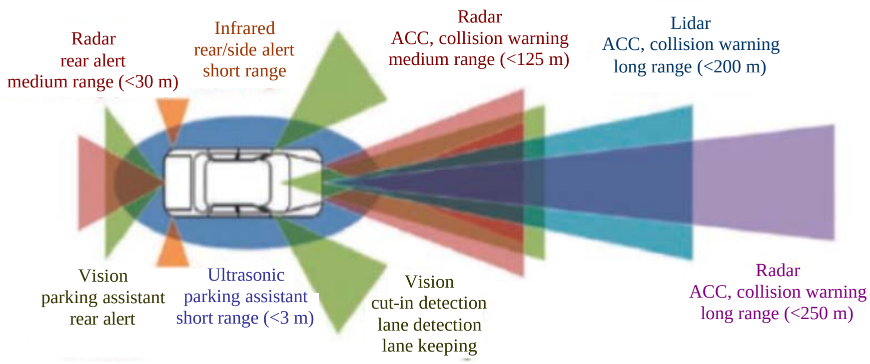

Fig. 1: Communication configuration of information convergence module

intermediary study format in which the camera sensor and the real-time information fusion module are separately provided is to minimize the data loss problem that may occur due to the nonlinear event processing used in the system configuration and communication confusion (Padgham, 2009; Stone, 2010). When the camera sensor of the model car transmits data of 160*120 size at 25 Frames Per Second (FPS/second), the PC acquires the result obtained by using the proposed image processing algorithm. And performs autonomous operation through a real-time information fusion module installed in the simulation vehicle.

In the designed and implemented autonomous navigation system, the real-time information fusion module of the sensor communicates with the PC and controls the PWM (Pulse Width Modulation) pattern of the servo motor and the electronic transmission to control the steering and acceleration of the simulation vehicle.

Figure 1 shows the communication configuration of PC and real-time information fusion module. The PC monitors and controls the state of the model car by using serial and wireless communication at the same time. Real-time information convergence module is divided into intermediary place and client (client) role. In this study, communication between a simulation vehicle and a PC is performed through inter-module communication using Radio Frequency Identification (RFID) communication method and Universal Asynchronous Receiver Transmitter (UART) communication. The client analyzes the message sent from the intermediary to perform acceleration, steering and other control of the model car.

SYSTEM STRUCTURE DESIGN AND IMPLEMENTATION OF AUTONOMOUS NAVIGATION SYSTEM

There is ADAS (Advanced Driver Assistance System) which is the most representative technology that enables autonomous driving. Based on the external environmental information detected by the sensors and cameras of the vehicle, the ADAS enables the driver to take appropriate measures or automatically control the vehicle to establish a safer operating environment, thereby minimizing or preventing damages caused by vehicle accidents (Buehler *et al*., 2007; Seraji, 2003). First, each node transmits its own ID and GPS information location information in a hello message periodically in order to obtain information with the preceding vehicle. The receiving node receives only the information of the preceding vehicle by calculating the direction vector that it moves. Calculate the distance of the front vehicle in the lane to see if the preceding vehicle is in the same lane. And calculates the angle [θ] through its direction vector. Then, if the coordinates of the front vehicle are set as (x_c, y_c), the distance F between the forward vehicle and the lane center can be obtained by the following Eq. 1:

$$l = |(x_0 - x_c)\sin(-\theta) + (y_0 - y_c)\cos(-\theta) \quad (1)$$

The obtained distance l can be determined by the following Eq. 2 whether the vehicle ahead is in the same lane:

$$\begin{cases} \text{True}, l \le \frac{\text{line}_{\text{width}}}{2} \\ \text{False, otherwise} \end{cases} \quad (2)$$

If it is determined that the preceding vehicle is in the same lane, the node that received the hello message calculates the position of the transmitting node and its position using the following Eq. 3:

$$\text{Length} = \sqrt{(x_c - x_0)^2 + (y_c - y_0)^2} \quad (3)$$

If the braking distance according to the speed is D and the reaction Time T is used in the following Eq. 4, the princess distance can be calculated through the sex and age information of the driver of the vehicle:

$$D_f = V_{current} \times T_{unalerted} \quad (4)$$

IMPLEMENTATION OF LANE RECOGNITION CONTROL SYSTEM USING SENSOR INFORMATION CONVERGENCE

Figure 2 shows the lane recognition results in various environments. In order to secure the robustness of the recognition system a simulation run test was carried out under various lighting conditions such as daytime and nighttime and weather conditions such as rainfall. In general, lane recognition results are difficult to analyze the error because it is difficult to accurately record the actual vehicle traveled path. In this study, we analyze the images of the recorded images, record all the positions of the lanes and determine the actual lane location based on the records. Since, this process must be performed every frame it is only performed for a certain period of time. Figure 3 shows the results for 1000 frames analyzed and compares the curve direction error and the straight run direction error, respectively. The results of each comparison show four data which are compared with the proposed particle filter and the conventional particle filter. In this case, PF2 and PF3 are the lane model consisting of the second order polynomial and the lane model consisting of the third order polynomial direction error and the straight run direction error, respectively.

The results of each comparison show four data which are compared with the proposed particle filter and the conventional particle filter. In this case, PF2 and PF3 are the lane model consisting of the second order polynomial and the lane model consisting of the third order polynomial. In the case of a general particle filter, the errors are largely different according to the lane model, and the actual lane position and error are large. The mean error of the CPF was -0.0662 m and the dispersion was 0.02026 while the mean error of PF2 and PF3 was -0.07652 and -0.18672 m, respectively and the dispersion was 0.03420 and 0.01852 which were significantly larger than CPF. In this way, the CPF proposed in most driving environments showed the best performance and was confirmed to be suitable for autonomous vehicles.

The obstacles were detected using three laser radars mounted on the vehicle and were designed to detect obstacles within 5, 10 and 25 m ahead depending on the installed angle. Figure 4 shows the recognized road boundaries. Since, the vehicle has driven in the right lane, it can be seen that the right road boundary is close to the left road boundary. In the case of some different results in a straight line, it is the result of a feature such as a tree. As shown in Fig. 4, there is some error in a sharp curve section. However, the straight line which is used together with the lane detection to recognize the driving lane shows sufficient performance to recognize the traveling direction of the vehicle. In addition, the lane and the road boundary recognition error in the abrupt curve can be filtered by using the vehicle model and the vehicle can be stably operated even in a rapid curve section.

Fig. 2: Applied communication module of autonomous driving system

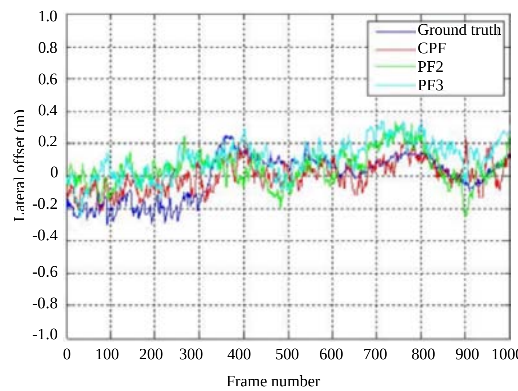

Fig. 3: Lane recognition estimation results using sensor information fusion

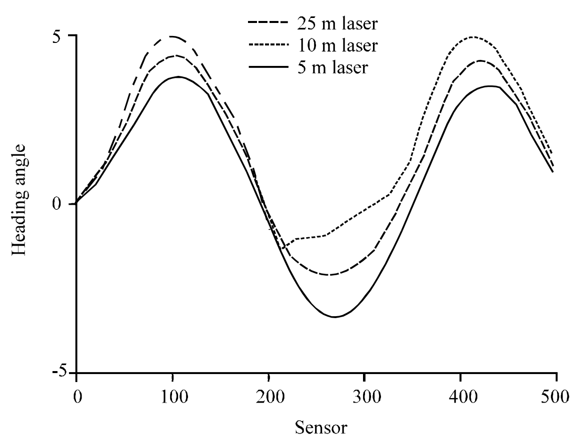

Fig. 4: Estimation result of road boundary recognition using sensor information convergence

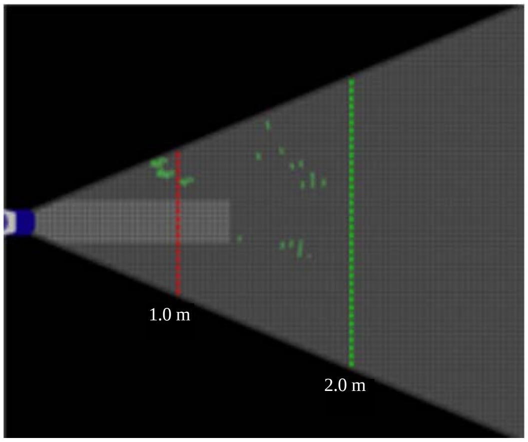

Fig. 5: Obstacle lane and crosswalk recognition using sensor information convergence

Figure 5 shows the finally recognized obstacles together with lane and crosswalk recognition results. As a result of this analysis when the distance from the pedestrian crossing is long a distance error occurs more than 5 m. In case of analyzing it on time basis, it can be seen that the distance from the pedestrian crossing is not constant at a long distance but this is a phenomenon caused by a long distance and does not greatly affect the actual distance control.

CONCLUSION

In order to analyze the performance of the autonomous image processing algorithm proposed in this study, simulation was carried out on the road conditions and the high speed driving at each step. The road conditions were divided into straight run and curved run. Experiments were carried out on the basis of predicted accuracy of the straight road run based on the accuracy of the control judgment and on the curve change of the curve run. In the step-by-step high-speed test, we measured and analyzed the running accuracy of each acceleration step in the same section.

Simulation was carried out in straight running and curved running. Experimental results show that the control accuracy is lowered as the model car travels at high speed in the process of real-time image processing. Also, it is found that the distortion of the obtained image or the change of the road condition greatly affects the performance of the image processing algorithm.

REFERENCES

Buehler, M., K. Iagnemma and S. Singh, 2007. The 2005 DARPA Grand Challenge: The Great Robot Race. Vol. 36, Springer, Berlin, Germany, ISBN-3: 978-3-540-73428-4, Pages: 517.

Elfes, A., 1989. Using occupancy grids for mobile robot perception and navigation. Comput., 22: 46-57.

Jung, H.G., Y.H. Lee, H.J. Kang and J. Kim, 2009. Sensor fusion-based lane detection for LKS+ ACC system. Intl. J. Automot. Technol., 10: 219-228.

Padgham, L., 2009. Michael Winik off, Developing Intelligent Agent Systems. John Wiley & Sons, Hoboken, New Jersey, USA.,.

Seraji, H., 2003. New traversability indices and traversability grid for integrated sensor/map-based navigation. J. Field Rob., 20: 121-134.

Stone, P., 2010. Multiagent Systems: A Survey from a Machine Learning Perspective. Carnegie Mellon University, Pittsburgh, Pennsylvania,.