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Environment Conscious Automated Vehicle Navigation System using PID Controller

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Abstract

Objective: The autonomous driving allures the attention of people for its technical ability to free up the time behind the wheel and from paying attention to the road. This idea encourages the development of a variety of more sophisticated cars day by day. The driverless car is a vehicle that is accomplished by identifying its environment and steering without a car driver. In short, autonomous vehicles are designed to travel between the destinations by keeping the vehicles on a lane even when the traffic conditions change. **Methods:** This paper focuses on establishing a technology to develop a unique approach for the integration of autonomous robots into transportation systems. **Findings:** In this intended method, the autonomous vehicles consist of three subsystems. First, the input unit consists of a camera and ultrasonic sensor to sense their environment and distance measurement. Second, a processing unit is capable of analyzing the sensory data to differentiate objects on the road, which is very useful in planning a path. And the third one is a control unit that interprets the information and makes appropriate decision for keeping the vehicle in a desired path. **Applications:** The proposed prototype is developed using Raspberry Pi as input and processing unit. A low cost Arduino board is used as a control unit.

Keywords: Arduino board, Autonomous Vehicles, Control Unit, Processing Unit, Raspberry Pi

1. Introduction

Intelligent transportation systems are evolving from the research center into industry, mainly in the field of autonomous systems. Since 1980, this technology was employed in numerous works[1]. The growth of new inventions, for example driving systems in automobiles has shown feasibility in controlling the throttle and steering selflessly. In 1990, testing an autonomous car on a track and demonstration of autonomous driving in a dynamic environment is possible. Since then, this field of research has become very vigorous as it imposed many challenges. Defense Advanced Research Projects Agency (DARPA) solved this issue by assessing the autonomous driving capabilities in different types of environments, urban and rural ones[1]. To overcome these challenges number of cars were developed. The automated cars consist of robust control algorithm for controlling the steering, speed and brakes electronically by means of a dedicated processor[2]. An automated driving also need an addition technology and sensors for counterpart the many problems. LIDAR sensors have an advantage of high resolution and wide range of view that examine the problem of detecting of road boundary even in structured or non-structured environment[3]. But the cost involved is too high. In addition, integration of LIDAR with sophisticated software poses a significant challenge. However, the robust vehicle platform with suitable sensors, decision making hardware and software infrastructure should be integrated properly to achieve the desired outcome. In[4], a car steering control using two fuzzy controllers is proposed, which is used to control the steering wheel position and speed of the car. Steering of a car is controlled by means of two input values, one is the lateral error and another one is angular error of the steering wheel. Two Differential Global Positioning System (DGPS) measure the both lateral and angular error. But, it is difficult to find the accurate control rules and membership functions for fuzzy logic Controller. Nested PID controller uses the steering angle as an

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input and is based on yaw rate. The gyroscope is used to calculate the yaw rate[5]. The car is equipped with artificial vision for lane keeping. Lane detection and Lane keeping algorithm without any artificial vision based on B-Snake model is proposed in[6]. It uses Canny/Hough Estimation of Vanishing Points (CHEVP) a robust control algorithm that provides an initial position for the B-Snake and is also robust against noise. H∞ controller proposed in[7], is used to control the rear wheel steering control and yaw rate control with closed loop driving system. This system also controls the speed of car by calculating angular speed of the car. Traction control system for electric vehicles by using fuzzy controller is presented in[8]. This system generates the electric signal to stop or slow down the car for decreasing the slip ratio. In[9], dynamic steering control with help of neural networks and bang-bang control is summarized. The control input is measured by calculating the distance error and orientation angle error for Automated Guided Vehicle (AGV). Tracing the path or road will be more precise when carried out at lower speeds. However, when the speed of the autonomous robot is increased, it wobbles and often gets off the path[10]. Therefore, some kind of control system on the autonomous robot is required to enable the robot to make it follow the track or predefined path efficiently even at the greater speeds[11]. The techniques and algorithms mentioned are very hard to implement in real time and dynamic conditions. This demands an efficient control algorithm for automatic vehicles in real time and dynamic environment[12]. In this paper, an automatic vehicle navigation system that uses a PID controller for lane keeping, Haar cascade classifier model for object detection and front collision system that uses the ultrasonic sensor for distance measurement is proposed. This paper is organized into following sections: Section 2 provides the operation of the processing unit which is used to analyze the captured data and to differentiate objects on the road. This technique is very useful in planning the path. Section 2 also describes the integration of artificial vision and PID control techniques. Section 3 demonstrates the implementation and results of the proposed autonomous car and the final section concludes the proposed work and instills the idea for future work.

2. Vehicle Model

Figure 1 shows the diagrammatic representation for environment conscious automated vehicle navigation system using PID controller. This system consists of input modules such as camera module and ultrasonic sensor are fed into a processing unit. Then processing unit translates the information sent by the input units. And translated data sent over serial communication to control unit for controlling steering wheel and motor.

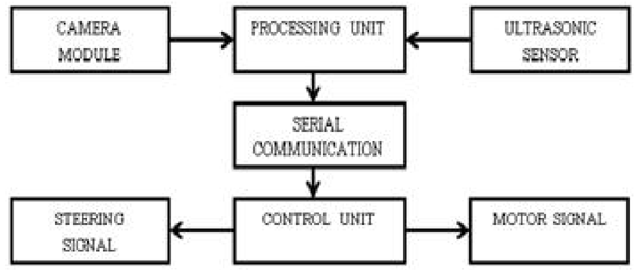


Figure 1. Diagrammatic representation of the system framework.

2.1 Processing Unit

The camera is the important part of the autonomous car for the proper functionality. The camera module is used to take pictures of the surroundings and camera image streamed into a processing unit, which trimmed down the pixels which are not in the range and spot the pixel present in the boundary, so the color image converted to a black image with white dots. In lane detection technique, it is necessary to calculate the center position of that road because road has a large area. Object Detection is also part of a processing unit which is based on Haar Cascade Classifier. Here object classification only focused on stop signal and traffic light detection. To distinguish various states of the traffic light (red, green), specific image processing model is needed for detection. Hence Figure 2 encapsulates the detection process using Haar Cascade classifier. A distance measurement task also handles by processing unit because it can only support one pi camera module. For that reason, the distance measurement is based on ultrasonic sensor, which transmits the ultrasonic waves and received back by the sensor. After transmitting the ultrasonic waves, the ultrasonic sensor will switch to receive mode. Hence the distance can be calculated by the time elapsed between transmitting and receiving of ultrasonic waves. After completion of processing, the information sent to the control unit over the serial communication.

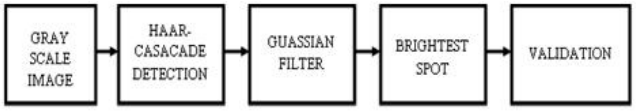


Figure 2. Haar cascade classifier.

2.2 Control Unit

A low cost Arduino board is used as a control unit. A control unit consists of PID control algorithm for proper control action. Therefore, the control algorithm computes the difference between the current position and target position in equation (1). According to the rate of error the control unit commands the steering wheel motors to take a left or right turn. This is a result of the proportional term P in equation (2), where Kp is a Proportional gain.

$$Difference = (Target\ Position) - (current\ Position) \quad (1)$$

$$P = Kp * (Difference) \quad (2)$$

Derivative term is responsible for providing the rate of change of error. This would help the car to recognize exactly how rapidly the error change periodically and accordingly control the car to attain the set position. The formula for Error Rate and derivative term D is given in the equation (3) and (4), where Kd is a Derivative gain.

$$Error\ Rate = \frac{(Difference) - (Earlier\ Difference)}{time} period \quad (3)$$

$$D = Kd \times (Error\ Rate) \quad (4)$$

Even after this, the error does not decrease approximately to zero. So the integral term is used to determine the future error by correlation the earlier errors. Integral gain I is calculated by adding derivative term and integral term in equation (4). This is used to counterpart the absolute error in the system, which is accumulative of a minor error at certain time period.

$$I = I + Difference \quad (5)$$

$$I = Ki \times (I) \quad (6)$$

Therefore, the combination of these three parameter control action is performed. The given Table 1 shows the effects of individual control methods.

3. Implementation and Results

In this section, the performance of the proposed PID controller based autonomous navigation system is analyzed. Figure 3 shows the camera that is mounted over the top of the car for wide range of view. The camera is used to capture the real time image of the surroundings. The captured video or images are fed to Raspberry Pi i.e. the processing unit. The Piuses Open CV for analyzing the captured image to differentiate the objects on the road, which is very useful in planning a path to reach the desired destination. Figure 4 (a) illustrates the captured real time image of surroundings by using the camera mounted on the top of the vehicle. And Figure 4(b) shows processed image using Open CV software for distinguishes the lane or road and the environment by converting the RGB image into Gray Scale image for lane detection. Figure 5(a) shows the front collision avoidance system which uses the ultrasonic sensor. The ultrasonic sensor continuously calculates the distance between the vehicles ahead. The Figure 5(b) shows, if measured distance crosses the predefined value the control signal is send to the motor and inform to stop the car or slow down the car immediately. The Table 2 describes the experimental result of traffic light detection using Pi camera and distance measurement using ultrasonic sensor. The Table describes the distance measurement using Pi camera and ultrasonic. The difference between the actual distance and measured distance shows the system is 90% accurate. The error in distance measurement is due to Pi camera calibration and high response time of control unit.

Figure 3. Front and back view of car.

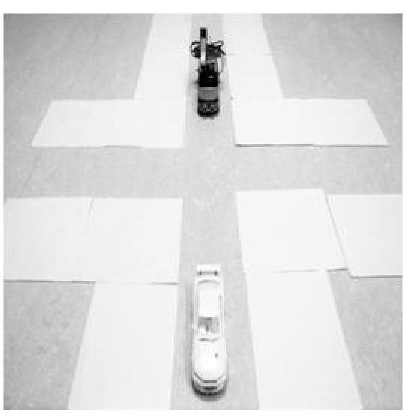
Table 1. Effects of individual terms

Control method	Expression	Effect
P	$Kp \times error$	It decreases a large part of present time error.
I	$error\ dt$	Decreases the absolute error in a system which is accumulative of a minor error at certain interval it helps to reduce the future error
D	$Kd \times error \frac{\square}{\square} dt$	Responds to the sudden output changes of Kp and Ki terms.

(a)

(b)

Figure 4. (a) Color image (b) Gray scale image.



(a)

(b)

Figure 5. (a) Front collision avoidance system distance measurement (b) front collision avoidance system applying break.

Table 2. Distance measurement

Distance (cm)	Actual Value	Measured Value
Traffic Light Detection	15	13.5
Front Collision Avoidance System	10	7

4. Conclusion

The proposed autonomous and unguided vehicles have greater possibilities to change the World's perspective of transportation. Autonomous cars will significantly influence the advancement in technology towards the intelligent transportation. This kind of vehicle will make safer driving, more convenient, less energy intensive and more sophisticated. And also enhance our freedom and decrease a road accident. Although the benefits are obvious, the vehicle needs to follow the legal framework and need a strong decision making algorithm to act like a human being in difficult situations. It barred autonomous vehicle to grow further more. It is time to take serious consideration for this kind of technological advancement and to establish into service for the benefit of our humanities. The autonomous have to do lots more like effective navigation even in any kind of weather and need a vehicle to vehicle communication for autonomous vehicles might permit the interaction between the vehicles ahead and avoid collisions, and traffic jams.

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