Design of control systems for ABC and speed control for autonomous vehicle

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Abstract. In this technological world automation is one of the prime domains to enhance upon. Automation of vehicles is a major domain in which top companies are working on. But designing and manufacturing of autonomous car changes the crux parts of a conventional vehicle which would be top dollar. For common people working in various industries dependent on automobile it is facile to develop the autonomous vehicle from pre-existing conventional vehicle. This paper focuses on developing a Control System for synchronized actuation of Accelerator, Brake and Clutch and speed control for pre-existing conventional vehicle. A synchronized motion of Accelerator Break and Clutch pedal has been realized based on the Forward command, Break command. In order to achieve smooth and robust movement of pedals, PID controller is implemented. To achieve desired speed of the vehicle, PID is implemented based on RPM of rear wheel and position of Accelerator pedal.

Keywords: Control Systems, ABC control, PID, Semi-Autonomous Vehicle

1. Introduction

During the past few decades, automation has been revolutionizing the technological world. In order to improve and develop various sectors of different industries, engineers are thriving to automate various processes. One of the key concepts in robotics and automation is autonomous vehicle. In designing and manufacturing of complete autonomous vehicle the crux and concept of conventional vehicle has to be overlooked, which involves huge investment and heavy buyers. In recent studies it has been stated that total number of automobiles has crossed way above 1.2 billion, which is not easy to replace. Common people whose daily tasks are dependent on automobiles can’t possibly afford it but automation could enhance their lives in a great deal. In this study we have attempted to convert a pre-existing conventional vehicle to a semi-autonomous vehicle in a budget friendly approach.

In this experiment conducted, we have designed a control system for actuation and release of Accelerator, Break and Clutch. This is achieved through PID controller for robust and smooth movement of pedal. For specific movement of vehicle namely forward or break, synchronization of pedals is controlled through a micro-controller. In case of speed control of vehicle, two PID controllers are designed based on the input speed given to achieve the desired speed of the vehicle.
2. Literature Survey
Many researches have been conducted in the field of autonomous vehicles with innovative ideas and latest technologies. However, there are many researches for partial automation and more effective ideas for budget-friendly automation of conventional vehicles. Chandni et al. [1] have devised a technique to control the vehicle to stay in track of the motion using perception, control, and actuator model. Path identification and impediment recognition is done by the perception module. Position and direction data from the navigation module trigger the control signals. These control signals are mapped into PWM for the working of separate engines to control guiding, acceleration, brake, and grasp of the self-governing vehicle. The paper describes the PID controlled steering system with PWM signals as the input. Babu et al. [2], have designed and fabricated a robotic system for converting a conventional car to a driverless car. A mechanical structure utilizing pneumatic actuators was created to control the mechanical frameworks like accelerator, clutch, brakes, and steering of the vehicle. The structured framework worked depending on the contributions from the vision module in the vehicle. Criticism frameworks gave constant input to the computational stage. The components in the customary frameworks were appended with various sensors and encoders, they are additionally used to make this framework work. Achanta et al. [3], have used PID controller for speed control of DC motor. For PID tuning they have used jaya Optimization algorithm. Guo Jin Bao et al. [4], have used a low power proximity switch sensor in place of a mechanical switch to design a low power Kitchen garbage crusher.

3. Control Systems
3.1 Dual Feedback System
Control systems, closed loop feedback is a major design where output of a controller is changed based upon the desired value and actual value. So closed loop feedback control system is used in areas where the desired output is reached in a concise way. By adding another feedback to the system, it is possible to enhance the working in a more consistent method as shown in figure 1.

![Figure 1. Dual Feedback system](image)

4. Methodology
4.1 Design of Control Systems for Pedals
A closed loop control system is designed to trace the movement of pedals. Instead of manual actuation of Break, to automate the process, a DC motor is used to pull and release the pedal. DC motor is controlled by using appropriate PWM signals generated from the PID controller. To track the movement of pedal, we attach a feed-back response to the system. This feed-back role is accomplished by using an ultrasonic sensor (HC-SR04). It measures the travel distance of the pedal and sends it to the micro-controller as seen in figure 2 (a)
Figure 2. (a) Closed loop feedback to control pedal (b) Flow chart for proximity switch-controlled feedback system.

In case of a situation where the motor doesn’t stop pulling the pedal due to coding error, or due to overshoot it crosses a safe limit, the pedal has to be limited to certain extreme position. So that the wear and tear of the system is reduced. In order to deal with this situation, we have attached a Proximity Switch Sensor, which has a maximum sensing range of 0.8 cm. When the pedal is in the detectable region of the proximity switch sensor, it is able to detect the presence of pedal and it sends a signal to micro-controller. This signal is an Interrupt command for the micro-controller. During the interrupt service routine this command is detected and signal severed for the DC motor. Flow diagram for this shown in figure 2 (b).

4.2 Forward Command

For forward movement of vehicle, Accelerator and Clutch has to move in a synchronized manner. A push button is used for forward command which is connected to micro-controller. Initial position of clutch pedal is checked, if not applied then Clutch is applied. Next, the position of Brake pedal is checked and released if it is applied. Finally speed of vehicle is checked.

Various scenarios have to be envisaged for forward command for proper movement of the vehicle. From rest to motion, the system has to follow a set of instructions to set in motion. When in motion the vehicle has to reach the desired Speed limit figure 3 (a) shows the flow chart giving the sequence of commands for the forward motion from rest. Once the vehicle starts to move further forward command works towards achieving the desired speed of the vehicle, as shown n figure 4(a).
4.3 Break Command

In order to stop the motion of vehicle, Break and Clutch have to move in a synchronized manner. During a Break command, the position of Clutch pedal has to be checked initially, if not applied, apply Clutch first and then check the position of Accelerator pedal, release Accelerator pedal if it is applied and then check the speed of vehicle. Two scenarios have been anticipated. From motion to rest, the System has to follow a set of instructions to stop the motion. When at rest, the System has to check the vehicle speed constantly and keep it zero. figure3(b) shows the flow chart giving the sequence of commands for the break command when vehicle in motion, figure 4(b) shows situation when break is applied during rest.

![Flow chart for forward command from rest](image1)

![Flow chart for break command in motion](image2)
4.4 Speed Control
In case of speed control of vehicle, RPM (Revolutions per minute) of the rear wheel is checked constantly using IR proximity sensor. PID is implemented to control the speed of vehicle. Accelerator is applied or released based on the desired RPM and actual RPM of the rear wheel. The system works differently for engaging and disengaging of Accelerator, because rate of increase in velocity is less when engaging accelerator compared to rate of drop in velocity while disengaging accelerator. So, two PIDs are separately used based on the two behaviours of the system as shown in figure 5.

5 Experimental Setup
5.1 Hardware Setup
In order to design a control system, we should have a working system which can perform the desired action. In order to realize the Accelerator, Brake and Clutch (ABC) of a vehicle, a design which brings in similar working mechanism is employed. We used bike clutch, yoke and clutch wire of a well-known
brand. These components together enact like manual actuation of pedals in a 4-wheeler. This set of components were then mounted on a stand as seen in figure 6 (a)

In order to sense the movement of pedal, a sensor is placed. So, a placeholder was attached for proximity switch sensor at 45 degrees from vertical line as displayed in figure6 (d). To find the traversal distance of the pedal, an ultrasonic sensor HCSR04 was attached to the experimental setup as shown in figure6 (c).

![Experimental Setup](image)

![DC motor placeholder](image)

![HCSR04](image)

![Proximity Switch sensor placeholder](image)

**Figure 6.** (a) Experimental Setup (b) DC motor placeholder (c) HCSR04 (d) Proximity Switch sensor placeholder.

5.2 Software Setup
Programming of MSP430 micro-controller is done through Energia IDE. Inputs from the sensor and appropriate decisions and actuation of motors were executed through the use of timers, interrupt signal and PWM signal generation. Another major aspect is realising PID controller through programming. The entire Control System was designed at 100Hz and PID controller was designed at 800Hz so that the system works in synchronisation

6. Results and Discussion
The designed control system is implemented and following results were recorded. Initially individual movement of the pedals were tested separately. The PID controller depends on the input value from the HCSR04 ultrasonic sensor. Values are taken by this sensor constantly and fed to micro-controller. Once the pedal reaches the extreme position where the pedal is within detection range of proximity switch sensor, it sends a high value to the micro-controller which in turn rises an Interrupt signal which serves as the input to the DC motor. The recorded value of distance measured is shown in figure 7.
Once synchronization of pedals is done based on the appropriate command, results were measured. Figure 8 is a set of PWM signals recorded when Forward command is given, firstly, engaging of Clutch pedal is done. Pulse width is gradually reducing because of PID controller. Once Clutch is engaged, Accelerator starts to engage. Once the pulse width of the accelerator engaging signal is 75% of the maximum width, Clutch starts to dis-engage.

**Figure 8.** PWM signals measured during forward command.

### 7. Conclusion and Future Work

The proposed control system is for controlling Accelerator, Brake and Clutch and separate system is designed for speed control of vehicle based on PID. The main task of the system is robust and smooth actuation of pedals through PID controller. Experimental system was designed for this and tested. Future scope for this project is to design and implement a full-scale autonomous vehicle from a conventional car utilizing better technologies and better controller.
References

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