Prototyping Adaptive Cruise Control on Electric Motorcycle

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Abstract. Electric motorcycle is one of the vehicles that can operate using alternative fuels, namely with electrical energy. Travel between cities over great distances, of course this results in a high risk of accidents. Additional features are needed that can warn and stop the electric motorcycle before crashing into other vehicles in front of it. Cruise Control is an automatic technology that is embedded in the automotive system to maintain a constant speed. Prototype refers to the physical and digital representation of pre-production models. This research focuses on applying ultrasonic sensors as distance detectors for the prototype adaptive cruise control system which will be installed as an additional feature on electric motorcycles. The method used in this research starts from simulating a series of systems on Proteus 7.9 software, then designing electrical and software devices on prototyping, and testing. The results obtained by adaptive cruise control mode by testing the variation of distance to PWM duty cycle changes in the simulation compared to prototyping, found an error of ± 1.53%, this shows the prototype Adaptive Cruise Control can work well.

1. Introduction

Based on data from the Indonesian Central Statistics Agency (BPS), the number of motorcycles in Indonesia has increased every year [1]. Technology installed in vehicles distributed in Indonesia is still limited to internal combustion engines [2]. This has an impact on increasing the use of fossil fuels and air pollution. Public demands for modes of transportation that are environmentally friendly and fuel-efficient have increased, marked by the number of efforts in researching and developing vehicles that are driven by electric motors [3]. Electric vehicles are vehicles powered by electric motors and use electrical energy stored in batteries [4]. Electric motorcycle is one of the vehicles that can operate using electrical energy [5]. In Indonesia, there are available types of electric motorcycles with speeds of 60 km/hour, equipped with disc brakes, near and far lighting lights, turn signal, brake lights and horns [6]. The use of motorbikes is not only for mobilization in cities, but also between cities that travel long distances and have a high risk of accidents. One of the things that causes traffic accidents on motorbikes
is the driver's unfocused while maintaining a constant speed that results in crashing into the vehicle in front of him. Additional features are needed that can warn and stop the electric motorcycle before crashing into other vehicles in front of it.

Cruise Control is an automatic technology that is embedded in the automotive system to maintain a constant speed [7]. The cruise control feature is currently developing into Adaptive Cruise Control which is equipped with radar so that it can detect the speed and distance of the surrounding vehicles [8]. Adaptive cruise control, abbreviated to ACC, describes a method of vehicle speed control which adapts to the traffic situation [9]. Besides, the use of the cruise control feature on a motorcycle or other vehicle can increase driving safety and fuel use efficiency, due to constant engine speed [8][10]. ACC with can improve traffic flow by maintaining safe distance inter-vehicle and connect it with emergency controller, so that ACC able to handle emergency brake situation [11]. In fuel use efficiency, ACC combined with regenerative braking on pure electric vehicle, can rate up to 43.65% braking energy recovery [12]. The addition of the ACC system can be a solution needed on electric motorcycle. There was invented throttle lock cruise control, a mounted accelerator sleeve and throttle housing which is mounted in handlebar of motorcycle [13], the speed locked only on certain throttle opening and disable to maintain the speed automatically. Research for modelling efficient cruise control of electric motorcycle had ever been conducted using simulation in MATLAB, SIMULINK [14], but this model limited only on maintaining speed at certain set point. Prototype refers to the physical and digital representation of pre-production models, regardless of loyalty, which serves to answer questions or test assumptions about design [15]. Because the previous result [11][12][14] mainly in software simulation and [13] hardware but only cruise control, so objective of this research is making a prototype (simulation and hardware) of the Adaptive Cruise Control (ACC) for electric motorcycle based Ultrasonic sensor.

2. Method
In this study focused on using an ultrasonic sensor as a distance detection sensor that is US-015 and using Arduino UNO R3 as the main microprocessor. The method starts from designing a series of Adaptive Cruise Control systems using Proteus 7.9 software, which is an open source electric simulator for circuit design. The making of a prototype consists of two stages, namely: Electrical Design, namely uniting components that have been designed on Printed Circuit Bord (PCB) and Designing Software, namely making coding to run a system designed.

After the prototype is created, it is tested for Adaptive Cruise Control mode. Data were taken about the system's response to variations in distance readings and their effects with changes in current, voltage to the electric motor, and changes in PWM values. Data validation is done by comparing the results of PWM duty cycle changes between simulations and prototypes with the same distance variation treatment. The method is illustrated by a flowchart shown in FIGURE 1.
3. Result and Discussion

Figure 2 is a series of system simulations using Proteus 7.9, on the left side of Arduino there is RV 1 (potentiometer) whose signal leg is connected to pin A0, valued at 10 kΩ, used as a substitute for throttle in simulations on Proteus. At the bottom of the Arduino there is a series of switches connected to pin 0, which functions to provide input signals to Arduino as a signal to switch modes from potentiometer to Adaptive Cruise Control mode, when the switch is connected.

In Figure 2 also shows the LCD circuit to display the ultrasonic sensor distance reading and there is a DC motor circuit along with a controller in the form of an NPN transistor Darlington, TIP 122, the base leg is connected to pin 9 which is a PWM pin, functioning to output a signal output to regulate the speed motor, then there are two diodes, namely type 1N4007, which serves as a safety from overcurrent (>1A) so that the motor used is not damaged due to excess current that occurs.

Figure 3 is a prototype series that has been put together (soldered) on a PCB. Explanation of each part of the prototype can be seen in Table 1, additionally after there are 4 LEDs, each of which are blue, green, yellow, and red, which are 4 distance partition indicators, which are set in the code. Blue LED indicates distance of x>50 cm, green-light 30 <x<50 cm, yellow-light 10 <x<30 cm, and red-light x<10 cm, where x is value of distance reading by Ultrasonic sensor in cm. This indicator was added to make it easier when making observations on testing. The prototype testing tool uses an oscilloscope that functions to view PWM signals, a multimeter to measure motor voltages, and an optocoupler sensor for motor speed detection.

Table 1. Part Name of Figure 3

| Number | Part Name                                      |
|--------|-----------------------------------------------|
| 1      | Terminal 9 V & Ground Input Power Supplies    |
| 2      | TIP 120 with Heatsink                         |
| 3      | Arduino signal input pin for LED              |
| 4      | LED (Distance Partition Indicator)            |
| 5      | Motor Control Pin (Throttle Port)             |
| 6      | Pin Input Button                              |
| 7      | Power 5V pin for Throttle                     |
| 8      | Trigger and Echo Input Pins                   |
| 9      | L7805 IC converter 9V to 5V                  |
The barrier object used for testing is thick plastic, which has a high density (waterproof), has a flat surface and the width exceeds the size of the ultrasonic sensor. The test results and observations of the prototype mode of Adaptive Cruise Control are presented in TABLE 2. The test data taken and observed are variations in the distance of the placement of barrier objects with changes in motor voltage, PWM duty cycle, motor speed, and LED conditions. The LED is used as an indicator of the distance partition, in accordance with the initial purpose of adding an LED to the prototype, the LED test successfully lights up according to the partition distance set in the code.

**Table 2. Adaptive Cruise Control Mode Prototype Testing Data**

| Distance (x cm) | Detail Distance (cm) | Voltage (V) | Duty Cycle (%) | Motor Speed (RPM) | LED Condition |
|----------------|----------------------|-------------|---------------|------------------|---------------|
|                | 65                   | 7.901       | 86.75         | 1200             |               |
| x>50           | 60                   | 7.873       | 86.65         | 1155             | Blue          |
|                | 55                   | 7.832       | 86.62         | 1125             |               |
|                | 49                   | 7.757       | 84.68         | 1155             |               |
| 30< x<50       | 40                   | 7.625       | 74.19         | 1050             | Green         |
|                | 35                   | 7.418       | 67.87         | 900              |               |
|                | 25                   | 5.882       | 39.29         | 840              |               |
| 10< x<30       | 20                   | 5.872       | 39.25         | 810              | Yellow        |
|                | 15                   | 5.862       | 39.25         | 810              |               |
|                | 9                    | 0           | 0.09          | 0                |               |
| x<10           | 8                    | 0           | 0.09          | 0                | Red           |
|                | 5                    | 0           | 0.09          | 0                |               |

As the distance of the barrier object placement is close to the Ultrasonic sensor, the value of the motor voltage, PWM duty cycle, and motor speed decreases. In accordance with the 4-distance partition mode Adaptive Cruise Control, for a partition distance of x>50 cm, the motor voltage value is 7.832 - 7.901 V. Distance 30 <x<50 cm, motor voltage 7.418-7.757 V. Distance 10 <=x<30 cm, motor voltage 5.862- 5.882 V. Then for distances x<10 cm, the motor voltage is 0 V.

As with the change in voltage, changes to the duty cycle are divided into 4 partitions. At a distance of x>50 cm (65cm to be exact) the maximum value of the duty cycle is 86.75%. When the distance x<10 cm, the duty cycle value is 0.09%, this happens because the Ultrasonic sensor still has a working voltage that affects the PWM output to maintain the PWM idle condition. The change in motor speed is the same as the change in motor voltage and PWM duty cycle. The maximum value of motor speed when the barrier object is at a distance of x>50 cm (x=65 cm to be exact) is 1200 RPM, as the object barrier distance approaches, the motor speed starts to drop to a distance of x<10 cm, the motor speed value becomes 0 RPM and the motor stops.

Then when transmission distance from 55 cm to 49 cm the speed should have decreased, but instead increased by 30 RPM from 1125 RPM to 1155 RPM, but this speed range is still in accordance with the distance partition set in the code, as evidenced by the decreasing duty cycle from 55 cm to 49 cm, from 86.62% to 84.68%. The increase was caused by the reading of the optocoupler sensor which was very much affected by the lighting of the prototype Adaptive Cruise Control test mode.
Table 3. Comparison of Ultrasonic Sensor Distance Reading Data Against Output PWM Simulation with Prototype

| Distance (cm) | Duty Cycle (%) | Error (%) |
|--------------|----------------|-----------|
|              | Simulation     | Prototype | Simulation-Prototype |
| 65           | 87.08          | 86.75     | 0.33                  | 0.37896 |
| 60           | 86.27          | 86.65     | 0.38                  | 0.44048 |
| 55           | 86.27          | 86.62     | 0.35                  | 0.4057  |
| 49           | 84.8           | 84.68     | 0.12                  | 0.14151 |
| 40           | 70.09          | 74.19     | 4.1                   | 5.84962 |
| 35           | 61.27          | 67.87     | 6.6                   | 10.772  |
| 25           | 39.21          | 39.29     | 0.08                  | 0.20403 |
| 20           | 39.21          | 39.25     | 0.04                  | 0.10201 |
| 15           | 39.21          | 39.25     | 0.04                  | 0.10201 |
| 9            | 0              | 0.09      | 0.09                  | 0       |
| 8            | 0              | 0.09      | 0.09                  | 0       |
| 5            | 0              | 0.09      | 0.09                  | 0       |
| Average      |                |           | 1.53303               |

Table 3 shows the results of comparison of distance variation data with changes in PWM duty cycle in the Simulation and Prototype Testing. PWM change data in the simulation is used as a benchmark data because the conditions in the simulation are ideal, when compared with the distance change data in the Prototype Testing the results obtained as shown in the table, the biggest error occurred at a distance of 40 cm is 5.84% and 35 cm is 10.77%.

Figure 4. Graphic Validation Of Data Reading Distance Ultrasonic Sensor Towards PWM Output Simulation With Prototype

Figure 4 is a graphical representation of Table 3, the x-axis is the value of distance variation (cm) and the y-axis is the duty cycle value (%) PWM, orange is a prototype graph, blue is a simulation graph. Obviously, the error occurred, the change in data between the simulation and the prototype formed a graph that almost coincided because the error value occurred below 0.45%, except in the range of 25 cm <x<49 cm, where the biggest error lies at a distance of 40 cm and 35 cm. In the simulation, the change graph for the range 25 cm <x<49 cm has a linear increase, while the prototype has an increase with a non-linear graphical form. Error occurs because of interference from external factors such as vibration and cabling when testing prototypes.
4. Conclusion
From all of the elaboration of the correlation graphs the distance of the placement of the object barrier to changes in motor voltage, PWM duty cycle, and motor speed indicate the Adaptive Cruise Control mode can run well, then the data validation, found the average testing error obtained was ± 1.53%, meaning overall the value of the PWM changes to the variation of the ultrasonic sensor readings on the prototype went well, and with errors that occurred below 5%, so that the tests carried out are valid and the system may be applicable to electric motorcycles as an additional feature by adjusting in real conditions.

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