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VEHICLE AUTOMATION USING FUZZY BASED PID TYPE CRUISING CONTROLLER

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ABSTRACT

In view of the increasing number of road accidents in recent years, it is conceded that road accidents have assumed the dimensions of a serious social problem. This paper describes the designing of fuzzy based PID-type (Proportional-Integral-Derivative) controller using VERILOG HDL to avoid the collisions between vehicles on the road. The proposed controller provides a reference for controlling the vehicle speed to either increase or decrease based on the distance of the preceding vehicle. A separate Fuzzy algorithm is developed to monitor and control the engine temperature. The model is established on a SIMULINK platform.

The model is coded and simulated using VERILOG HDL. The verified VERILOG model is synthesized using the synthesis tool from Xilinx to get Register Transfer Level (RTL) hardware architecture of the PID modulus. This controller is cheaper in cost compare with the conventional PID controller system. This can be used to reduce the road accidents and ensure the safety of the road users in the future.

KEYWORDS: PID, Fuzzy

INTRODUCTION

The increasing number of traffic accidents in recent years has assumed the dimensions of a serious social problem, making it imperative to find effective ways of reducing traffic accidents and fatalities. This paper presents the designing of a PID controller based on Fuzzy logic that can be used by vehicles on road to make a smooth and safe drive by enabling it to accelerate or decelerate based on the status of the leading car while maintaining a safe distance away from it.

The best known controllers used in the industries are the proportional - integral - derivative (PID) controller because of their simple structure, robustness and variable structure. The PID controller is used for a range of problems like motor drives, automotive, flight control, instrumentation etc. PID controllers provide robust and reliable performance for most systems if the PID parameters are tuned properly. Among the tuning methods, the Ziegler-Nichols (ZN) technique has been very popular.

However, the conventional PID controller is not suitable for nonlinear system. Fuzzy system is well known with its non-linearity characteristic behavior. Therefore, the nonlinear characteristic of the conventional PID controller can be improved greatly using fuzzy logic algorithm.

In this paper, the control system is modelled and designed using VERILOG, then it is synthesized using XILINX Field Programmable Gate Array (FPGA) for rapid prototyping. The FPGA implementation allows for immediate manufacturing realization and negligible prototype costs. In testing, FPGA allows designers the freedom to redesign portions of their circuit for optimization, without performing full redesign iterations to improve a design..

FUZZY BASED PID-TYPE CRUISE CONTROLLER

This section covers the specifications of the model of the fuzzy based PID type cruise controller. The models of the controller based on fuzzy rules are known as, the Fuzzification module, Inference module, Implication module, and Defuzzification module. All the relevant and crucial parameters are explained and illustrated, including the set of fuzzy rules applicable. The objective of this fuzzy controller is to control the vehicle speed. Figure 1 shows the block diagram of the fuzzy PID controller.

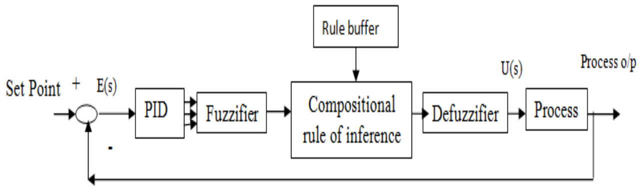

Figure 1: Block Diagram of Fuzzy PID Controller

The three inputs to the controller are calculated for the following variable stages:

1. Error = crisp input.
2. Change in error, ΔE = current error - previous error.
3. Rate of change of error= current delta error - previous delta error.

The inputs and output can be defined using the linguistic terms as NLARGE, NSMALL, ZERO, PSMALL and PLARGE. The graphical representation of the membership functions is shown in Figure 2.

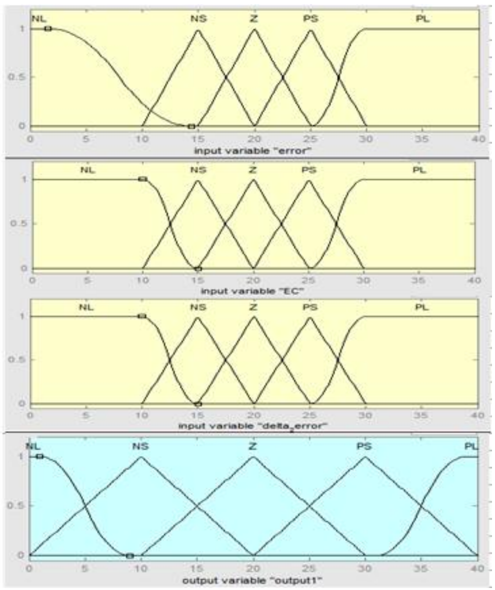

Figure 1: Membership Functions of Fuzzy Based PID Type Controller

A system with three inputs and having five linguistic terms has a total of 5×5×5 =125 different rules can be used to describe the complete fuzzy control strategy. In Table 1, sample fuzzy rules are listed.

Since the input grades are connected by a logical "AND" operator, one input is dependent upon the other, selecting the minimum value will satisfy both conditions. Therefore, taking the minimum of the three variables will be used as the output grade of membership function in each rule.

Table 1: Sample Fuzzy Rules of PID Type Fuzzy Controller

Error	Delta Error	Delta^2 Error	Output
NLARGE	NLARGE	NLARGE	NLARGE
NLARGE	NLARGE	ZERO	NLARGE
ZERO	ZERO	ZERO	ZERO
ZERO	ZERO	PLARGE	PLARE

ENGINE TEMPERATURE CONTROLLER

This section covers the specifications of the model of the fuzzy based enginecontroller.The controller adjusts the temperature of the engine according to the current temperature and the target value. A simple block diagram of temperature control system is shown in figure 2.

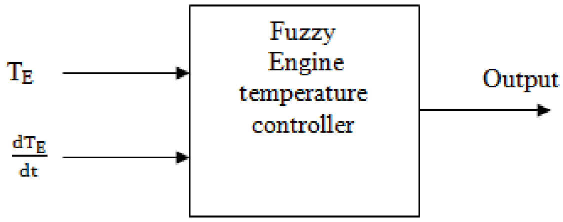

Figure 2: A Simple Block Diagram of Temperature Control System

There are two control variables to adjust the engine temperature: error, which is the difference between the current temperature and the target set temperature and the rate of temperature error change (error dot) with time.

Figure 4 illustrates the 3 fuzzy variables, for both input and output are termed Z (Zero), P (Positive) and N (Negative). The triangular membership function will be used throughout this application because of their simplicity and efficiency of implementation in VERILOG. The values of the x-axis of the membership function representing the actual reading from the temperature sensor. Similarly, the y-axis for the grade of the membership functions. Based on these 2 inputs, the fuzzy logic model determines the amplitude of the voltage signal that is necessary to be sent to the heater in order to maintain a constant temperature.

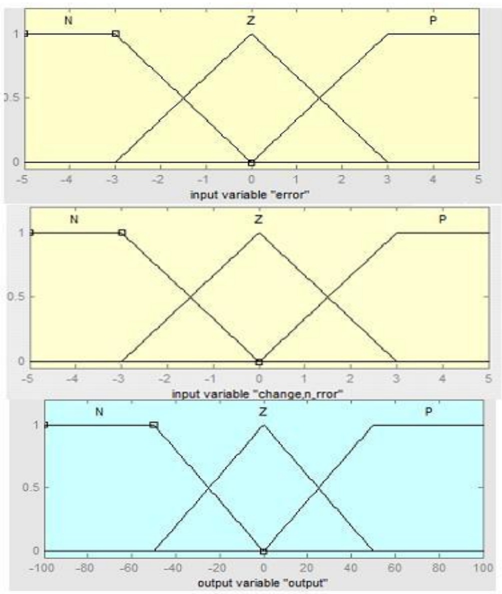

Figure 3: Membership Functions of the Fuzzy Temperature Controller

A system with two inputs and having three linguistic terms has a total of 3 × 3 =9 different rules can be used to describe the complete control strategy. In Table 2, sample fuzzy rules for the temperature control system are listed.

Table 2: Fuzzy Rule Matrix of Temperature Controller

Change in Error/Error	N	Z	P
N	C	H	H
Z	C	NC	H
P	C	C	H

IMPLEMENTATION

The whole system is coded in VERILOG HDL, and simulated using Modelsim SE 6.2d. The simulated VERILOG HDL code is synthesized using Xilinx ISE environment and downloaded in Spartan-3E FPGA kit.

Xilinx ISE is a software tool produced by Xilinx for synthesis and analysis of HDL designs, which enables the developer to synthesis their designs, perform timing analysis, examine RTL diagrams, simulate a design's reaction to different stimuli, and configure the target device with the program. The Xilinx ISE system is an integrated design environment that consists of a set of programs to create (capture), simulate and implement digital designs in FPGA or CPLD target device. All the tools use a graphical user interface (GUI) that allows all programs to be executed from toolbars, menus or icons.

There are two modules in this vehicle automation and each module represents various parameters such as temperature of the engine and speed of the vehicle. Each module is separately synthesized using Xilinx tool and downloaded to the FPGA board. The functionality of the modules is tested on the board using toggle switches and output is monitored with output LEDs. Vehicle automation is done using FPGA to reduce the complexity and cost of the existing CAN mechanism. In future more parameters can be added to improve the performance of the car automation system. Also the system can be optimized for speed, area and power using optimization techniques.

SIMULINK MODEL OF FUZZY BASED PID CONTROLLER

Fuzzy logic toolbox from MATLAB is used to develop a controller for fuzzy logic. Using the Fuzzy Inference System Editor (FIS), the editor involve is FIS editor, membership function editor and rule editor. Meanwhile, rule viewer and surface viewer are used to display the output of the controller designed. Afterwards, once the controller is complete, it is integrated with MATLAB simulink.Figure 5 shows the simulink model of fuzzy based PID type controller.

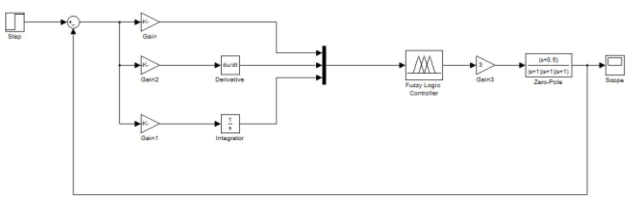

Figure 4: Simulink Model of Fuzzy Based PID Controller

RESULTS AND DISCUSSIONS

A vehicle speed and temperature control system to avoid vehicle collision and to control the engine temperature has been modelled and its functionality verified by simulation. The system provides a reference for controlling vehicles speed and temperature and the distance between vehicles is adjusted based on the above the set point. The modules are synthesized using Xilinx ISE 13.2 to confirm the implementation feasibility. The simulation results as well as synthesis results is presented below.

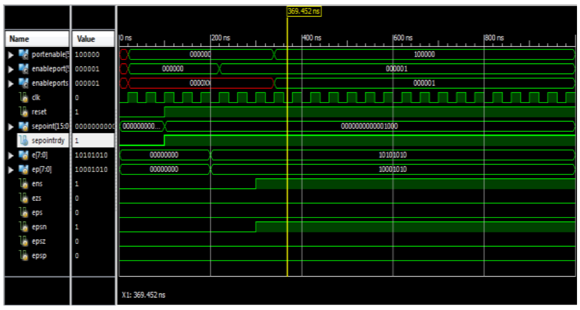

Figure 5: Simulation Result of Vehicle Automation

Figure 7 shows the output response of fuzzy based PID controller obtained in Simulink. It shows that the response of the Fuzzy PID Controller is comparatively better than the conventional PID Controller.

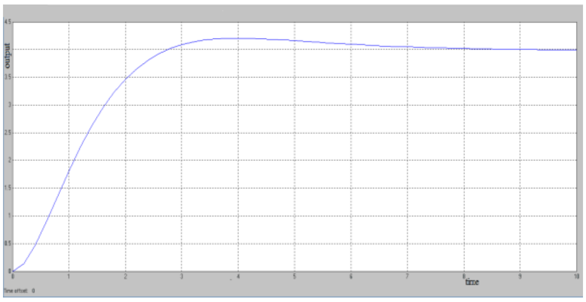

Figure 7: Simulink Output

Figure 8 shows the schematic of the system. From the figure we can see that the whole design is divided into six blocks such as pid_controller part, error_cal part, fuzzy_top part, port_connect part, rulematrix part and flc_new part. The pid_controller part, error_cal part, fuzzy_top part and port_connect part are used to perform the speed control. The pid_controller part is the forepart of the system which contains adders and multiplies. The error_cal part is used to calculate the three crisps inputs of the PID type Fuzzy Controller System. The fuzzy_top part is used to perform fuzzification, inference and defuzzification. The design of engine temperature control is performed with flc_new part and rulematrix part. The rulematrix part uses the state diagram approach and flc_new uses the normal implementation of fuzzy controllers.

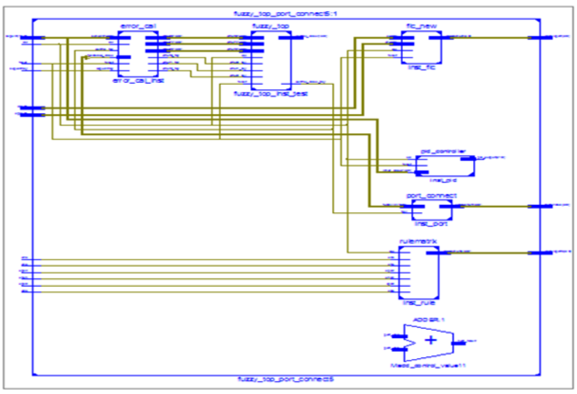

Figure 6: Final Schematic

CONCLUSIONS

A fuzzy based PID controller for transportation applications is being proposed in this project. The described PID controller also has developed with all fuzzy rules for designing the hardware PID chip using VERILOG HDL. Then, the synthesis tool has used to get the logic gates of hardware PID modules. The designed PID chip can be used for the targeted application. The cruising system based on PID controller can be used to avoid the collision between vehicles on the road. The controller algorithm will be further optimized by improving the membership function, the rule base, and the tuning method. It should be done to obtain better control over its application because there are many constraints those needs to be considered in the real world and to ensure the safety of the road user in the future.

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