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Fuzzy Based PID Controller using HDL

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ABSTRACT

This paper describes the designing of PID-type (Proportional-Integral-Derivative) controller based on Fuzzy algorithm using HDL to use in transportation cruising system. The cruising system with Fuzzy concept has developed to avoid the collisions between vehicles on the road. The developed Fuzzy Logic Controller (FLC) provides a reference for controlling the vehicle speed either increase or decrease. The controlling speed depends on the distance of the preceding vehicle when it gets too close or alert the driver when necessary. The Mamdani Fuzzy Inference theory is studied, and developed in Matlab package at first for designing the PID-type FLC hardware system. The behavioral of the PID-type FLC algorithm is then simulated using VHDL language. The comparison of simulation results between Matlab and VHDL are presented for designing the PID-type hardware implementation. The developed and designed Fuzzy based PID- type cruising controller is cheaper in cost compare to conventional PID controller system, and, thus we can propose this developed chip to use to the entry-level vehicles such as the national car. This can be further reduced the road accident and ensure the safety of the road users in the future.

INTRODUCTION

This project PID controller [1] is the best known as industrial process controller. It is robust in wide range of performance. However, conventional PID controller is not suitable for nonlinear system. Therefore, PID-type Fuzzy Controller is preferred in the non-linear process due to its simplicity, robustness, and variable structure. Moreover, the PID controller does not require explicit knowledge of the model of the dynamic plant, which is complex and very hard to obtain. The PID controller mostly can be applied to the control process such as motor drives, flight controls, high- speed trains, and others application. Improvement on the PID controller system can lead to huge effect in the control process for industrial application. Therefore, the PID-type Fuzzy controller system is investigated, design and simulated in this project. Fuzzy system [2] is well known with its non-linearity characteristic behavior, Therefore, the non-linear characteristic of the conventional PID controller can be improved greatly using fuzzy logic algorithm. Besides, most of the research works have done on the Fuzzy PID controller, which are, focusing on the conventional two-input PI (Proportional-Integral) or PD (Proportional-Derivative) type as proposed by Mamdani. This is because the three-inputs of PID controller are a complex task, as more parameters have to be considered in building the fuzzy rule base. It is difficult to determine the control rules for the Integral mode input (e), as the steady state error of a system is very hard to define. Therefore, the three inputs of the controller define as error (e), change in the error (e) (also known as Derivative), and the rate of change of error (2e) (also known as acceleration error). Besides it, there is no proper way of tuning method available until now. Trail-and error method is required in optimizing the controller .Furthermore, the number of rule base increases exponentially with the increase of member function. If the number of input is m, and the number of membership function for each input is n, the total number of IF-ELSE rules is equal to mn.

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PID CONTROLLER

The PID controller, which consists of proportional, integral, and derivative elements is widely used in feedback control of industrial processes. In applying PID controllers, we must design the control system that is, we must first decide which action mode to choose and then adjust the parameters of the controller so that our control problems are solved appropriately. To that end, we need to know the characteristics of the process. As the basis for the design procedure, we must have certain criteria to evaluate the performance of the control system [3].

PID - "proportional, integral, and derivative." A PID controller is a controller that includes elements with those three functions. In the literature on PID controllers, acronyms are also used at the element level: the proportional element is referred to as the "P element," the integral element as the "I element," and the derivative element as the "D element."

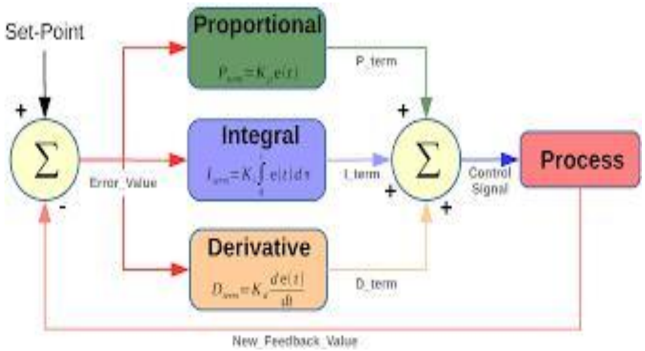

Fig.1: Block diagram of PID controller

The PID controller was first placed on the market in 1939 and has remained the most widely used controller in process control until today. An investigation performed in 1989 in Japan indicated that more than 90% of the controllers used in process industries are PID controllers and advanced versions of the PID controller.

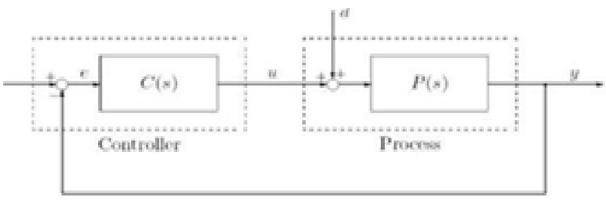

Fig.2: Conventional feedback control system

PID control is the method of feedback control that uses the PID controller as the main tool. The basic structure of conventional feedback control systems is shown in using a block diagram representation. The purpose of control is to make the process variable y follow the set-point value r. To achieve this purpose, the manipulated variable u is changed at the command of the controller.

As an example of processes, consider a heating tank in which some liquid is heated to a desired temperature by burning fuel gas. The process [4] variable y is the temperature of the liquid, and the manipulated variable u is the flow of the fuel gas. The "disturbance" is any factor, other than the manipulated variable, that influences the process variable. assumes that only one disturbance is added to the manipulated variable. In some applications, however, a major disturbance enters the process in a different way, or plural disturbances need to be considered. The error e is defined by e = r – y. The compensator C(s) is the computational rule that determines the manipulated variable u based on its input data, which is the error e in the case of The last thing to notice about is that the process variable y is assumed to be measured by the detector, which is not shown explicitly here, with sufficient accuracy instantaneously that the input to the controller can be regarded as being exactly equal to y. Early PID control systems had exactly the structure of conventional feedback control systems, When used in this way, the three elements of the PID controller produce outputs with the following nature:

P element : proportional to the error at the instant t, which is the "present" error.

I element : proportional to the integral of the error up to the instant t, which can be interpreted as the accumulation of the "past" error.

D element : proportional to the derivative of the error at the instant t, which can be interpreted as the prediction of the "future" error.

Thus, the PID controller can be understood as a controller that takes the present, the past, and the future of the error into consideration. After digital implementation was introduced, a certain change of the structure of the control system was proposed and has been adopted in many applications. But that change does not influence the essential part of the analysis and design of PID controllers. So we will proceed based on the structure of conventional feed back control system up to tuning of the PID controller, where the new structure is introduced.

The following section examines PID controller theory and provides further explanation of the question 'how do PID controller work'.

Proportional Response (Gain) :

The proportional component depends only on the difference between the set point and the process variable. This difference is reffered to as the Error term. The error is multiplied by a negative (for reverse action) proporti onal constant p, and added to the current output. P represents the band over which a controller output is proportional to the error of the system. The proportional gain(K) determine the ratio of output response to the error signal. For instance, if the error term has a magnitude of 10, a proportional gain of 5 would be produce a proportional response of 50. In general, increasing the proportional gain will increase the speed of the control system response. However, if the proportional gain is too large, the process variable will begin to oscillate. If k is increased further, the oscillations will become larger and the system will become unstable and may even oscillate out of control.

Proportional only control can provide a stable process temperature but there will always be an error between the required setpoint and the actual process temperature.

Integral Response:

The integral component sums the error term over time. The result is that even a small error term will cause the integral component to increase slowly. The integral response will continually increase over time unless the error is zero, so the effect is to drive the Steady-State error to zero. Steady-State error is the final difference between the process variable and set point. A phenomenon called integral windup results when integral action saturates a controller without the controller driving the error signal towards zero.

Derivative Response:

The derivative component causes the output to decrease if the process variable is increasing rapidly. The derivative response is proportional to the rate of change of the process variable. Increasing the derivative time (Td) parameter will cause the control system to react more strongly to changes in the error term and will increase the speed of the overall control system response. Most practical control systems use very small derivative time (Td), because the Derivative Response is highly sensitive to noise in the process variable signal. If the sensor feedback signal is noisy or if the control loop rate is too slow, the derivative response can make the control system unstable [5].

Tuning:

The process of setting the optimal gains for P, I and D to get an ideal response from a control system is called tuning. There are different methods of tuning of which the "guess and check" method and Ziegler Nichlols method will be discussed [3-5].

The gains of a PID controller can be obtained by trial and error method. Once an engineer understands the significance of each gain parameter, this method becomes relatively easy. In this method, the I and D terms are set to zero first and the proportional gain is increased until the output of the loop oscillates. As one increases the proportional gain, the system becomes faster, but care must be taken not make the system unstable. Once P has been set to obtain a desired fast response, the integral term is increased to stop the oscillations. The integral term reduces the steady state error, but increases overshoot. Some amount of overshoot is always necessary for a fast system so that it could respond to changes immediately. The integral term is tweaked to achieve a minimal steady state error. Once the P and I have been set to get the desired fast control system with minimal steady state error, the derivative

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term is increased until the loop is acceptably quick to its set point. Increasing derivative term decreases overshoot and yields higher gain with stability but would cause the system to be highly sensitive to noise. The Ziegler-Nichols method is another popular method of tuning a PID controller. It is very similar to the trial and error method wherein I and D are set to zero and P is increased until the loop starts to oscillate. Once oscillation starts, the critical gain Kc and the period of oscillations Pc are noted.

- Control P Ti Td
- P 0.5Kc - -
- PI 0.45Kc Pc/1.2 –
- PID 0.60Kc 0.5Pc Pc/8

FUZZY LOGIC:

Logic started as the study of language in arguments and persuasion, and it may be used to judge the correctness of a chain of reasoning, in a mathematical proof for example. In two valued logic proposition either true or false but not both the true or false which is assigned to a statement is its truth value. In fuzzy logic a proposition may be true or false or have an intermediate truth value, such as may be true .The sentences is high is an example of such proposition in fuzzy controller [2]

CONNECTIVITES:

In daily conversation and mathematics, sentences are connected with the words and, or , if –then, if and only if .These are all connectives. The sentence which is modified by word not is called negation of the original sentence .The word and is used to join sentences called conjunction of two sentences. Similarly a sentence formed by connecting two sentences with the word ''or'' is called the disjunction of the two sentences. From two sentences we may construct one of the form ''If ... then...''; this is called a conditional sentence. The sentence following ''If '' is the antecedent and the sentence following ''then'' is the consequent.

METHODOLOGY AND WORKING

PID Controller with fuzzy algorithm:

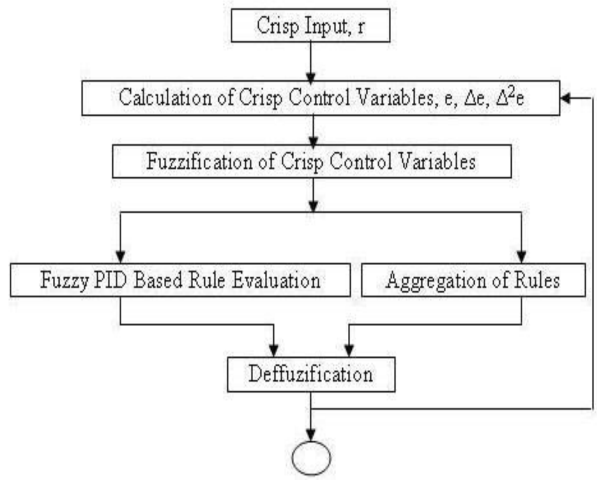

Fig.3: shows the flow chart of PID-type fuzzy controller algorithm for implementing PID-type FLC hardware design.

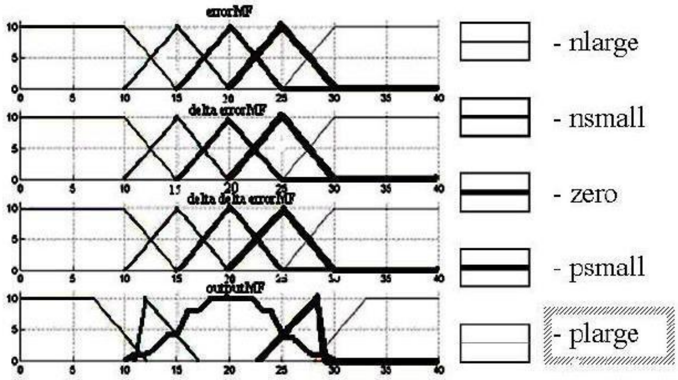

Fig.4: Inputs and output membership function of PID-type Fuzzy Controller

The three inputs of the Fuzzy PID controller are calculated for the following variable stages:

1. Error input = crisp input
2. Delta error input = current error - previous error
3. Delta^2 error input = current delta error - previous delta error

MODELLING OF PID CONTROLLER

The behavior of PID-type Fuzzy controller algorithmic program for planning a hardware system has developed victimization VHDL language. The developed code in VHDL is employed to perform four Mamdani Fuzzy interface processes also. during this step, there are six modules of inflammatory disease controller

i. Fuzzification: degree_truth.vhd, and cutMF.vhd
ii. Rule Evaluation: rule_base.vhd, and rule_degree.vhd
iii. Aggregation rules and Defuzzification: COG.vhd, and
iv. One variable calculation: var_cal.vhd) block are allotted for implementing hardware style.

The higher than six modules are combined along into the controller unit (controller.vhd) to perform the four Mamdani Fuzzy abstract thought processes. The var_cal.vhd module is employed to calculate the 3 crisps inputs of the inflammatory disease sort Fuzzy Controller System. The Current_delta_error is up to the distinction between the input and old_error pins whereas the Current_delta2_error is equal to the difference between the old_error and also the old_delta_error. Next, this module are going to be feedback the Next_old_error and Next_delta_old_error output to Old_error and Old_delta_error at the input severally for the variable calculation operation.

The Fuzzification steps have computed with 3 crisp inputs victimisation the degree_truth.vhd and cutMF.vhd module to perform the Fuzzification task. The degree_truth.vhd module is set the input membership operate supported crisp input. On the opposite hand, cutMF.vhd module determines the input membership operate that involves resembling every of the degree of truth.

Application:
The targeted application of the Fuzzy primarily based inflammatory disease controller during this work is that the transportation cruising system. The cruising system that developed is to avoid the collision between vehicles on the road. The system sense the space of the preceding vehicle and cut back the speed once it get too shut or alert the motive force when necessary. Besides, it conjointly limits the acceleration of the vehicle reckoning on the space of the preceding vehicle. this technique is being developed by Mercedes Benz and is put in in its printing operation of S-Class. However, the technology developed is pricey because the microwave radar system and image process is concerned. Therefore, solely the posh cars will fancy such accent. The Fuzzy primarily based inflammatory disease cruising controller that developed during this work is cheaper and may be applied to the entry level vehicles like the national automobile. this may additional cut back the road accident and make sure the safety of the road user within the future. The output of the PID-type Fuzzy Controller provides a reference for a automobile to either increase or decrease the speed of the vehicle. Example: If the set-point is twenty unit of distance, then the automobile are going to be weigh down if the space of the preceding vehicle is below twenty units of distance. If the space is higher than twenty unit of distance, then the vehicle is allowed to accelerate. However, the speed of acceleration and swiftness is reckoning on the space of the vehicle. the speed of swiftness and allowed acceleration is depends on the space of the vehicles. once the 2 vehicles is just too with reference to one another, that is below ten units of distance, the controller can offer medium force in decelerating the vehicle and at the identical time, alert and warn the motive force to use the brakes for imperative braking. this can be to make sure the protection of the travellers rather than giving onerous stop to the vehicle which can injure the passenger because of the unexpected momentum.

Synthesis:
Synthesis is that the method of reworking one illustration within the style abstraction hierarchy to a different representation. Synthesis method has performed exploitation synthesis tools (Quartus II) for synthesizing the compiled VHDL style codes into gate level schematics. It ab initio processes the VHDL building blocks to Register Transfer Level (RTL) block for all six hardware modules of inflammatory disease controller system. The elements of modules are like multiplier factor, registers, gates and flipflops etc. whereas synthesizing the look, high-density lipoprotein library browser was wont to synthesize the look in a very class-conscious manner. during this paper, we've conferred one amongst the RTL blocks among of six modules.Next, the Technology mapping step has been

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performed exploitation Altera's APEX20KE (EP20K200EFC484-2X) package to urge the technology read of the assorted modules of PID-type Fuzzy Controller chip.

RESULTS

The targeted application of the Fuzzy based PID controller in this work is the transportation cruising system. The cruising system that developed is to avoid the collision between vehicles on the road. The system sense the distance of the preceding vehicle and reduce the speed when it get too close or alert the driver when necessary. Besides, it also limits the acceleration of the vehicle depending on the distance of the preceding vehicle.

This system is being developed by Mercedes Benz and is installed in its new line of S-Class. However, the technology developed is expensive as the radar system and image processing is involved. Therefore, only the luxury cars can enjoy such accessory. The Fuzzy based PID cruising controller that developed in this work is cheaper and can be applied to the entry level vehicles such as the national car. This can further reduce the road accident and ensure the safety of the road user in the future.

The output of the PID-type Fuzzy Controller provides a reference for a car to either increase or decrease the speed of the vehicle. For example, if the set-point is 20 unit of distance, then the car will be slow down if the distance of the preceding vehicle is below 20 units of distance. If the distance is above 20 unit of distance, then the vehicle is allowed to accelerate. However, the rate of acceleration and deceleration is depending on the distance of the vehicle. By referring in Fig.8, the rate of deceleration and allowed acceleration is depends on the distance of the vehicles. When the two vehicles is too near to each other, which is below 10 units of distance, the controller will give medium force in decelerating the vehicle and at the same time, alert and warn the driver to apply the brakes for urgent braking. This is to ensure the safety of the passengers instead of giving hard stop to the vehicle which may injure the passenger due to the sudden momentum.

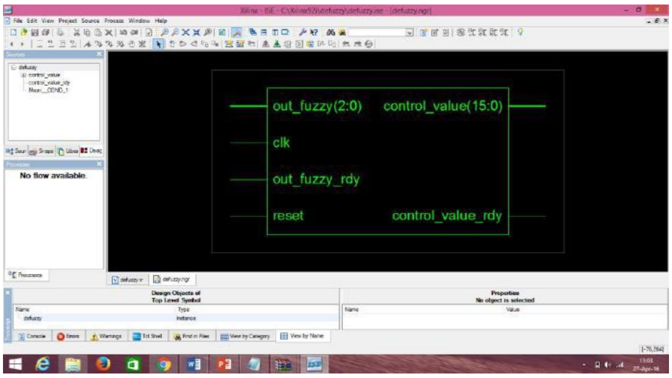

Fig.5: RTL for defuzzy

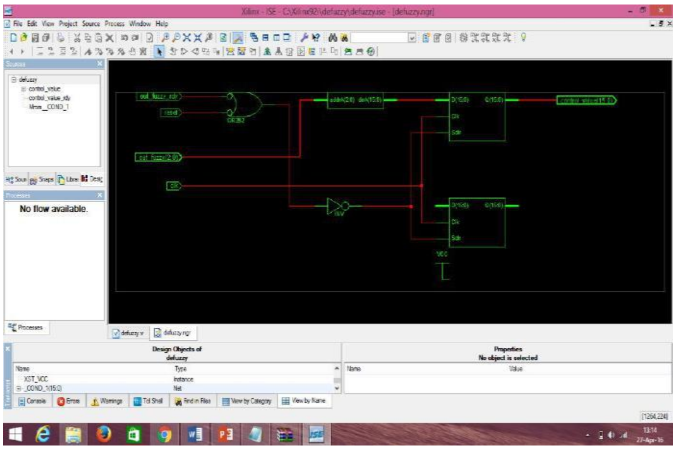

Fig.6: RTL internal circuit for defuzzy

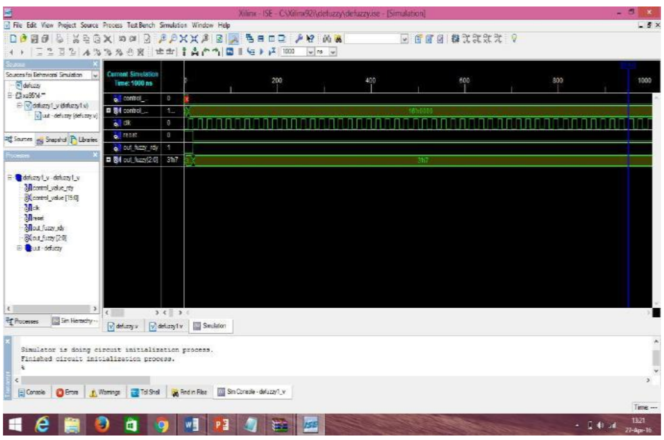

Fig.7: Simulation for defuzzy

CONCLUSION

The PID sort fuzzy controller rule has delineate 1st mistreatment MATLAB platform. The delineate PID

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controller conjointly has developed with all fuzzy rules for coming up with the hardware PID chip mistreatment VHDL. Then, the synthesize tool has accustomed get the logic gates of hardware PID modules. The designed PID chip is accustomed the targeted application. As associate example, transportation cruising system. The cruising system supported PID chip is avoided the collision between vehicles on the road.

The controller rule are additional optimized by rising the membership perform, the rule base, and therefore the standardisation methodology. It ought to be done to get higher management over its application as a result of there are several constraints those must be thought of within the world and to make sure the security of the road user in the future.

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