

ANALYSIS OF AN EFFICIENT FUZZY BASED VLSI ARCHITECTURE FOR TRANSPORTATION APPLICATIONS

Submitted in partial fulfilment of requirements for the award of
Bachelor of Engineering in
Electronics and Communication Engineering

by

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**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAAC
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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of B. Geetha Lakshmi (39130063) and B. Tulasi (39130060) who carried out the project entitled "**ANALYSIS OF AN EFFICIENT FUZZY BASED VLSI ARCHITECTURE FOR TRANSPORTATION APPLICATIONS**" under our supervision from November 2022 to April 2023.

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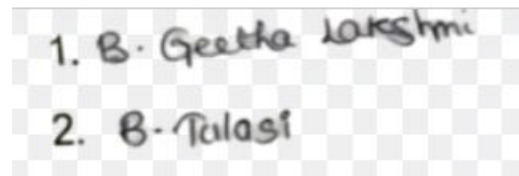
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DECLARATION

We, B. Geetha Lakshmi (39130063) and B. Tulasi (39130060) hereby declare that the Project Report entitled “**ANALYSIS OF AN EFFICIENT FUZZY BASED VLSI ARCHITECTURE FOR TRANSPORTATION APPLICATIONS**” done by us under the guidance Dr.G.D. ANBARASI JEBASELVI., M.E., Ph.D., Associate Professor is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.



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ABSTRACT

PID-type (Propagation-Integral-Derivative) controller based on a Fuzzy algorithm using VHDL to use in transportation cruising system was described. The cruising system with a Fuzzy concept has been developed to avoid 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 it alerts 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 behavior of the PID-type FLC algorithm is then simulated using VHDL language. The comparison of simulation results between MATLAB and VHDL is presented for designing the PID-type hardware implementation. The synthesis tool from the Quartus-II environment is chosen to synthesize the designed VHDL codes for obtaining the Register Transfer Level (RTL) hardware architecture of the PID modules. The developed and designed Fuzzy based PID-type cruising controller is cheaper compared to the conventional PID controller system, and, thus we can propose this developed chip to use for entry-level vehicles such as the national car. This can be further reduced road accidents and ensure the safety of road users in the future.

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LIST OF SYMBOLS AND ABBREVIATIONS

PID	PROPAGATION INTEGRAL DERIVATIVE
MATLAB	MATRIX LABORATORY
PI	PROPORTIONAL INTEGRAL
PD	PROPORTIONAL DERIVATIVE
FLC	FUZZY LOGIC CONTROLLER
PLC	PROGRAMMABLE LOGIC CONTROLLER
FCM	FUZZY COGNITIVE MAP

CHAPTER 1

INTRODUCTION

1.1 . INTRODUCTION

PID controller is the best known as industrial process controller. It is robust in wide range of performance. However, conventional PID controller is not suitable for non-linear 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 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 are defined as error (e), change in error (also known as Derivative), and the rate of change of error (also known as acceleration error). Besides it, there is no proper way of tuning method available until now. Trial-and-error tuning method is required in optimizing the controller. Furthermore, the number of rule base increase exponentially with the increase of membership function. If the number of inputs is m , and the number of membership function for each input is n , then the total number of the IF-Else rules is equal to mn .

It has been reported that as a result of land transportation, around 40,000 fatalities have been reported every year in the USA. In 2006, 3,490 drivers under

the age of 20 years old had lost their lives in the USA alone. Statistics also indicate that, in 2008, over 31,000 people are killed in car accidents in reported developing countries. One of the main reasons for the accidents and fatalities is known to be due to the human mistakes and driver judgment errors. Other reasons lay on the vehicle and road conditions as well as behavior or other vehicles in the vicinity. The result of high number of fatalities is pressuring authorities and researchers to come up with some solutions to minimize driver mistakes and reduce the number of accidents on the roads. In last decade, several new technologies have been successfully introduced to aid drivers for safety purposes, some of these are: - Advanced Driver Assistance Systems can reduce the number of accidents caused by the drivers. It is based on the attention of the driver being kept alert. It also assists the drivers to take correct action when necessary and to eliminate wrong decision making. ADAS can be implemented in four categories, these being: the warning systems that observes car position on the track between the lanes, the pedestrian protector, the adaptive cruise control, which maintains a safe distance from other vehicles by making use of the information on the speeds and positions of the vehicles, and the traffic sign perception that recognizes the information from the traffic lights so that information can be used for safe stopping and starting at the traffic lights. In this study, the Mercedes model has been considered to sense vehicles and nearby objects while vehicle is in motion. However, the model has been extended to for sensors using two types of radars: 1) short-range 24 gigahertz radar 80-degree with 30 meters of range, and 2) long-range 77 gigahertz radar 9-degree with 145 meters of distance measuring capability.

On the other hand, detection of the vehicles on the rear and sides of a vehicle is very significant to improve the safety. In an ordinary vehicle, a driver uses a mirror to observe the right, left hand sides. In this project, the distance among the vehicle will be sensed in four sides by using radar sensor arrays. They will be used for the right and the left-hand sides and the rear. These radars will be short range, 24 gigahertz, and 110-degrees with 6 meters. The detection range will overlap by 0.5 meter with the front and rear radars. Short- range 24 gigahertz 180- degree with 4 meters of range will be used to cover the rear of the vehicle. On the other hand, car Active Safety System is an in-vehicle system that provides warnings or other forms of assistance to drivers based on in-vehicle sensors such as the radar, LIDAR, and

other sensors. On board the vehicle sensors provide information about the position and the motion of other vehicles within a defined the range. It has been suggested in that the application of this class can reduce car accidents by almost 75%. In driving situation, the most significant information comes from the front of the vehicle. Assuming that a vehicle with a rectangular shape is equipped with appropriate sensors, the information can be used to remain within lanes, to adjust the speed, and to detect any other objects and obstacles in front of the vehicle. Equally, detecting the objects and obstacles at the rear of the vehicle is also important for safety reasons particularly if there is another vehicle approaching dangerously, as well as during turning, overtaking, and parking. Objects at the right and left side of the vehicle should also be detected to avoid side collisions and safe parking. In this study, the application of fuzzy logic set to control individual vehicle have been investigated. This approach is based on the suitable and timely detection of obstacles in the vicinity and to assist decisions making for drivers.

1.2. PID CONTROLLER WITH FUZZY ALGORITHM

The Fig. 1 shows the flow chart of PID-type fuzzy controller algorithm for implementing PID-type FLC hardware design. The crisp inputs of the PID fuzzy controller have computed in MATLAB platform.

In this simulation stage the membership function of the controller is shifted 20 steps to the positive side and the setpoint is 20 (actual setpoint = 0). Therefore, the crisp input is shifted 20 steps towards the positive side as well. As an example of the input of -6, the input read by the controller is $(-6 + 20) = 14$. It shows the Input 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. Delta2 error input = current delta error - previous delta error

The mathematical models describing the driving a vehicle can be highly complex and nonlinear. In one study, a combination of six inputs and 3 outputs had

been considered, which has been adapted in this study. To simplify the model, fuzzy logic theory has been proposed for several reasons such as: - a) Fuzzy logic has been tested to deal with this kind of systems and to provide meaningful and easy to understand results, b) it can incorporate human knowledge, experience, and behavior into control algorithms, and c) it can allow the system imitate the human driving behavior.

By using fuzzy logic toolbox of MATLAB, a program was created to examine vehicle control model. It is assumed that the vehicle requires controlling due to presence of other vehicles, objects, or obstacles at time t within the incremental time, Δt , the controlling system performs its functions in by having five fuzzy rules: -

- 1) Is the road condition safe? If safe continue, if not slowdown.
- 2) Is the front distance safe? If yes continue, if not slowdown or stop.
- 3) Are the left and right distances safe? If both are safe then continue; if both are not safe then slowdown or stop; if left side safe and right side not slowdown and go left; otherwise go to right.
- 4) Is the speed safe? There are three situations:
 - a) if the speed is slower than flow of the traffic then increases the speed,
 - b) if the speed is faster than the flow traffic then decreases the speed, and
 - c) if the speed matches road limit, then continues with the same speed.
- 5) Rear distance is also affected by the speed. There are three satiations:
 - a) if the speed is slow and rear distance is safe then continue and if not safe then increase the speed,
 - b) if the speed is fast and rear distance is safe then decrease the speed and if not safe then continue, and
 - c) if the speed matches road limit and rear distance is safe then continue and if not safe then increase the speed.

1.3. MODELING OF PID CONTROLLER USING VHDL

The behavior of PID-type Fuzzy controller algorithm for designing a hardware system has developed using VHDL language. The developed code in VHDL is used to perform four Mamdani Fuzzy interface processes as well. In this step, there are six modules of PID 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 have been carried out for implementing hardware design. The above six modules are combined into the controller unit (controller.vhd) to perform the four Mamdani Fuzzy Inference processes. The var_cal.vhmodule is used to calculate the three crisps' inputs of the PID-type Fuzzy Controller System.

The Current_delta_error is equal to the difference between the input and old error pins whereas the Current_delta2_error is equal to the difference between the old_error and the old_delta_error. Next, this module will be feedbacking the Next_old_error and Next_delta_old_error output to old error and Old_delta_error at the input respectively for the variable calculation operation.

The Fuzzification steps have computed with three crisp inputs using the degree_truth.vhd and cutMF.vhd module to perform the fuzzification task. The degree_truth.vhd module is determined the input membership function based on crisp input. On the other hand, cutMF.vhd module determines the input membership function that involves corresponding to each of the degree of truth.

The rule_based.vhd module is used to determine the output membership function on its input membership function from cutMF.vhd module. Since the total number of rules involve is equal to $2^3=8$, therefore eight rule_based.vhd modules are needed to perform each of the rule base operation. Besides, the degree of truth of the input membership function found by degree_truth.vhd module is "anded" together to obtain the minimum value of output membership function.

The three inputs of input_c, old_error, and old delta are considered the inputs of the PID-type Fuzzy controller system as same as the PID controller inputs of error (e), delta error error_{2e} respectively. The output_c is the output of the controller that represents the new error after the Fuzzy Inference processes. Nex_error and

nex_delta is the current error and delta error value, which will be fed back to old error and old delta error respectively for the next controller operation. The Num_c and den_c is for monitor purposes only, which allows the output of Aggregation of Rules of each cycle for calculating manually. Besides it, the output_c is plotted to obtain the graphical view of the operation of the PID controller system.

1.4. DESIGN OF A CONTINUOUS PID CONTROLLER

The controllers that are used to control processes can have several structures. The choice of the structure determines how well the plant can be controlled. The plant poses some guidelines and restrictions on the controller. The choice of a controller determines the best possible performance that is achieved by a well-tuned controller

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A PID controller structure is selected to control the plant, as PID controller is used extensively in industry as an all-in-all controller, mostly because it is an intuitive control algorithm. Unity Pro software for Schneider Electric programmable logical controllers has the function block, which replicates a PID controller with a transfer function.

Controller's output is determined through the discrete PID closed loop algorithm. The sampling time depends on the PLC program cycle, which varies from Ms to ms and that is why the discrete-time controller approximates a continuous controller and is tuned as if it was a continuous controller.

A computer with Unity Pro software was connected to the PLC1 through the Ethernet, to supervise program states and to draw needed graphics. System response to the unit step input has been researched. The parameters of the discrete-time PID controller are calculated, using the parameters of the PID controller, designed in MATLAB environment. Communications between the PLCs were carried out using the deterministic Modbus Plus network.

The parameters of the discrete-time PID controller are calculated, using the parameters of the PID controller, designed in Unity Pro environment. Communications between the PLCs were carried out using the deterministic Modbus Plus network.

1.5. FUZZY SUPERVISED PID CONTROLLER

PID controller primarily comprises of three parameters which influence the controller action, these parameters are namely proportional gain, derivative gain and integral gain. The proportional gain block generates a control signal in proportion to the error, derivative gain block generates control action depending upon rate of change of error and integral block generates an action depending upon summation of past errors. While in operation these parameters are being adjusted by a Fuzzy supervisor. The Fuzzy supervisor emulates an experienced human operator. This is done by the means of linguistic rules, membership functions, fuzzification methods, defuzzification methods, an inference engine and scaling factors, the fuzzy block comprise of all of this [3,6,8]. Any changes taking place in the parameters of the system, the controller adapts itself to these changes through the directions of fuzzy supervisor and try to maintain the performance of the system.

The fuzzy supervisor itself comprise of a number of parameters that needs to be adjusted. Doing this manually will be quite time consuming and may require great deal of effort also. So, to save this time and effort we can make use of an algorithm which can optimally adjust these parameters. Here we have made use of Ant Colony Algorithm.

The Ant Colony algorithm is based on the food gathering behavior of ants. The ACO is an algorithm implementation that adapts the behavior of real ants to solutions of minimum cost path problems on graph. Real ants can find the shortest path from a food source to their nest, without using visual cues by exploiting pheromone (A chemical to which ants highly respond and follow its trail depending on its intensity) information. While walking, ants deposit pheromone on the ground, and follow when Ant encounters several trails of pheromone it will have greater probability of following that trail which has higher depositing of pheromone.

This algorithm has been implemented for optimizing the scaling factors of the fuzzy supervisor as it takes great deal of time and efforts in their adjustment. Rest of the parameters can be adjusted easily.

In control applications, the FCM approach is generally used for the support or design of supervisory controllers. It is very rare to use the FCM approach to design a main controller for process control applications. In, the FCM method is used as the main controller for the temperature and humidity control of a room in winter and summer operation season. The performance of the FCM controller on this system was compared with a PID controller. The results show that the FCM controller is a better choice for this system. In, a dynamic fuzzy cognitive map method is used to control an industrial mixer. The performance of the FCM controller is compared with the performance of a fuzzy logic controller, and similar performance results are obtained. In, the main controller based on the FCM structure is designed for control of a heatex process. FCM based controllers are designed for the path tracking application of an unmanned air vehicle in. In, three different FCM based controller models are proposed in the PI controller form, and their effective performances are shown by performing simulation studies on a nonlinear system.

In this study, a new nonlinear PID controller structure is proposed by using the FCM approach. Two different FCM based PID (FCM-PID) controller models, FCM-PID-Model-1 and FCM-PID-Model-2, are introduced and their performances are evaluated. The conventional parallel PID structure with three inputs (the error, the derivative of the error, and the integral of the error) and conventional fuzzy PID controller structure with two inputs (the error and the derivative of the error) are used for the proposed FCM PID-Model-1 and FCM-PID-Model-2, respectively. In this way, control performances can easily be improved in control applications by replacing existing PID controllers with its proposed counterpart model. Additionally, conventional PID tuning methods can be applicable to a certain degree for the proposed controllers. In the proposed FCM-PID models, each input signal is fuzzified by using a membership function. Then, causal relationships are specified by using weight parameters. Finally, the FCM inference is performed by using an activation function. Thus, the proposed FCM-PID-Model-1 and FCM-PID-Model-2

have four and six tuning parameters in total, respectively. To show the effectiveness of the proposed FCM-PID controller models, simulation studies are done on a fourth order linear system. A conventional PID and a fuzzy PID controller are used for the performance comparison. The parameters of the controllers are tuned by using a genetic algorithm. The performance criteria in the comparisons are chosen as settling time, integral absolute error (IAE), integral square error (ISE), integral time absolute error (ITAE), and integral time square error (ITSE). The results show that the performances of the proposed controllers are better than the performances of the fuzzy PID controller and the conventional PID controller.

The control performance for such systems can be improved by using nonlinear PID control structures. One way to design a nonlinear PID controller is to use soft computing methods such as the fuzzy logic approach. Soft computing methods are frequently used in the modeling and control applications of high order and/or nonlinear systems.

1.6. DESIGN OF FUZZY LOGIC CONTROLLER

The design of fuzzy logic controller described in 3 steps.

- Fuzzification
- Rule Base
- Defuzzification

In the fuzzification step the error and change in error signals are normalized to values which lie in between -1 to 1. Then the normalized inputs and outputs are described by different membership functions. The membership functions for the

inputs and outputs are given in figure below. The triangular and trapezoidal membership functions make the calculations easier and controller to be simple.

The defuzzification method is adopted in this work is of centroid type.

The PID type FLC is a combination of both PD and PI type FLC. The complete structure of PID type FLC is given in the figure below. The output of a PID type FLC is the sum of both the PD and PI output. The output side has two scaling factors 'K0PI' and 'K0PD' for PI and PD type FLC respectively.

First, $e(k)$ and $Ae(k)$ are normalized into the range $[-128, 128]$ for convenience. Then we transform the absolute value of $e(k)$, $Ae(k)$ to their logarithms. So, the fuzzy rule is also applicable when the closed-loop error or its change rate is small. In this paper, we fuzzy $e(k)$, $Ae(k)$ into two fuzzy variables E and R , both of which include the following fuzzy sets $\{NB, NM, NS, ZO, PS, PM, PB\}$ where N represents negative, P positive, ZO zero, B big, M medium, S small.

In fuzzification, we input designed $e(k)$, $Ae(k)$ (8bits) to produce the membership function of the fuzzy sets. In the stage, there are 7 resulting fuzzy sets $\{NB, NM, NS, ZO, PS, PM, PB\}$. So we code the fuzzy set into 3-bits Fuzzy Set Code. In hardware function division, we must make a compromise between the precision of the algorithm and the system scale. We modify the algorithm: the continuous membership function is quantized to only four values 0, 1/3, 2/3, 1. The simulation result confirms that this digitization does not affect the control performance. As we use the membership functions, there are two fuzzy sets for each crisp value of $e(k)$ or $Ae(k)$, whose membership is 1/3 or 2/3. So for FPGC, the task of fuzzification is transformed from the producing of the membership to the producing of the Fuzzy Set Code corresponding to these two memberships. We use 128×3 ROM to store the fuzzy set code for each crisp value of $e(k)$ or $Ae(k)$. In design, we input $e(k)$ or $Ae(k)$ (8 bits) as the address of ROM and obtain the Fuzzy Set Code as the output.

By using the membership functions and using the product to determine the truth value of the i th rule, we have $C_p = I$. Then as we use the center of gravity method for the defuzzification. The defuzzification output is the summation of the product of the conclusion of each fuzzy rule and its truth value. Because the denominator of the conclusion of the fuzzy rule is 7 and the truth value of the rule can only take values of 0, 1/3, 2/3, 1, we only need to shift-left the output of the four rule memory 2 bit, 1 bit, 0 bit, 0 bit corresponding to $\times 4$, $\times 2$, $\times 2$, $\times 1$, produce their sum, and then divide the sum by 63. Division by 63 can be approximated by right-shift 6 bits.

In fuzzy inference, we adopt the Rule-Driven form whose core is to obtain the conclusion and the truth value for each fuzzy rule. We can use ROM to store the fuzzy rule. The input of ROM is the Fuzzy Rule Code and the output is the conclusion.

The truth value of the fuzzy rule is obtained as the production of the membership of the antecedents ($e(k)$ or $Ae(k)$).

In each inference, four fuzzy rules are effective which is called Effective Rules. In this paper, the truth values of these Effective Rules are fixed to $4/9, 2/9, 2/9, 1/9$. Then the task of fuzzy inference is transformed from the obtaining of the conclusion and the truth value for each fuzzy rule to the producing of the Fuzzy Rule Code for the four Effective Rules. The Fuzzy Set Code obtained in the fuzzification is combined to produce the Fuzzy Rule Code.

The fuzzy model has been modified to competition function model. This model is based on the safety by using adapting following distance theory. In this model, competition function is the main criteria in the system. It has been reported that as a result of land transportation, around 40,000 fatalities have been reported every year in the USA. In 2006, 3,490 drivers under the age of 20 years old had lost their lives in the USA alone. Statistics also indicate that, in 2008, over 31,000 people are killed in car accidents in reported developing countries. One of the main reasons for the accidents and fatalities is known to be due to the human mistakes and driver judgment errors. Other reasons lay on the vehicle and road conditions as well as behavior or other vehicles in the vicinity.

The result of high number of fatalities is pressuring authorities and researchers to come up with some solutions to minimize driver mistakes and reduce the number of accidents on the roads. In last decade, a number of new technologies have been successfully introduced to aid drivers for safety purposes, some of these are: -

Advanced Driver Assistance Systems (ADAS) can reduce the number of accidents caused by the drivers. It is based on the attention of the driver being kept alert. It also assists the drivers to take correct action when necessary and to eliminate wrong decision making. ADAS can be implemented in four categories, these being: the warning systems that observes car position on the track between the lanes, the pedestrian protector, the adaptive cruise control (ACC), which maintains a safe distance from other vehicles by making use of the information on the speeds and positions of the vehicles, and the traffic sign perception that

recognizes the information from the traffic lights so that information can be used for safe stopping and starting at the traffic lights.

In this study, the Mercedes model has been considered to sense vehicles and nearby objects while vehicle is in motion. However, the model has been extended to for sensors using two types of radars: 1) short-range 24 gigahertz radar 80-degree with 30 meters of range, and 2) long-range 77 gigahertz radar 9-degree with 145 meters of distance measuring capability. On the other hand, detection of the vehicles on the rear and sides of a vehicle is very significant to improve the safety. In an ordinary vehicle, a driver uses a mirror to observe the right, left hand sides. In this project, the distance among the vehicle will be sensed in four sides by using radar sensor arrays. They will be used for the right and the left-hand sides and the rear. These radars will be short range, 24 gigahertz, and 110-degrees with 6 meters. The detection range will overlap by 0.5 meter with the front and rear radars. Short- range 24 gigahertz 180- degree with 4 meters of range will be used to cover the rear of the vehicle.

On the other hand, Car Active Safety System (CASS) is an in-vehicle system that provides warnings or other forms of assistance to drivers based on in-vehicle sensors such as the radar, LIDAR, and other sensors. On board the vehicle sensors provide information about the position and the motion of other vehicles within a defined the range. It has been suggested in that the application of this class can reduce car accidents by almost 75%.

In driving situation, the most significant information comes from the front of the vehicle. Assuming that a vehicle with a rectangular shape is equipped with appropriate sensors, the information can be used to remain within lanes, to adjust the speed, and to detect any other objects and obstacles in front of the vehicle. Equally, detecting the objects and obstacles at the rear of the vehicle is also important for safety reasons particularly if there is another vehicle approaching dangerously, as well as during turning, overtaking, and parking. Objects at the right and left side of the vehicle should also be detected to avoid side collisions and safe parking.

In this project, the application of fuzzy logic set to control individual vehicle have been investigated. This approach is based on the suitable and timely detection of obstacles in the vicinity and to assist decisions making for drivers.

PID controllers are widely used in industrial applications and provide an effective control performance for the systems having dominant linear characteristics. However, performances of linear PID controllers reduce as the nonlinear characteristics and the order of dynamical systems increase. The control performance for such systems can be improved by using nonlinear PID control structures. One way to design a nonlinear PID controller is to use soft computing methods such as the fuzzy logic approach. Soft computing methods are frequently used in the modeling and control applications of high order and/or nonlinear systems.

The fuzzy cognitive map (FCM) method, which is one of the soft computing methods, was first proposed by Kosko in 1986. Then it has gained popularity and is used in many fields such as economy, health, security, engineering, business, and management. The fuzzy cognitive map method is effectively used in engineering applications since it provides a way to express complex systems by using existing knowledge and human experience. In control applications, the FCM approach is generally used for the support or design of supervisory controllers. It is very rare to use the FCM approach to design a main controller for process control applications. In, the FCM method is used as the main controller for the temperature and humidity control of a room in winter and summer operation season. The performance of the FCM controller on this system was compared with a PID controller. The results show that the FCM controller is a better choice for this system. In, a dynamic fuzzy cognitive map method is used to control an industrial mixer. The performance of the FCM controller is compared with the performance of a fuzzy logic controller, and similar performance results are obtained. In, the main controller based on the FCM structure is designed for control of a heatex process. FCM based controllers are designed for the path tracking application of an unmanned air vehicle in. In, three different FCM based controller models are proposed in the PI controller form, and their effective performances are shown by performing simulation studies on a nonlinear system. In this study, a new nonlinear PID controller structure is proposed

by using the FCM approach. Two different FCM based PID (FCM-PID) controller models, FCM-PID-Model-1 and FCM-PID-Model-2, are introduced and their performances are evaluated. The conventional parallel PID structure with three inputs (the error, the derivative of the error, and the integral of the error) and conventional fuzzy PID controller structure with two inputs (the error and the derivative of the error) are used for the proposed FCM-PID-Model-1 and FCM-PID-Model-2, respectively. In this way, control performances can easily be improved in control applications by replacing existing PID controllers with its proposed counterpart model. Additionally, conventional PID tuning methods can be applicable to a certain degree for the proposed controllers. In the proposed FCM-PID models, each input signal is fuzzified by using a membership function.

Then, causal relationships are specified by using weight parameters. Finally, the FCM inference is performed by using an activation function. Thus, the proposed FCM-PID-Model-1 and FCM-PID-Model-2 have four and six tuning parameters in total, respectively. To show the effectiveness of the proposed FCM-PID controller models, simulation studies are done on a fourth order linear system. A conventional PID and a fuzzy PID controller are used for the performance comparison. The parameters of the controllers are tuned by using a genetic algorithm. The performance criteria in the comparisons are chosen as settling time, integral absolute error (IAE), integral square error (ISE), integral time absolute error (ITAE), and integral time square error (ITSE). The results show that the performances of the proposed controllers are better than the performances of the fuzzy PID controller and the conventional PID controller. The organization of the study is as follows. In Section 2, the proposed controller models are given. In Section 3, simulation studies are presented. Finally, in Section 4, the results and future studies are provided. 2. Proposed FCM-PID Controller Model.

CHAPTER 2

LITERATURE SURVEY

This literature survey discusses about the designing and implementation of fuzzy based pid controller using VLSI.

2.1 LITERATURE SURVEY

Md.AI-Amin and Md. Saiful Islam et.al., (2021) describes the temperature control system plays an essential role to increase the percentage of industrial products. Its energy efficiency is the reason behind its popularity. Intelligent temperature control processes are used for heating purposes in industrial equipment as its disqualified materials when it is not well performed physically. To keep track of this process, fuzzy logic controller and proportional integral derivative are the most effective approaches. In this paper, the authors are proposing a Fuzzy Logic Control system-based new model for controlling the temperature of a furnace system. Authors utilize FLC instead of proportional integral derivative (PID) because of the lack of considerate temperature governance process as well as its parametric reform complication. Authors work for reducing percentage overshoot, rise time, and settling time by designing new membership function and rules declaration. This proposed model is capable of providing more accurate results with robustness performance and high stability compared with conventional PID controllers. Performance of this method was measured with the help of percentage overshoot, faster response time, settling time, steady-state error. This proposed model shows that the fuzzy self-tuning PID controller is more effective and appropriate for the industries of the furnace system.

Teng-Yi Wang, Chia-Der Chang et.al., (2018) describes the intelligent controller to improve performance of a mobile robot. We used MSI I homer robot in this experiment. By way of combination of traditional PID controller and Fuzzy Logic controller can achieve steady state in the short time. We tried to add hybrid system in the Fuzzy PID controller to further improve the performance of a mobile robot. Performance comparisons between hybrid Fuzzy PID controller and Fuzzy PID controller are provided. From simulation results it can be found that both the

overshoot and settling time are decreased to meet the requirement. In conclusion, the hybrid Fuzzy PID control method can improve dynamic response of mobile robot effectively.

Seyed Mohamad Ali Tousi, Abbas Mostafanasab et.al., (2020) describes a new particle swarm optimization (PSO)-based optimization algorithm, and the idea of a running match is introduced and employed in a non-linear system PID controller design. This algorithm aims to modify the formula of velocity calculating of the general PSO method to increase the diversity of the searching process. In this process of designing an optimal PID controller for a non-linear system, the three gains of the PID controller form a particle, which is a parameter vector and will be updated iteratively. Many of those particles then form a population. To reach the PID gains which are optimum, using modified velocity updating formula and position updating formula, the position of all particles of the population will be moved into the optimization direction. In the meanwhile, an objective function may be minimized as the performance of the controller get improved. To corroborate the controller functioning of this method, a non-linear system known as inverted pendulum will be controlled by the designed PID controller. The results confirm that the new method can show excellent performance in the non-linear PID controller design task.

S. Janarthanan, K.N.Thirukkuralkani et.al., (2014) describes the design of a controller for the conical tank system is a challenging problem, because of its non-linearity behavior. The Proportional-Integral-Derivative controllers have played a vital role in many processes oriented industrial applications, for past few decades. This paper deals with design of non-Integer order Proportional Integral Derivative or Fractional Order Proportional Integral Derivative (FOPID) controller for a level control process of single conical tank system. FOPID provides more flexibility in designing a controller than using standard Proportional Integral Derivative (PID) controllers, due to selection of five parameters instead of three. Though the tuning of FOPID is complex, it can guarantee the desired control performance and the robustness to the loop gain deviations. The comparison of various tuning methods using PID controller is simulated. FOPID controller has been designed for the same conical tank system and the performances of both the PID and FOPID controllers have been simulated and compared.

Reza Ezuan Samin, Lee Ming Jie, Mohad.Anwar Zawawi et.al., (2011) describes the implementation of PID controller using Programmable Logic Controller (PLC) in heating tank of mini automation plant. PID controller is implemented by using ladder diagram in PLC OMRON CJIM-CPU12. A temperature control unit CJ1W-TC001 is also used where the temperature control unit is a special I/O unit that receives inputs directly from thermocouple, to perform PID control. Desired temperature or set point (SP) is set by the user using the Human Machine Interface (HMI) and the controller within the PLC will try to maintain the current temperature base on the set point temperature set by the user. Temperature control is very difficult to be implemented by using ordinary control techniques; hence the purpose of this research is to implement PID controller design using programmable logic controller (PLC) in order to control the time to heat up a particular solution to a desired temperature efficiently without scarifying the stability of the system. A complete analysis using different kind of PID parameters is presented in terms of system response. Performance of the controller is examined in terms of settling time, rise time and percent overshoot. Finally, a comparative assessment of the PID controller on the system performance is presented and discussed.

Ravinder Kumar and Mahendra Kumar et.al., (2015) describes the hybrid fuzzy logic – PID tuning controller for damping low frequency oscillations using Unified Power Flow Controller (UPFC) applied on a single- machine infinite-bus (SMIB) system. The intention of the Fuzzy Logic based UPFC controller is to damp power system oscillations. UPFC controller depend upon amplitude modulation index of shunt converter (exciter) mE. So, this index has been considered. System response with Damped-UPFC controller without fuzzy logic and PID-fuzzy logic (using mamdani-type inference) based UPFC controller is compared at various conditions of power system. Relevant models have been developed and simulated in Matlab/Simulink R2013a. The hybrid PID-Fuzzy Logic based UPFC controller is designed by selecting appropriate controller parameters based on the facts of the power system performance. All studies show that the PID- fuzzy logic controller has an excellent capability in damping low frequency oscillations.

Rinki Mauryaa, Manisha Bhandarib et.al., (2016) describes this article propose a hybrid fractional order PID controller which is optimized with classical proportional integral derivative controller (PID) gives an exquisite response. Here the two tuning methods are used to evaluate the parameters of PID controller, first one is Ziegler-Nichols and other one is Astrom- Hagglund method. The parameters of FO-PID controller in use as the proportional constant, integral constant is by Ziegler- Nichols and derivative constant by Astrom-Hagglund method. In order to obtain required solutions, two non-linear equations are derived to find the fractional order of the integral term and derivative term The step response shows the benefits of above discussed hybrid fractional order PID controller when comparing with existing controller. Simulated results are carried by matlab 2012(a).

Swagat Pati, Abinash Panda, Sattapriya Mohanty et.al., (2014) describes the Conventional PID controllers have been extensively used for the control of induction motor drives in industries. But the performance of these controllers is greatly affected by parameter variation and modelling uncertainties. Also, these types of controllers have stability issues. But on the other hand, fuzzy logic based PID controllers are robust fast and accurate. In this paper the performance of a scalar V/F controlled induction motor drive is evaluated using conventional PID controller and fuzzy PID controller and the results are compared. The whole modelling and simulation work is done using Matlab/Simulink environment.

Leonas Balasevicius, Asta Kunickaite and Vytis Svajunas Janusevicius et.al., (2007) describes the discrete-time PID controller is presented for a process with delay control. The discrete-time PID controller design in programmable logic controller has been researched. Finally, the complete algorithm is tested in the programmable logic controller, and the results of this test are explained.

Jing Li, Bao-Sheng Hu et.al., (2006) Tuning the parameters of PID controller is very important in process control. This paper proposes a FPGC (Fuzzy PID Gain Conditioner) algorithm, a method based on fuzzy control, which tunes the PID controller on- line. The VLSI architecture of the algorithm is presented in this paper. It can not only realize the algorithms effectively but also improve the performance of the controller significantly. The FPGA prototype implementation based on this

VLSI structure is also given. Finally, a virtual control system is used to test the effectiveness of the design.

Sudarshan K. Valluru, Madhusudan Singh, Arnav Goel, Manpreet Kaur, Daksh Dobhal, Kumar Kartikeya, Aditya Verma and Anshul Guptha et.al., (2018) describes the three-term PID controllers are significantly used in most of the benchmarked systems as controllers. However, the benchmarked Single Input Multiple Output (SIMO) systems may require more than one PID controllers in the control loops, the way to design PID controllers is not an easy task. Although, the linear PID (L-PID) controllers are not yielded a satisfactory control result for a benchmarked system due to the presence of inherent nonlinearities. In order to improve performance, the linear PID controllers are modified by nonlinear characteristics. In this paper, the linear and nonlinear PID (NL-PID) controllers are implemented for the stabilization and control of Gantry Crane System as a test problem. The experimental results prove that the multi-loop NL-PID controllers exhibit more robustness to outer large with fast external disturbances. The L-PID and NL-PID controllers are compared to find out the best controller, which gives optimum responses and can also handle external disturbances.

B Vasu Murthy, Y V Pavan Kumar and U V Ratna Kumari et.al., (2012) describes that in the area of process control engineering, PID controller plays a very vital role, which can be used as a process controller for the general industrial processes like liquid level, temperature, pressure, flow, and etc. Most of the research papers in the area of process control deals with setting up of these PID controller gains. There were many tuning algorithms evolved starting from the famous Ziegler - Nichols in 1942. But still, it is a major challenge for setting of PID controller gains. Also, since PID controller is an off-line controller, the gains are set offline and then the controller is put in to the process loop. Hence this conventional off-line PID controller cannot cope up with the online process variations due to the non-linear disturbances/ noises. Hence PID controller is associated with poor disturbance rejection. Based on these typical challenges from the conventional tuning methods, the paper proposes an original philosophy of providing $\pm 10\%$ disturbance rejection feature to the PID controller. The novelty used in the design is automatic tuning of PID controller gains by the use of intelligent predictors like

Artificial Neural Networks (ANN). This provides the facility of online automatic tuning of PID controller gains and so, good disturbance rejection for the system. The whole system is modeled and simulated by using MATLAB/Simulink software. The results show that the system has good disturbance rejection up to $\pm 10\%$ with the proposed control strategy.

SamarthSingh, R. Mitra et.al., (2014) describes the Proportional Integral Derivative (PID) controllers are widely used controllers. Most of the process industries make use of this controller. The reason behind it is that it is known to structure give reliable operation, near optimal performance and as simple structure. However, it is crucial that PID controller must be tuned properly. By various methods PID can be tuned in an offline fashion but because of parameter variation and disturbances taking place in system need for online tuning of these controller parameters arise. This paper deals with the fuzzy supervised PID have been optimally adjusted by making use of Ant Colony algorithm. A comparison of the robustness of the two controllers i.e., optimally offline tuned PID and Fuzzy supervised PID has been done on the basis of their performance when a system is subjected to parameter variations. From the conclusion of these results, it is found that a combination of the two controllers is giving better performance as compared to the two controllers applied alone. Finally, optimally offline tuned PID and the combination of the two controllers have been implemented on the Magnetic levitation system and results obtained from it also points towards the same.

Di Li, Huilin Ge et.al., (2019) we propose an interval 2 fuzzy PID controller (it2f-pid) to operate the uncertain model in inverted pendulum. There are two important problems in the construction of type 2 fuzzy logic system, one is type reduction and the other is rule redundancy. The former one problem aims at calculating the center of mass of a type 2 fuzzy set. For the problem of type reduction, most of the reduction methods are computation-intensive, and an improved EKM algorithm is proposed. This algorithm improves EKM algorithm in two ways. First, change the initialization conditions at the switch point. Then, the method of searching the switch point is improved, so that it can search up and down. When it comes to the later problem, i.e., rule redundancy, the concept of normalized difference should be given first. It is presented to describe the variation of adjacent

singular values to reflect the essential difference between redundant rules and important rules. Then, the number of effective singular number is determined according to the critical point of the effective singular number, and the rule is determined by TLS decomposition to construct the 2-type fuzzy model. Finally, the it2f-pid controller of the new method is compared with the it2fpid controller of the uncertain boundary method, the simplified it2f-pid controller, and the type 1 fuzzy pid controller. Simulation and experimental results show that the performance of the controller has been significantly improved compared to the t1f-pid controller.

Vimala Vindhya, Venkat Reddy et.al., (2013) describes the PID-Fuzzy hybrid controller to improve the dynamic response of Digitally DC-DC converter. Classical linear techniques have stability limitations around the operating points. Fuzzy-PID hybrid controller has been available as a control methodology to control power digitally controlled DC-DC converter under load variations .The fuzzy controller is implemented As gain scheduler that computes proportional constant (k_p),Integral constant(k_i),and derivative constant (k_d) values for PID controller ,non-linear Fuzzy logic controller (FLC),series combination of PID and FLC are introduced .The buck regulator topology is selected to illustrate the effect of each controller type on the converter performance. Comparision between Fuzzy-PID hybrid controller, classical PID controller and ordinary Fuzzy logic controller are presented. The comparision of results obtained separately from PID controller, Fuzzy logic Controller and Fuzzy-PID hybrid controller for a DC-DC converter shows the advantage of the proposed algorithm in terms of transient response under load variation conditions. Simulations were carried out using MATLAB/Simulink.

2.2 LITERATURE SUMMARY

The behavior of PID-type Fuzzy controller algorithm for designing a hardware system has developed using VHDL language. The developed code in VHDL is used to perform four Mamdani Fuzzy interface processes as well. In this step, there are six modules of PID controller.

2.3 PROBLEM DEFINITION

To analyze an efficient fuzzy based PID Controller for transport applications

2.4 OBJECTIVES OF THE PROJECT

- To increase the efficiency of the PID controller for Low Power Applications
- In order to improve Efficiency Low Power Techniques will be applied in all circuits
- To compare, the characteristics of PID controller in terms of power, delay and power delay product
- To identify the Feasibility of PID controller for transportation applications

CHAPTER 3

EXISTING METHODOLOGY

In this chapter existing system PID controller has been discussed. It has structure shown in Fig.3.1

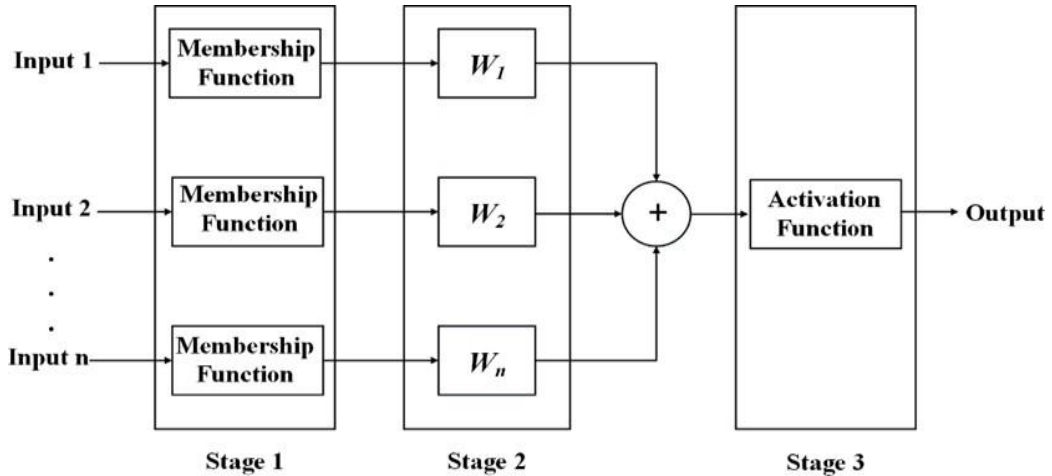


Fig.3.1 Fuzzy Based PID Control System

It has been assumed that the control objective is to bring the process output $y(t)$ to a prescribed set-point y . The PID controller, whose parameters are tuned by the FPGC, generates the control signal $u(t)$ based on the closed-loop error $e(t) = y - y(t)$. We define: $e(k)$ as the closed-loop error and $\Delta e(k) = e(k) - e(k-1)$ as the change rate of the closed-loop error at the k th sampling time.

The internal structure of the proposed FCM-PID controller models can be divided into three stages as shown in Figure 1. In the first stage, input signals are fuzzified by using membership functions. In the second stage, causal relationships between fuzzified inputs and the output are determined by using appropriate weight parameters. Finally, the crisp output value is obtained by using an activation function.

3.1 FUZZIFICATION

First, $e(k)$ and $Ae(k)$ are normalized into the range $[-128, 128]$ for convenience. Then we transform the absolute value of $e(k)$, $Ae(k)$ to their logarithms. So, the fuzzy rule is also applicable when the closed-loop error or its change rate is small. In this paper, we fuzzify $e(k)$, $Ae(k)$ into two fuzzy variables E and R , both of which include the following fuzzy sets: $\{NB, NM, NS, ZO, PS, PM, PB\}$ where N represents negative, P positive, ZO zero; B big, M medium, S small. The membership functions of these fuzzy sets for $e(k)$ and $Ae(k)$ are shown.

3.2 DEFUZZIFICATION

By using the membership functions and using the product to determine the truth value of the i th rule, we have $C_p = 1$. Then as we use the center of gravity method for the defuzzification. The defuzzification output is the summation of the product of the conclusion of each fuzzy rule and its truth value. Because the denominator of the conclusion of the fuzzy rule is 7 and the truth value of the rule can only take value of 419, 219, 119, we only need to shift-left the output of the four rule memory 2 bit, 1 bit, 0 bit corresponding to $\times 4$, $\times 2$, $\times 2$, $\times 1$, produce their sum, and then divide the sum by 63. Division by 63 can be approximated by right-shift 6 bits.

3.3 TUNING OF PID CONTROLLER

Finally, the PID controller parameters K_p , K_i , K_d are calculated from equation (2) by using the K_{sh} , W , K_{th} obtained. In this paper, K_p , K_i is obtained using the Ziegler-Nichols methods. It is based on the belief that a priori knowledge is useful to improve the overall control performance.

3.4 FUZZY INFERENCE

In fuzzy inference, we adopt the Rule-Driven form whose core is to obtain the conclusion and the truth value for each fuzzy rule. We can use ROM to store the fuzzy rule. The input of ROM is the Fuzzy Rule Code and the output is the conclusion. The truth value of the fuzzy rule is obtained as the production of the membership of the antecedents ($e(k)$ or $Ae(k)$).

In each inference, four fuzzy rules are effective which is called Effective Rules. In this paper, the truth values of these Effective Rules are fixed to $4/9, 2/9, 2/9,$

1/9. Then the task of fuzzy inference is transformed from the obtaining of the conclusion and the truth value for each fuzzy rule to the producing of the Fuzzy Rule Code for the four Effective Rules. The Fuzzy Set Code obtained in the fuzzification is combined to produce the Fuzzy Rule Code.

Several sensors can be used suitably located at the front, the rear, the right-hand side and the left-hand side of a vehicle to determine its position relative to other vehicles and other objects in the vicinity. The information from the sensors can be used for modeling as well as other reasons such as: the PathSearching (PS), Obstacle-Avoidance (OA), and Goal-Seeking (GS) purposes. In the case of modeling, Cartesian Coordinates can be used for position determination. Since the position is determined relative to others vehicles and objects in the vicinity, the location of the sensors on the vehicle itself, the types of sensors selected, the probability of detection, and the sensor response time carry particular importance for the safety reasons and the overall system response.

Let us consider that the vehicle is the reference of distance from other vehicle Radars can be used to detect the objects surrounding the vehicle on variety ranges and using different wave lengths. The target of detection, which is another vehicle, needs to be considered as a sizable object with clearly predicted path. In this study it is assumed that targets on the right- and left-hand sides have the same speed and are running in parallel to the vehicle. There two other vehicles on in the front and one at the rear also moving with the same speed between the parallel road lanes on a straight line.

3.2. ADVANTAGES OF PID CONTROLLER

- It only acts on the error between the desired signal and the controlled signal. Hence, no extra measurements of the internal states are needed
- It is efficient and robust against some common uncertainties if properly tuned
- Easy to implement in hardware and easy to implement though microcontrollers, PLC etc.
- Provides good stability, rapid response and relatively stable
- Can be tuned without a great amount of experience required

3.3. DISADVANTAGES OF PID CONTROLLER

- Only control results in offset-Never reaches SP
- Action is instantaneous-As soon as error is produced, control action is taken
- Used to stabilize unstable output
- Not optimal for the problems
- Not depending on the process

CHAPTER 4

PROPOSED SYSTEM

In order to improve efficiency, existing system as PID controller will be analyzed using 130nm, 32nm CMOS Technology. Further, FUZZY based PID controller will be modified` and analyzed using 130nm,32nm CMOS Technology in terms of power, speed, and power delay product. This out performance an efficient FUZZY based PID controller for high speed and low power application.

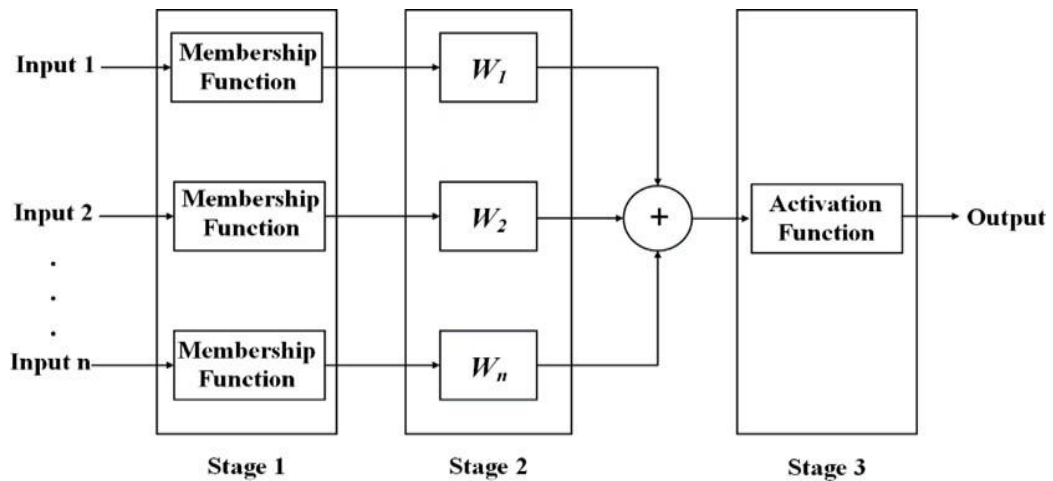


Fig.4.1 Fuzzy Based PID Control System

The internal structure of the proposed FCM-PID controller models can be divided into three stages as shown in Figure 1. In the first stage, input signals are fuzzified by using membership functions. In the second stage, causal relationships between fuzzified inputs and the output are determined by using appropriate weight parameters. Finally, the crisp output value is obtained by using an activation function.

4.1 MATLAB SOFTWARE TOOL

MATLAB is an abbreviation of "matrix laboratory" is a proprietary multi-paradigm programming language and numeric computing environment developed by MathWorks. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages. Matlab is a programming language similar to other well-known languages such as Java, C#, etc., which comes with its own IDE (that is Integrated Development Environment) and set of libraries. Matlab is an abbreviation of the term "Matrix Laboratory" since it was initially referred to as the matrix programming language.

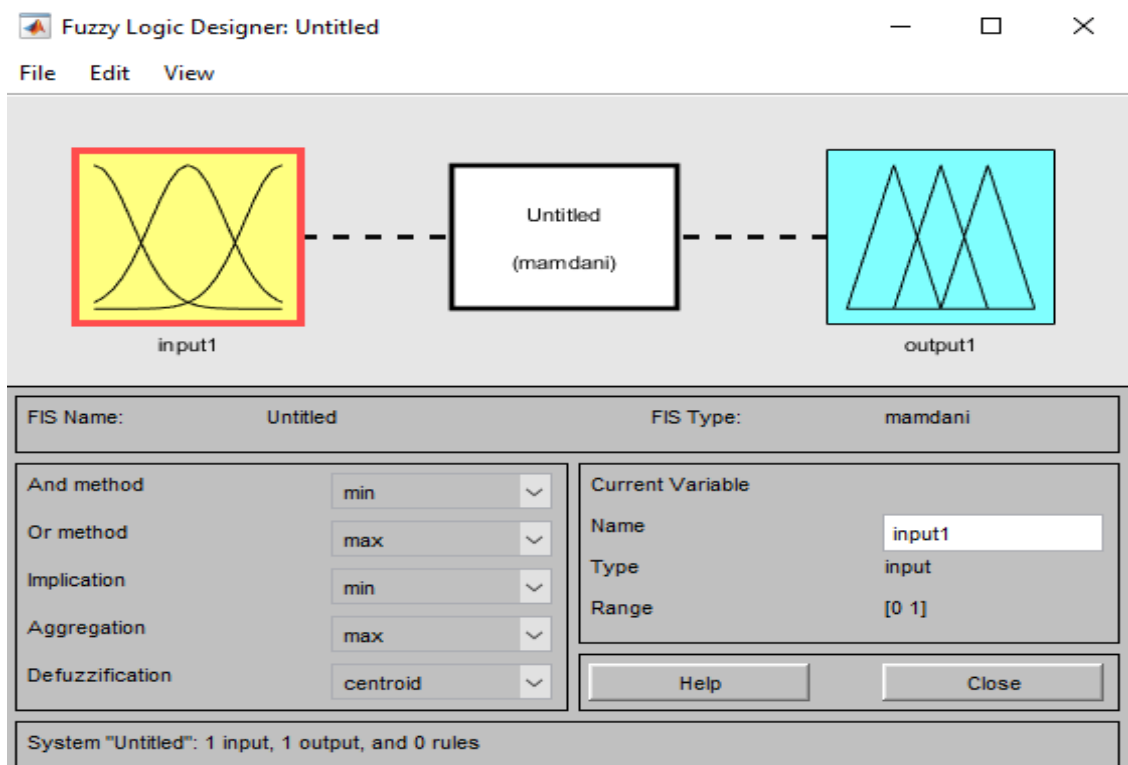


Figure 4.2 FUZZY LOGIC DESIGNER

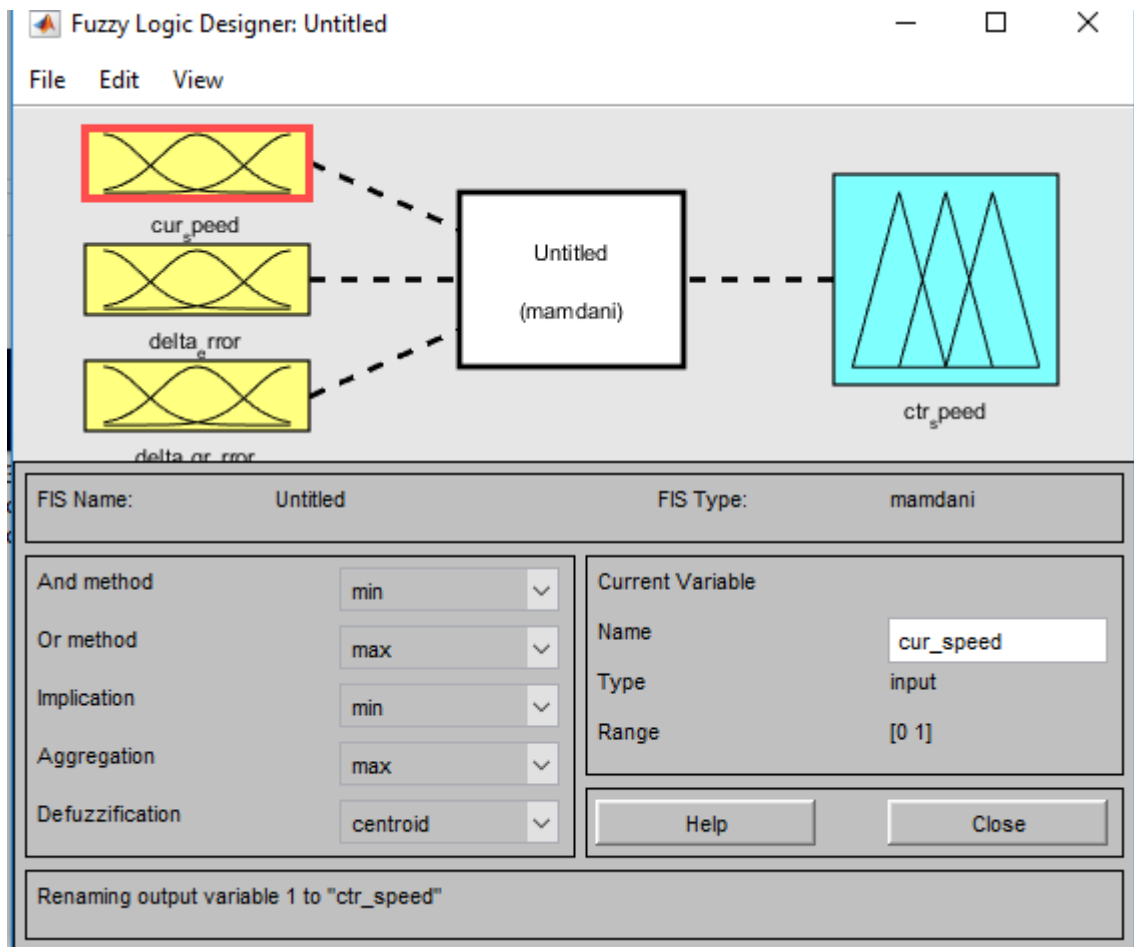


Figure 4.3 ANALYSIS OF MEMBERSHIP FUNCTIONS

4.2 XILINX SOFTWARE TOOL

Xilinx designs, develops, and markets programmable logic products, including integrated circuits (ICs), software design tools, predefined system functions delivered as intellectual property (IP) cores, design services, customer training, field engineering and technical support.

The main design toolkit Xilinx provides engineers is the Vivado Design Suite, an integrated design environment (IDE) with a system-to-IC level tools built on a shared scalable data model and a common debug environment.

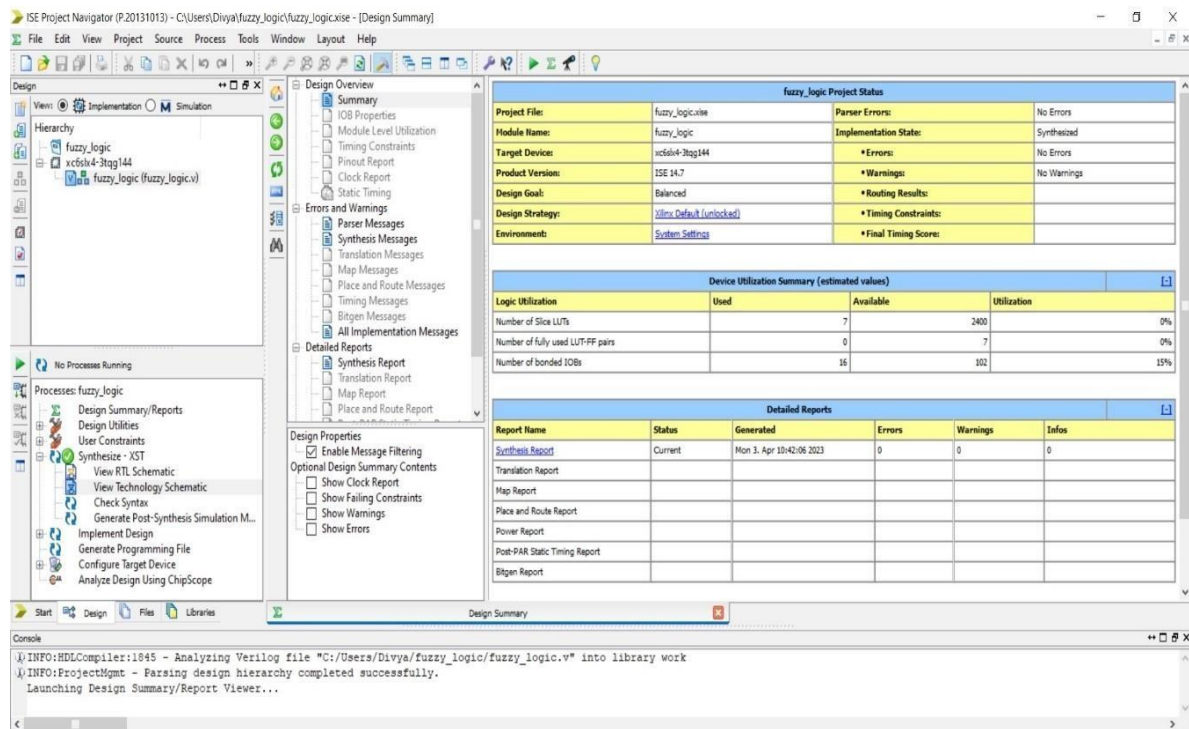


FIGURE 4.4 XILINX SOFTWARE TOOL

4.3 MODELSIM SOFTWARE TOOL

ModelSim is a multi-language environment by Siemens for simulation of hardware description languages such as VHDL, Verilog and System C, and includes a built-in C debugger. ModelSim simulates behavioural, RTL, and gate-level code - delivering increased design quality and debug productivity with platform-independent compile. Single Kernel Simulator technology enables transparent mixing of VHDL and Verilog in one design. Learn more about the current status of ModelSim Student Edition and options available.

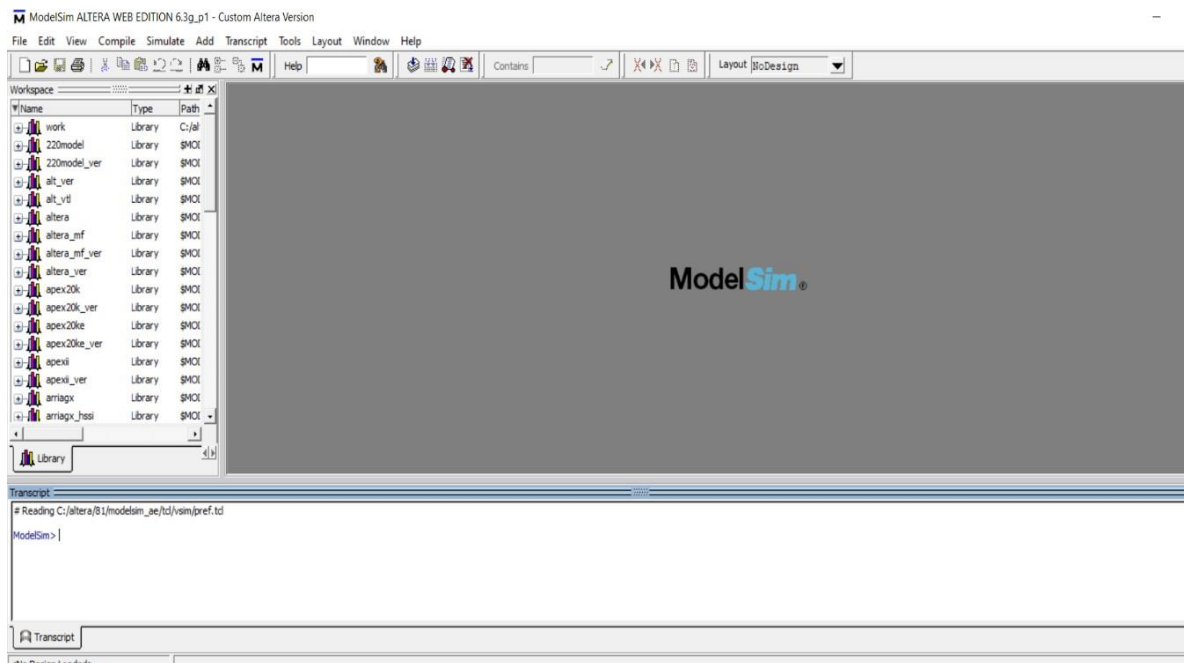


FIGURE 4.5 MODELSIM SOFTWARE TOOL

4.3.1 SIMULATION OUTPUTs

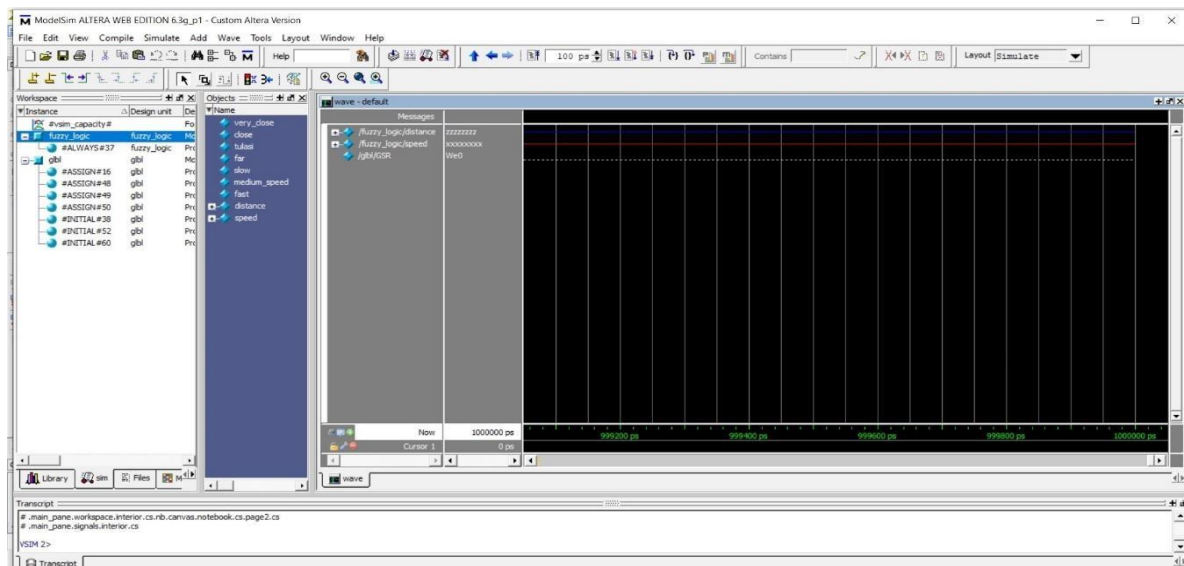


FIGURE 4.6 MODELSIM SIMULATION SCREEN

4.4 MULTIPLEXER

A multiplexer is a combinational circuit that has 2^n input lines and a single output line. Simply, the multiplexer is a multi-input and single-output combinational circuit. The binary information is received from the input lines and directed to the output line. Based on the values of the selection lines, one of these data inputs will be connected to the output.

Unlike encoder and decoder, there are n selection lines and 2^n input lines. So, there is a total of 2^N possible combinations of inputs. A multiplexer is also treated as Mux.

A multiplexer (sometimes spelled multiplexor and also known as a MUX) is defined as a combinational circuit that selects one of several data inputs and forwards it to the output. The inputs to a multiplexer can be analog or digital. Multiplexers are also known as data selectors.

A multiplexer is useful for transmitting a large amount of data over the network within a certain amount of time and bandwidth.

Multiplexers that are built from transistors and relays are termed as analog multiplexers which are used in analog applications and Multiplexers that are built from logic gate termed as digital multiplexers which are used in digital applications. The inverse of a multiplexer is known as a demultiplexer.

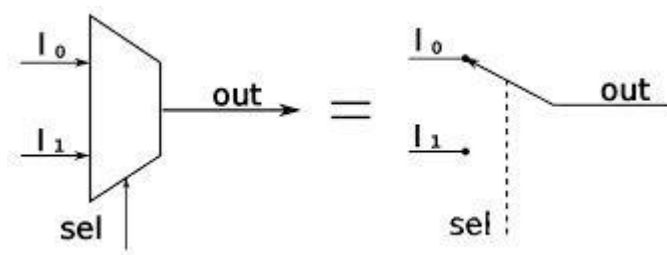


Fig 4.7 Multiplexer

In digital systems, many times it is necessary to select a single data line from several data-input lines and the data from the selected data input line should be available on the output line. The digital circuit which does this task is a multiplexer.

A multiplexer is a digital circuit that selects one of the n data inputs and forwards it to the output. The selection of one of the n inputs is done by the select inputs. To select one of several inputs, we need m select lines such that $2^m = n$.

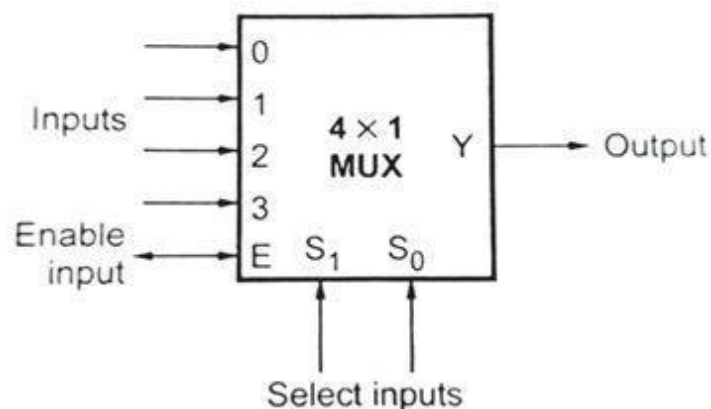
Depending on the digital code applied at the select inputs, one of the n data inputs is selected and transmitted to the single output. Hence, a multiplexer has maximum 2^n data input lines, ' m ' selects lines, and one output line.

The multiplexer works like a multiple-input and single-output switch. The output gets connected to only one of the n data inputs at a given instant of time. Therefore, the multiplexer is 'many into one' and it works as the digital equivalent of an analog selector switch.

There are many types of multiplexers – like 2-to-1, 4-to-1, and 8-to-1 multiplexers. Each one has a different circuit, truth table, Boolean expression, and working principle. Let's discuss each type of multiplexer one by one.

4.4.1 4 x 1 Multiplexer

4x1 Multiplexer has four data inputs A_3 , A_2 , A_1 & A_0 , two selection lines s_1 & s_0 and one output Y . The block diagram of 4x1 Multiplexer is shown in the following figure.



One of these 4 inputs will be connected to the output based on the combination of inputs present at these two selection lines. Truth table of 4x1 Multiplexer is shown below.

INPUTS		Output
S_1	S_0	Y
0	0	A_0
0	1	A_1
1	0	A_2
1	1	A_3

4.1 Truth Table of Multiplexer

Here, the 4-input multiplexer connects one of four 1-bit sources to a common output, hence it produces a 4-to-1 multiplexer.

Digital multiplexers are sometimes also referred to as “Data Selectors” as they select the data to be sent to the output line and are commonly used in communications or high-speed network switching circuits such as LAN’s and Ethernet applications.

The rotary switch, also called a wafer switch as each layer of the switch is known as a wafer, is a mechanical device whose input is selected by rotating a shaft. In other words, the rotary switch is a manual switch that you can use to select individual data or signal lines simply by turning its inputs “ON” or “OFF”. So how can we select each data input automatically using a digital device.

In digital electronics, multiplexers are also known as data selectors because they can “select” each input line, are constructed from individual Analogue Switches encased in a single IC package as opposed to the “mechanical” type selectors such as normal conventional switches and relays.

They are used as one method of reducing the number of logic gates required in a circuit design or when a single data line or data bus is required to carry two or more different digital signals. For example, a single 8-channel multiplexer.

Generally, the selection of each input line in a multiplexer is controlled by an additional set of inputs called control lines and according to the binary condition of these control inputs, either “HIGH” or “LOW” the appropriate data input is connected directly to the output. Normally, a multiplexer has an even number of 2^n data input. Note that multiplexers are different in operation to Encoders. Encoders can switch an n -bit input pattern to multiple output lines that represent the binary coded (BCD) output equivalent of the active input. We can build a simple 2-line to 1-line (2-to-1) multiplexer from basic logic NAND.

4.5 ADDERS

A combinational circuit that performs the addition of bits is called an Adder. Each computer has an adder located in its CPU(ALU) that is responsible for the process of addition. There are two types of Adders. They are also used in other parts of the processor, where they are used to calculate addresses, table indices, increment and decrement operators, and similar operations.

Adder is used to add binary numbers. Adder circuit is basically a combinational logic circuit. It is a memory less circuit and performs an operation assigned to it logically by a Boolean expression. The output depends upon the present input at any given time.

An adder or summer is a digital circuit that performs addition of numbers. In many computers and other kind of processors, adders are used not only in the arithmetic logic units, but also in other parts of the processor, where they're used to calculate addresses, table indices, increment and decrement operators, and similar operations.

Although adders can be constructed for many numerical representations, such as binary-coded decimal or excess-3, most common adders operate on binary numbers. In cases where two's complement or one's complement is being used to

represent negative numbers; it is trivial to modify an adder into an adder subtractor. Other signed number representations require more logic around the basic adder.

Binary carry-propagate adders have been extensively published, heavily attacking problems related to carry chain problem. Binary adders evolve from linear adders, which have a delay approximately proportional to the width of the adder, example ripple-carry adder (RCA), to logarithmic-delay adders, such as the carry-look ahead adder (CLA), there are some additional performance enhancing schemes, including the carry-increment adder and the Ling adder that can further enhance the carry chain, however, in Very Large Scale Integration (VLSI) digital system. The most efficient way of offering binary addition involves utilizing parallel-prefix trees, this occurs because they have the regular structure that exhibit logarithmic delay. Parallel-prefix adders compute the sum bit in two steps: one to obtain the carry at each bit, with the next to compute the sum bit based on the carry bit. Unfortunately, prefix trees are algorithmically slower than fast logarithmic adders, such as the carry propagate adders, however, their regular structure promote excellent results when compare to traditional CLA adders.

This happens within VLSI architectures because a carry-look ahead adder, such as the one implemented in one of Motorola's processors, tends to implement the carry chain in the vertical direction instead of a horizontal one, which tends to increase both wire density and fan-in/out dependence. Therefore, although logarithmic adder structures are one of the fastest adders algorithmically, the speed efficiency of the carry-look ahead has been hampered by diminishing returns given the fan-in and fan-out dependencies as well as the heavy wire load distribution in the vertical path. In fact, a traditional carry-look ahead adder implemented in VLSI can actually be slower than traditional linear-based adders, such as the Manchester carry adder.

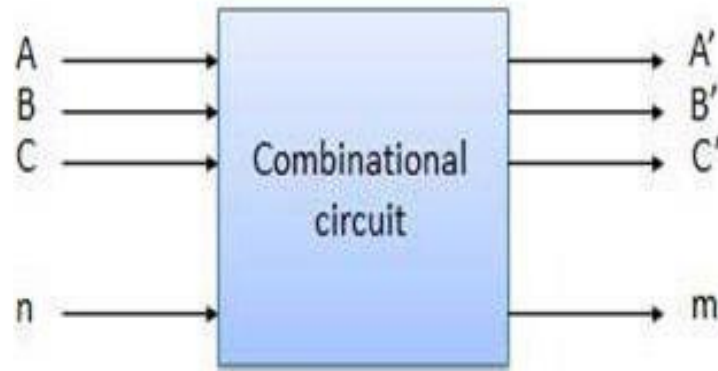


Fig 4.8 Adder

4.5.1 HALF ADDER

A half adder is a type of adder, an electronic circuit that performs the addition of numbers. The half adder can add two single binary digits and provide the output plus a carry value. It has two inputs, called A and B, and two outputs S (sum) and C (carry). The common representation uses a XOR logic gate and an AND logic gate.

A half adder is used to add two single-digit binary numbers and results into a two-digit output. It is named as such because putting two half adders together with the use of an OR gate results in a full adder. In other words, it only does half the work of a full adder.

The adder works by combining the operations of basic logic gates, with the simplest form using only a XOR and an AND gate. This can also be converted into a circuit that only has AND, OR and NOT gates. This is especially useful since these three simpler logic gate ICs (integrated circuits) are more common and available than the XOR IC, though this might result in a bigger circuit since three different chips are used instead of just one.

So, coming to the scenario of half adder, it adds two binary digits where the input bits are termed as augend and addend and the result will be two outputs one is the sum and the other is carry. To perform the sum operation, XOR is applied to both their inputs, and AND gate is applied to both inputs to produce carry.



Fig 4.9 Block Diagram of Half-Adder

Whereas in the full adder circuit, it adds 3 one-bit numbers, where two of the three bits can be referred to as operands and the other is termed as bit carried in. the produced output is 2-bit output and these can be referred to as output carry and sum. By using a half adder, you can design simple addition with the help of logic gates. Let's see an example of adding two single bits.

Inputs		Outputs	
A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

4.2 Truth Table of Half-Adder

in the above table,

1. 'A' and 'B' are the input states, and 'sum' and 'carry' are the output states.
2. The carry output is 0 in case where both the inputs are not 1.
3. The least significant bit of the sum is defined by the 'sum' bit.

$$0+0 = 0$$

$$0+1 = 1$$

$$1+0 = 1$$

$$1+1 = 10$$

These are the least possible single-bit combinations. But the result for 1+1 is 10, the sum result must be re-written as a 2-bit output. Thus, the equations can be written as

$$0+0 = 00$$

$$0+1 = 01$$

$$1+0 = 01$$

$$1+1 = 10$$

The output '1' of '10' is carry-out. 'SUM' is the normal output and CARRY is the carry-out. Now it has been cleared that a 1-bit adder can be easily implemented with the help of the XOR Gate for the output 'SUM' and an 'AND' Gate for the Carry. For instance, when we need to add, two 8-bit bytes together, then it can be implemented by using a full-adder logic circuit. The half-adder is useful when you want to add one binary digit quantities.

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A way to develop two-binary digit adders would be to make a truth table and reduce it. When you want to make a three binary digit adder, the half adder addition operation is performed twice. In a similar way, when you decide to make a four-digit adder, the operation is performed one more time. With this theory, it was clear that the implementation is simple, but development is a time taking process.

The simplest expression uses the exclusive OR function:

$$\text{Sum} = A \text{ XOR } B$$

$$\text{Carry} = A \text{ AND } B$$

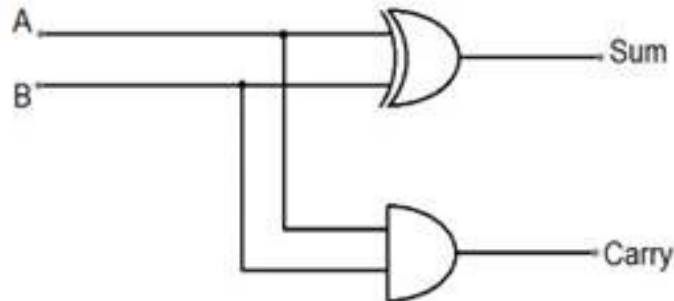


Fig 4.10 Logic Circuit of Half-Adder

And an equivalent expression in terms of the basic AND, OR, and NOT is:

$$\text{SUM} = A.B + A.B'$$

The implementation of half adder can be done through high-speed CMOS digital logic integrated circuits like 74HCxx series which include the SN74HC08 (7408) & SN74HC86 (7486).

The main reason to call these binary adders like Half Adders is, that there is no range to include the carry bit using an earlier bit. So, this is a main limitation of Has once used like binary adder particularly in real-time situations which involve adding several bits. So this limitation can be overcome by using the full adders.

The output '1' of '10' is carry-out. 'SUM' is the normal output and CARRY is the carry-out. Now it has been cleared that a 1-bit adder can be easily implemented with the help of the XOR Gate for the output 'SUM' and an 'AND' Gate for the Carry. For instance, when we need to add two 8-bit bytes together, then it can be implemented by using a full-adder logic circuit. The half-adder is useful when you want to add one binary digit quantities.

4.5.2 FULL ADDER

The half adder is used to add only two numbers. To overcome this problem, the full adder was developed. The full adder is used to add three 1-bit binary numbers A, B, and carry C. The full adder has three input states and two output states i.e., sum and carry.

A full adder is a circuit that has two AND gates, two EX-OR gates, and one OR gate. The full adder adds three binary digits. Among all the three, one is the carry that we obtain from the previous addition as C-IN, and the two are inputs A and B. It designates the input carry as the C-OUT and the normal output as S (or SUM).

Just like the Half Adder, the Full Ladder is a combinational type of logic circuit-meaning, it has no storage element. But it has additional logic gates. Thus, it adds the previous carry to generate the complete output. Thus, it is called the Full Adder. One can also designate a Full Adder using one OR gate and two Half Adders. The OR gate here generates a carry that it obtains after the addition. We obtain the sum of these digits in the form of output from the second Half Adder. The equation for the output that you can obtain by the EX-OR gate is the sum of all the binary digits. Here, the output that you obtain from the AND gate is the carry that you obtain by addition. This equation is in the form of a logical operation.



Fig 4.11 Block Diagram of Full Adder

The full-adder has three inputs and two outputs, whereas half adder has only two inputs and two outputs. The first two inputs are A and B and the third input is an input carry as C-IN. When a full-adder logic is designed, you string eight of them together to create a byte-wide adder and cascade the carry bit from one adder to the next.

Inputs			Outputs	
A	B	C _{in}	Sum	Carry
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

4.3 Truth Table of Full Adder

The difference between a half-adder and full-adder is that the output carry is designated as C-OUT and the normal output is represented as S which is 'SUM'. With the above full adder truth-table, the implementation of a full adder circuit can be understood easily. The SUM 'S' is produced in two steps: By XORing the provided inputs 'A' and 'B'. the result of A XOR B is then XORed with the C-IN, this generates SUM and C-OUT is true only when either two of three inputs are HIGH, then the C-OUT will be HIGH. So, we can implement a full adder circuit with the help of two half adder circuits. Initially, the half adder will be used to add A and B to produce a partial Sum and a second-half adder logic can be used to add C-IN to the Sum produced by the first half adder to get the final S output.

If any of the adder logic produces a carry, there will be an output carry. So, C-OUT will be an OR function of the half-adder Carry outputs. Look at the implementation

of the full adder circuit shown below. The implementation of large logic diagram is possible with the above full adder logic a simpler symbol is mostly used to represent the operation. Given below is a simpler schematic representation of a one-bit full adder.

CHAPTER 5

RESULTS AND DISCUSSION

The existing and proposed architecture are simulated by using MATLAB and Xilinx simulator. Output of the existing Fuzzy based PID controller and proposed Fuzzy based PID controller are analyzed from the results and it is concluded that the propose architecture reduces the power consumption compared with the existing system. The synthesis is done.

5.1 Analysis of Fuzzy Based PID Controller Using MATLAB Tool

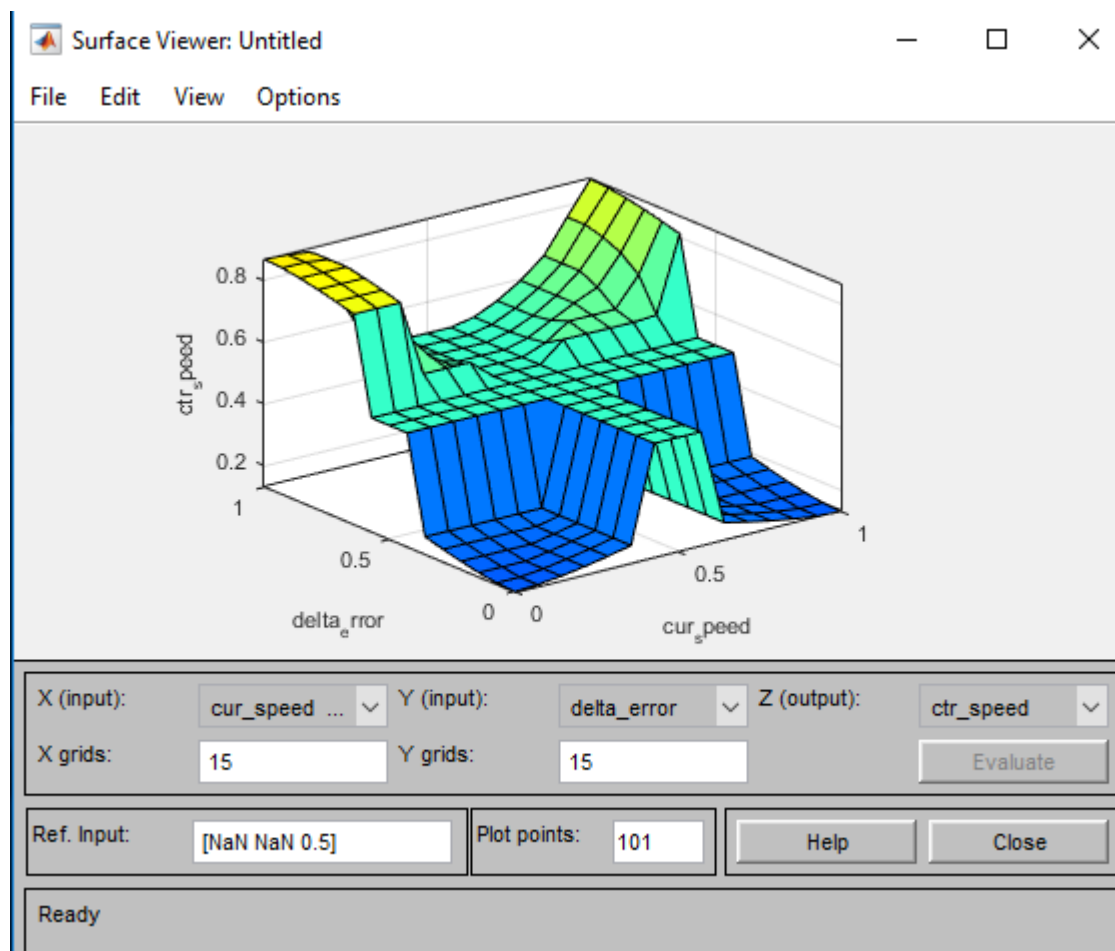


Fig 5.1 Simulation Result of Vehicle Automation Using MATLAB

Figure 5.1 shows the simulation output fuzzy based PID controller using MATLAB software tool.

The inputs given were cur _speed, delta _error, delta _sqr _error and output is taken by ctr _speed.

5.2 Analysis of Fuzzy Based PID Controller Using Xilinx Tool

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 Vehicle Automation Using Fuzzy Based PID Type Cruising Controller 23 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

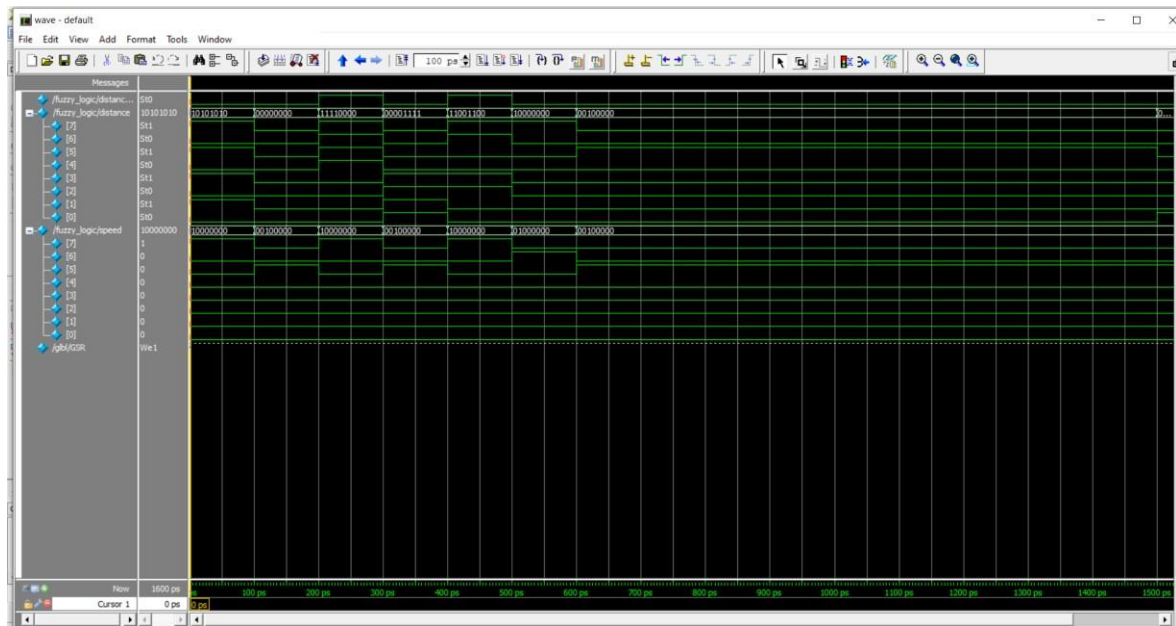


Fig 5.2 Simulation Result of Vehicle Automation Using XILINX

Figure 5.2 shows the simulation output of fuzzy based PID controller using Xilinx software tool.

The input given to fuzzy logic controller is distance between the preceding vehicle and the following vehicle and the output taken is speed.

5.3 ANALYSIS OF RTL SCHEMATIC USING XILINX TOOL

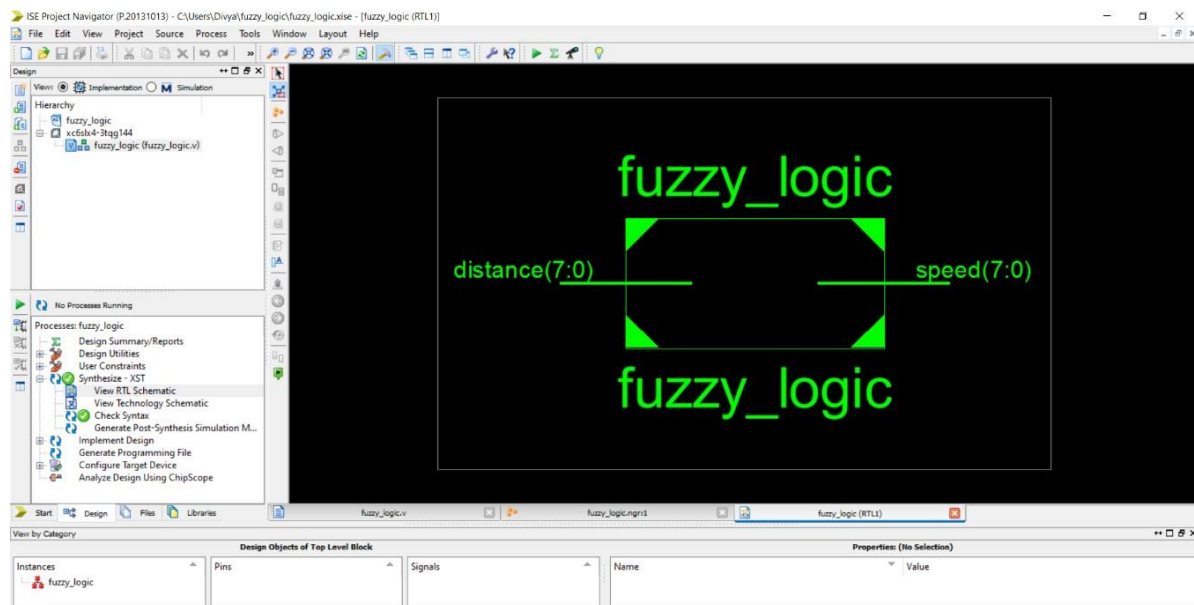


Fig 5.3 Analysis of RTL Schematic

The above figure 5.3.1 shows the RTL schematic of Fuzzy based PID controller. The input given was distance and output is taken by speed.

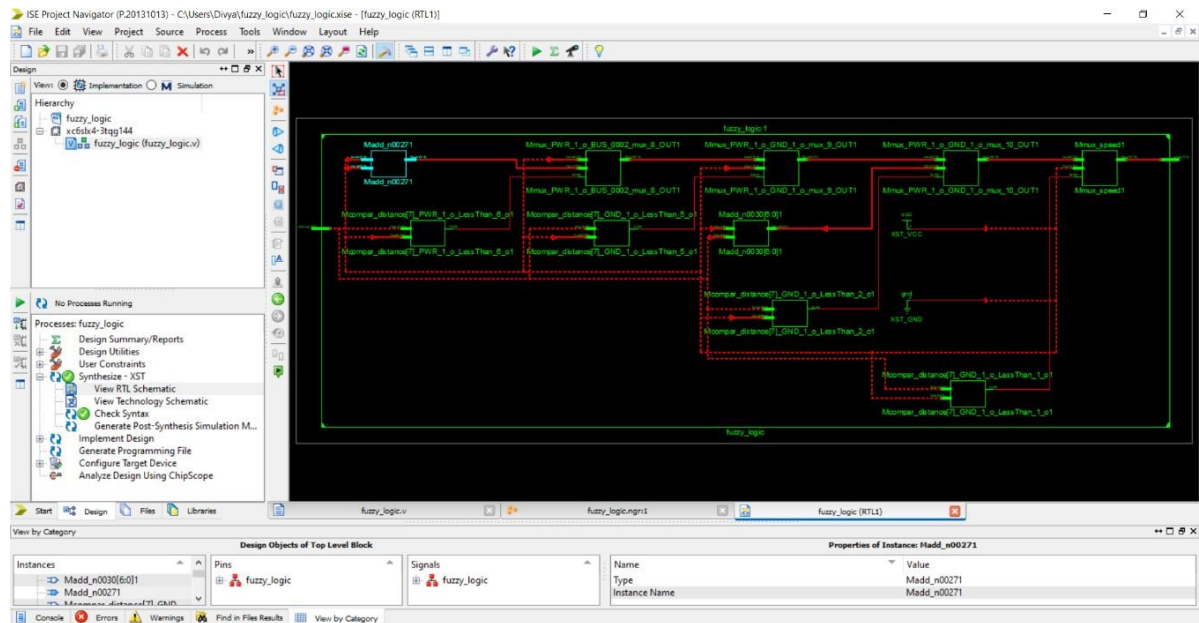


Fig 5.3 Analysis of RTL Schematic

Figure 5.3.2 shows Analyzed RTL Schematic of fuzzy based PID controller using Xilinx software tool.

The input given was distance and output is taken by speed.

RTL Schematic is comprised of MUX and adder.

Multiplexer also known as data selector, is a device that selects between several analog or digital input signals and forwards the selected input to a single output line. The selection is directed by a separate set of digital inputs known as select lines.

Adder allows digital information from several sources to be routed onto a single output line.

5.4 ANALYSIS OF LUT'S USING XILINX TOOL

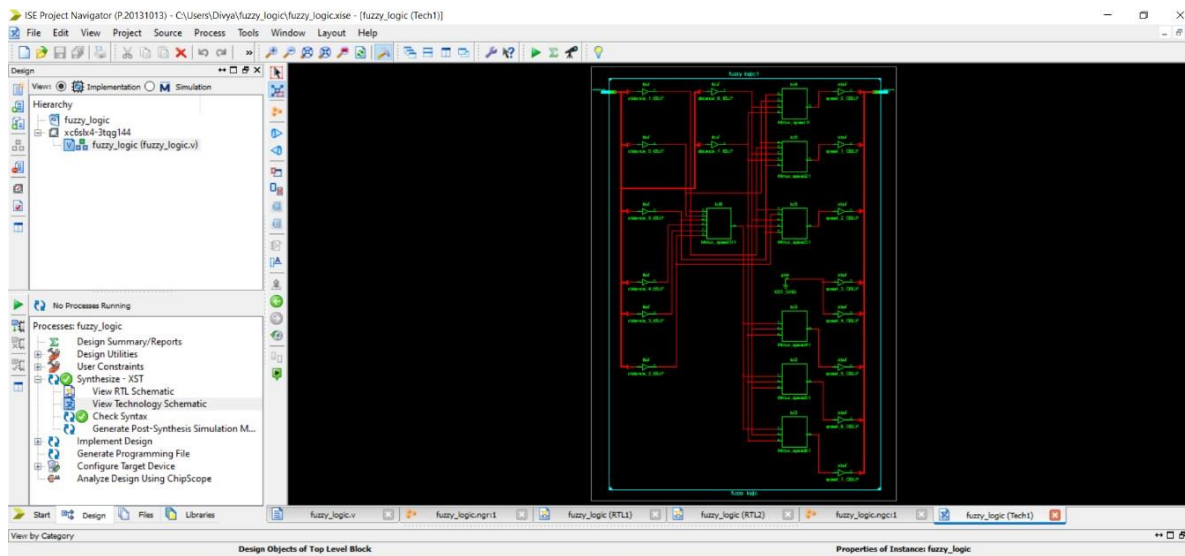


Fig 5.4 Analysis of LUT's using Xilinx Tool

CHAPTER 6

CONCLUSION

The PID type fuzzy controller algorithm has described first using MATLAB platform. The described PID controller also has developed with all fuzzy rules for designing the hardware PID chip using VHDL. Then, the synthesize tool has used to get the logic gates of hardware PID modules. The designed PID chip can be used to the targeted application. As an example, transportation cruising system. The cruising system based on PID chip can be avoided 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.

In this study, fuzzy cognitive map based PID controller design is introduced. Two different FCM based PID controller models are proposed and their performances are evaluated by performing simulation studies. The simulation results show that the proposed FCM- PID controller models exhibit better control performance than the conventional PID and fuzzy PID controllers. Therefore, the proposed FCM based PID controller models can effectively be used in practical control applications. Existing PID controllers can easily be replaced with FCM based PID controller counterparts to improve the control performances. Additionally, conventional PID tuning methods can be applicable to a certain degree for the proposed controllers since they preserve the basic PID form. Moreover, the proposed FCM based PID controller models provide additional design degrees of freedom due to their membership functions and activation functions. By using different types of functions, nonlinear characteristics and performances of FCM based PID controller models can be increased especially in control applications of complex systems. Similarly, parameters of these functions can be used for fine tuning of controllers.

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.

A vehicle position control strategy has been presented by applying fuzzy logic techniques. The strategy of the control systems has been developed in a flow chart form and the fuzzy set control system has been simulated using MATLAB fuzzy logic toolbox. The simulation has six input and three output variables. Input variables are the road conditions, the left-hand side distances, the right-hand side distances, the front and rear distances, and the speed. Output variables are fuel throttle intensity, the brake system intensity, and the steering wheel control. It has been shown that the throttle fuel and brake system are proportionally affected by road conditions. Suitable sensor system has been proposed based on radar technology. FMCW radar has been utilized for four sides of the vehicle. 24 GHz is used for short range and 77 GHz for long range with different beam angles.

Fuzzy logic has been applied into various areas including transportation engineering. In the area of transportation engineering, it has been applied to model traffic flow, transportation planning, and traffic control and so on. In all these applications fuzzy logic has proved to be successful in overcoming the drawbacks of other methods in the respective areas.

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