

Design and Implementation of ANFIS Algorithm Using VHDL for Vehicular System

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Abstract:-In this paper an (Adaptive Neuro Fuzzy(NF) Inference System algorithm)ANFISA proposed and try to implemented using FPGA(FIELD PROGRAMMABLE GATE ARRAY)for the behavior of the system will be nonlinear. In the application of designing the algorithm for vehicular controlling of nonlinear active suspension system. The algorithm for neural was Back propagation(BPN) and for fuzzy takagi- sugeno-kang active suspension systems is very important for guaranteeing the passengers feel the comfortable riding and also road handled quality for a vehicle. It is shown that the ANFIS can modelize a nonlinear system very accurately by means of data taken from mathematical model. Firstly the MATLAB SIMULINK toolboxes were use for to simulate the proposed controllers in the pre view paper and to display the responses of the controlled model under different types of disturbance. But in this paper the implementation of the (ANFIS)adaptive neuro fuzzy inference system algorithm using FPGA boards has been try to investigated in this work. The Xilinx ISE software is employed to synthesis the VHDL codes used to program the FPGA.

Key words: ANFISA, (NASS)Nonlinear Active Suspension System, Neuro-fuzzy Control(NFC), FPGA.

I. INTRODUCTION

Now (FPGA)Field programmable gate array have been introduce as one of used in the hardware field of digital signal and provided acceptable results in real-time applications, using parallel processing. And the ANFIS algorithm is one of the trusted and try to used in the field of nonlinear characteristics. Because of the computational complexity many of algorithm were running with the lower rate. But in FPGA it quite possible to handle the non linear characteristics. More recently ANN has been implemented with reconfigurable FPGA. By the early century wooden springs for the one horse vehicle and for heavy vehicle steel springs were used for the riding comfort during the traveling. The drawbacks of excess vehicular vibrations are that: reduced vehicle-frame life, reduced limitation of vehicle speed and there were pessimistic biological effects on passengers and damaging consequences to cargo. [1]Modern suspensions of the vehicle are tried to provide superior handling characteristics and to improve comfort under spiteful vibrations caused by road irregularities. In the few years ago there would be a increasing the interest in the research activity and has also been shown to combine the neural network(NN) and the fuzzy systems methodologies(FSM). By integrating both the methodologies was the primary function to improve strength in order to achieve learning and adaptation capabilities and also the representation of knowledge via fuzzy if-then rules, producing the so-called (neuro-fuzzy systems)NFS. And the controller were designed were in the fuzzification block the if then rules were used. In the following if then rules were explained. Due to complex system structure, so that the

circuitry has very complicated for logic system to be implement. Therefore, many researchers were think to proposed digital rather than analogue circuits because of the complexity and therefore implement the fuzzy logic system. Reference [4] developed software for synthesize Boolean equation for the fuzzy controllers. Also, the implementation of controller on a hardware i.e fuzzy controller(FC) on the field programmable gate array has been described. The FPGA development system on the developed software collectively provides a complete automation propose tool for fuzzy controllers(FC). Reference [5] in this it will be implemented a fuzzy controller(FC) on an FPGA and also it will be presented using VHDL for a motor unit. In Reference [6] simulation and implementation of a logic controller were using the fuzzy system for a diesel determined impartial synchronous generator have been designed. The developing the controller using hardware descriptive language and implemented in FPGA. Reference [12] depicted a two style to fuzzy logic model it will be based on two strategies: behavioural modelling using VHDL and the structural modeling VHDL based on particular architecture for a fuzzy processor. Reference [13] described the implementation of fuzzy systems(FS), a neural networks(NN) and fuzzy neural networks(FNN) using FPGA on a hardware using Xilinx software. Reference [5] there will be adaptive generalized predictive control method for nonlinear system for more than one order that was many input and many output and established the stability and convergence of blocked loop system. In this [6] obstacle avoidance there was program for mobile robot that thesaurus a neuro fuzzy algorithm using altera field programmable gate array development path. FPGA development and the implementing board were used

to be a successful system platform for the NF(neuro-fuzzy) algorithm to be implemented and tested . Another example of research related was done by Cao [2] on Navigation for self-sufficient guide Vehicle Using the NF(neuro fuzzy) Techniques. In this research, algorithm it used the system that is able to be in charge of the operation such as SMPA (Sense, Map, Plan, and Act). NF system is able to modify and take out new rules from a correctly training. It offers the accuracy and learning capabilities which are suitable for hindrance avoidance task. The successful implementation of artificial neural network(ANN) was first published over a decade ago [8]. Ugui and Sanchez [9] describe that FPGA are very well suited for developing systems having the cellular structures, such as NN(neural network), fuzzy system rules, or cellular automata because it allows a immense degree of give for evolving circuits. Cavslu [10] has demonstrated the hardware implementation of neural network using Xilinx FPGAs, an Intel based FPGA architecture.

II. MATHEMATICAL MODEL

A. Nonlinear Combination

The modeling of the suspension part is like a nonlinear helix in equivalent with a nonlinear constraint that is on the damper and a nonlinear hydraulic actuator. The frictional forces which consider as a nonlinear due to rubbing of piston seals with the cylinders wall and also rasping of tire and road.

[1]The equations of motion for the vehicle nonlinear suspension using the Newton laws of motion.

I. Vertical Motion

According to,

$$M\ddot{z}_c = -\sum_{i=1}^4 F_{Ki} - \sum_{i=1}^4 F_{Ci} + \sum_{i=1}^4 F_{Pi} \quad \dots(1)$$

Where F_{Ki} and F_{Ci} are the nonlinear spring force and nonlinear damping force that on the suspension forces , respectively[1].

II. Pitching motion

$$J_x \ddot{\alpha} = (F_{K1} - F_{K2} - F_{K3} + F_{K4}) \frac{b}{2} + (F_{C1} - F_{C2} - F_{C3} + F_{C4}) \frac{b}{2} + (F_{P4} - F_{P1} + F_{P3} - F_{P2}) \frac{b}{2} + T_x \quad \dots(2)$$

where the distance between the front wheels (or rear wheels)denoted by $b[1]$.

III. Rolling Motion

$$J_y \ddot{\eta} = (F_{K3} + F_{K4}) J_2 - (F_{K1} + F_{K2}) J_1 + (F_{C3} + F_{C4}) J_2 - (F_{C1} + F_{C2}) J_1 + (F_{P1} + F_{P2}) J_1 + (F_{P3} + F_{P4}) J_2 + T_y \quad \dots(3)$$

L1 is the distance between the centre of frontage wheel axle and centre of gravity of the vehicle, L2 is the distance between the centre of severity of the vehicle and the centre of rare wheel axle.

Adaptive neuro fuzzy inference system is very useful and handles nonlinearity effectively. From literature survey it has been concluded that as vehicular suspension shows properties of nonlinearity, the ANFIS is best suited for non linear behavior of vehicle. The algorithm in VHDL which the simulation result is analyses for the vehicle parameter. The proposed ANFIS algorithm gives the parameter of the vehicle in which vertical displacements at each corner of the vehicle to reach low level. It means we need to low that displacement parameter as early as possible that will give the better ride comfort and the road handling have been improved. In real world, construction of mathematical models (white-box models)it is very tricky because we seldom to have a complete knowledge of the process that we require to model [6].some fractional order PID controller will be used to deal with this mathematical model parameter[1].An (EA)Evolutionary algorithm has been used to serve for this purpose.

III. FUZZY LOGIC BASED CONTROLLER

In the figure represent the typical fuzzy controller(FC) in Figure1. Which will be Based on the fuzzy logic and the knowledge base controller , consisting of fuzzy rules that will explain the behaviour of the typical (FC)fuzzy controller, and an inference system that combine active rules according to submitted entries to the controller [8]. As the rules were used the fuzzy set of the inference system ,in the fuzzification there will be need to transform real measures in fuzzy sets and in the defuzzication to interface with and transforming the fuzzy sets scalar values with the inference system to a process to be controlled.

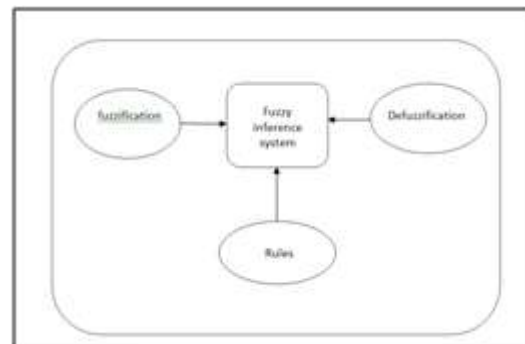


Figure 1. Typical fuzzy control system

An expansion of the classic sets that fuzzy sets will be interpreted , because by associating a value of the element that varies in between 0 and 1 ,they allow partial relevance of an element to a given set [4] . A membership function $\mu_A(x) = [0,1]$ will be described by each fuzzy set , such as Negative, Zero and Positive joints in "Figure 2".That concept exactly used in the controller during process designing of a controller.

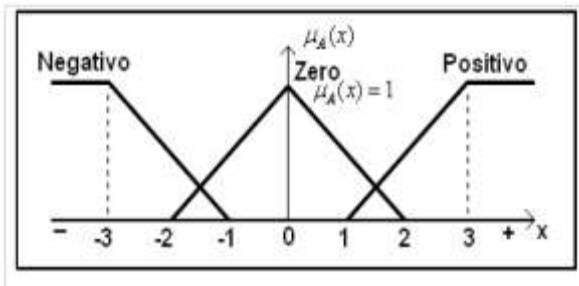


Figure 2. Membership functions and terms of linguistic variable

Operations of Union (U), Intersection (∩) and Complement of the fuzzy sets will be performed which was based on their membership functions as the well-known expressions as below

$$\mu_{A \cup B}(x) = \max[\mu_A(x), \mu_B(x)] = \mu_A(x) \vee \mu_B(x)$$

$$\mu_{A \cap B}(x) = \min[\mu_A(x), \mu_B(x)] = \mu_A(x) \wedge \mu_B(x)$$

$$\mu_{\neg A}(x) = 1 - \mu_A(x)$$

operators can be used as logical connectives AND (∧) and OR (∨). Rules can be written using these connectives and fuzzy sets:

- Rule 1: IF X is A1 AND Y is B1 THEN Z is C1
- Rule 2: IF X is A2 AND Y is B2 THEN Z is C2

where X, Y and Z are linguistic variables, A1, A2, B1, B2, C1 and C2 are terms (fuzzy sets).

IV. DESIGN OF THE PROPOSED SYSTEM

In this figure when the proposed system connected to the whole setup .And after that the application were check i.e. the suspension system. So for that the ANFIS algorithm were design and implement it on the FPGA using the VHDL coding.

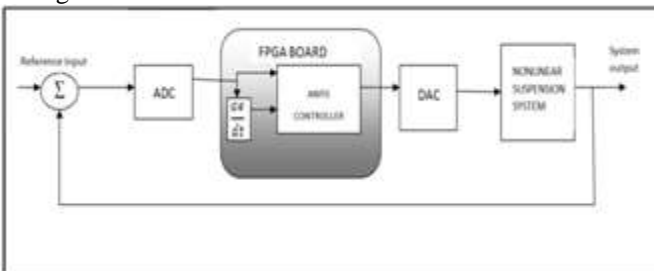


Figure 3. Layout of FPGA board with whole system

In this paper ANFIS algorithm were study and design for the application. The darker portion of the above fig is the main goal. That is try to investigate on the FPGA board were the VHDL coding for ANFIS algorithm. The optimal values of the ANFIS model have been used to implement and design the FPGA boards (four FPGA boards have been designed, one for each NF controller). Figure 3 shows the connection of the FPGA board with process system that is with the actual hardware system. To get the appropriate analysis of the application which was used on the vehicle will be examined when the setup will be connected to the vehicle. Therefore the active suspension system should be used to solve the conflict. And the algorithm will help to examine

that system. Most of these methods mainly apply the Back-Propagation

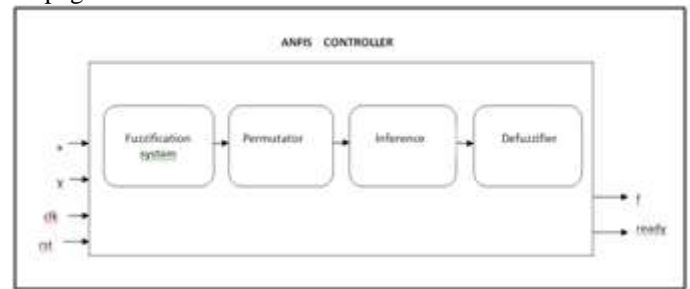


Figure 4. ANFIS block diagram

(BP) learning algorithm for adjusting the parameters of the neural network.

1. Fuzzifier:

The 1st subsystem is the Fuzzifier. In the fuzzifier it collectively form of the following block: comparator, flip flop and the synchronizer. Fuzzification is the process of transforming crisp values into marks of membership for linguistic terms of fuzzy sets. The flip flop for the delay .Comparator for compare the membership function with the data and finally the synchronizer was there for valid in and flip flop out . In the design summary of the fuzzifier the number of inputs and the output and the area occupied on the IC were defined by the LUT and IOB'S in the summary

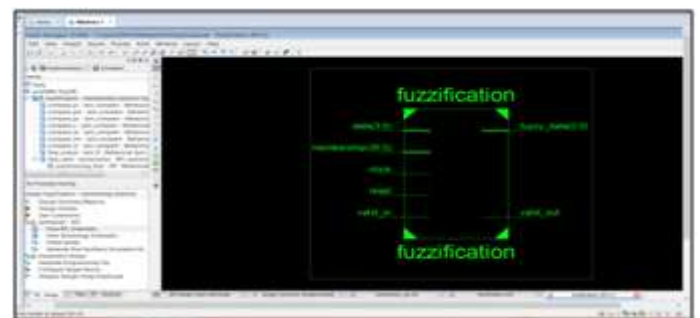


Figure 5. Fuzzifier block diagram

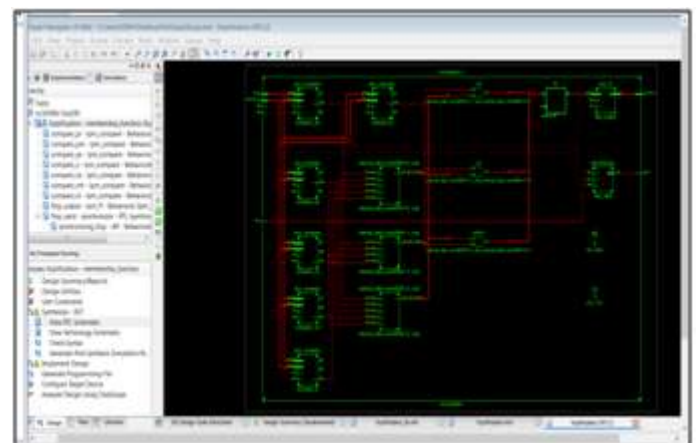


Figure 6. Fuzzifier block diagram (internal blocks)

Device Utilization Summary (estimated values)			
Logic Utilization	Used	Available	Utilization
Number of Slices	4	4650	0%
Number of Slice Flip Flops	7	9312	0%
Number of 4 input LUTs	1	9312	0%
Number of bonded I/Os	10	60	15%
Number of GCLAs	1	24	4%

Design summary of fuzzifier

2. Permutator:- Mainly the permutator block has two primary functions: to store the membership values that are calculated by the previous subsystem and later to make it in a serial fashion, each possible permutation so that all membership values can be multiplied by the next subsystem. So the data in from the previous was applied and then the shifting of the data was done in the given data.

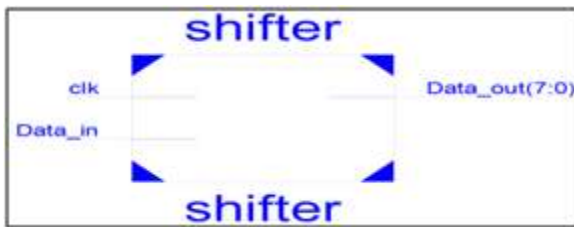


Figure 7 Permutator block diagram

3. Inference: This 3rd subsystem is composed of stages and a controller. I Figure 7. Permutator block diagram multiplied by obtaining the weight or the rule in the rotation. The data obtained from the previous sub system was multiplied and then transfer to the next system block. and the simulation result also shown in the “fig” below .



Figure 8. Inference block diagram

4. Defuzzifier:- The last subsystem in which the Defuzzifier composed of a divider and a controller. Its function that described by the following equation

$$f = \frac{num}{den} = \frac{\sum_i r w_i}{\sum_i w_i} \dots(6)$$

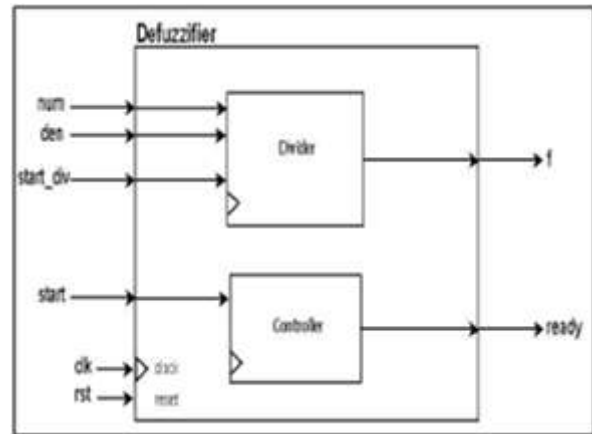


Figure 9. Defuzzifier block diagram

V. CONCLUSION

In the above paper study the some parameters of vehicle related to the suspension using the PID controller and the vehicle behaviour during lane change. A number of models and controllers have been developed in attempts to enhance and improve the riding and handling qualities in modern vehicles. In the above paper ANFIS algorithm were proposed and used the FPGA. To improve the vertical displacements at each corner of the vehicle to reach low level. The quarter vehicle models only deal with vertical motions of the vehicle body and do not take into account the pitch and roll motions. Due to the complex mathematical relationships in nonlinear active suspension system, most of those researchers approximate the active suspension systems as linear models when designing the controllers. Therefore the very fast and accurate controller was trying to developed to meet as much control objectives as possible. For nonlinear behaviour ANFIS algorithms were try to investigate using the VHDL coding for the model. In the above simulation of the fuzzification is shown and also the permutator and inference was shown.

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