FPGA Implementation of Fuzzy Logic Controller For Elevator Group Control System

Rajesh Kumar Patjoshi
Electronics and Commonucation Engineering,
National Institute of Technology, Rourkela, India
Email : rajeshpatjoshi1@gmail.com

Kamala Kanta Mohapatra
Electronics and Commonucation Engineering,
National Institute of Technology, Rourkela, India
Email : kmaha2@rediffmail.com

Abstract : -

This paper concerns on implementation of a fuzzy logic controller (FLC) on a Field-programmable Gate Array (FPGA) system for intelligent control of elevator system. The search for an intelligent group controller that can satisfy multicriteria requiements of an elevator group control system has become a great challenge for researchers. This proposed approach is based on algorithm which is developed to reduce the amount of computation required by focusing only on the relevant rules and ignoring those which are irrelevant to the condition for better performance of the group of elevator system. Simulation was carried out by considering two inputs i.e. elevator car distance and number of stops. Based on these data the Fuzzy Controller can calculate the Performance Index (PI) of each elevator car. And the car which has maximum PI gives the answer to the hall calls. This would facillitate reducing the average waiting time (AWT) of the passenger.

Key words :- ***Fuzzy Logic, Intelligent control, Performance Index Average Waiting Time (AWT).***

I. INTRODUCTION

In control engineering analysis and design, FPGA based Fuzzy logic control (FLC) for elevator group system, has been attractive because it offers a compromise between special purpose ASIC hardware and general purpose processors. This purposed FPGA based Fuzzy Logic Controller for elevator group system can reduce the design development cycle, simplify the design complexity, and also improve the control performance that simplifies implementation and reduces the hardware costs.

Many researchers have reported about Fuzzy Logic Controller for group control of elevator system[2]. They described the validation of five dispatching algorithms for elevator system that were implemented on spartan-3 FPGA based board in an integrated approach reducing the area and improving performance. The overall system is composed of several LCS, which implement the dispatching algorithm. The EGCS-based Fuzzy Logic (FEGCS) runs on a PC and under different traffic situation determines the best algorithms to be run in each LCS in order to reduce the avergae waiting time of passenger and also reduces the power consumption.

Elevator group controller based Fuzzy Logic Framework with self tunning scheme for reducing the average waiting time (AWT) of passenger is presented in the literature[1].

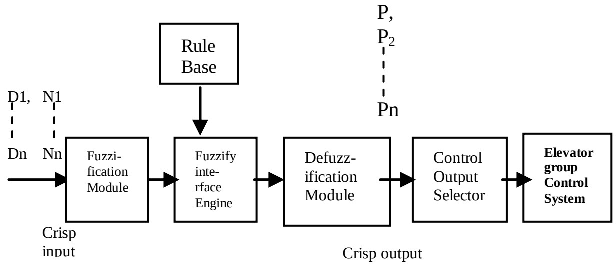
Fuzzy Controller described in [1], has evaluated six set of rule and each rule set consists of a different number of rules (between 12 and 14). Hence fuzzy computation time is large for response to hall call even if it is a self tuning fuzzy controller.

In the present investigation we present a conventional FLC that uses reduced number of rules that facilitates reduction of computation time of the FLC. In this work, Simulation was carried out by considering two inputs i.e. elevator car distance and number of stops.

The design is fit on Spartan 3E (XC3S500E) having maximum operating frequency is 35.754 Mhz. the design uses 35% slices, 15% slices Flip flop, 19% 4 inputs LUTS and 35% IOBs.

II. DESIGN METHODOLOGY OF PROPOSED FPGA BASED FUZZY LOGIC CONTROL FOR ELEVATOR GROUP SYSTEM

A conventional FLC is designed on a simple concept by reducing the number of rules that facilitates reduction of computation time of Fuzzy Logic Controller for better performance of elevator group control system. Basically the FLC is divided into four components. Figure-1 shows the diagram of the Basic Structure of Proposed FPGA based Fuzzy Logic Controller for intelligent control of Elevator System. It consists of Fuzzification Module, Rule Base, Fuzzy Interface Engine, Defuzzification Module.



D : Car Distance N : No.of Stops

Fig. 1 : Basic Structure of the proposed Fuzzy Logic Cotroller for Elevator Group Control System

ISBN:978-81-906109-7-1

A. Fuzzification Design Module for the proposed FPGA based Fuzzy Logic Controller for Elevator Group Control System.: -

The fuzzification block has five outputs, one for each fuzzy value defined in the inputs Universe of Discourse. However, the fuzzification process entails that, for any single crisp value of the input X_i, only two adjacent fuzzy values are significant (with non-zero-membership values). By ignoring the insignificant fuzzy values, the number of output signals can also be reduced from five to two. The possible combinations of significant fuzzy values for an arbitrary inputs are :

B_i^1 and B_i^2; and B_i^2 and B_i^3;

It is found that using just three variables, ADR_i, B_i_A and B_i_B, all the combinations can be sufficiently represented for any value of x_i as shown by the following statements:

ADR_i = "00" : B_i_A = B_i^1 , B_i_B = B_i^2

ADR_i = "01" : B_i_A = B_i^2 , B_i_B = B_i^3

ADR_i = "10" : B_i_A = B_i^3 , B_i_B = B_i^4

ADR_i = "11" : B_i_A = B_i^4 , B_i_B = B_i^5

Figure-2 illustrates how these conditions correspond with the universe of discourse.

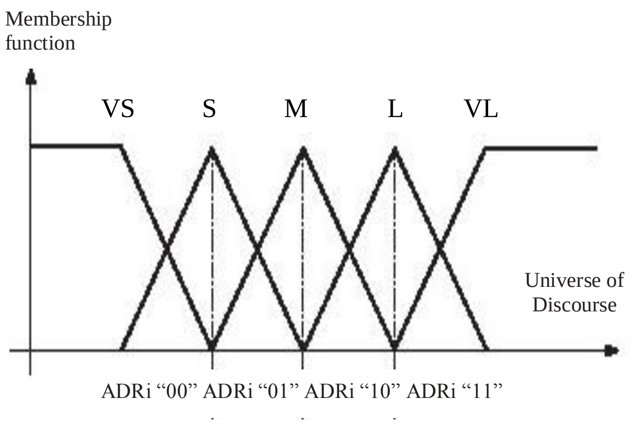


Fig. 2 : Input Fuzzy set

B. Mini FAM Table :-

The FAM table of the FLC design is shown in table-I. here we describes an algorithm which is developed to reduced the amount of computation required by focusing only on the relevant rules and ignoring those which are irrelevant to the condition in question,. It is known that for every set of inputs, only for fuzzy rules are relevant at any one time.

An easier way of explaining the technique is to imagine the entire FAM table to be covered from view. Access to the content of the FAM table is only allowed through a small window and only four adjoining rules can be viewed through this window at a time. Therefore, instead of having to access 25 rules, the inference engine only has to access four rules during every computation. The window can move around the FAM table and its position is identified by an index *j* defined as:

ADR1 = "00" & ADR2 = "00" → *j* = 0
ADR1 = "00" & ADR2 = "01" → *j* = 1
ADR1 = "00" & ADR2 = "10" → *j* = 2
ADR1 = "00" & ADR2 = "11" → *j* = 3
ADR1 = "01" & ADR2 = "00" → *j* = 4
ADR1 = "01" & ADR2 = "01" → *j* = 5
ADR1 = "11" & ADR2 = "11" → *j* = 15

There are sixteen 'window positions' altogether and the first six are shown in Fig.3. The shaded blocks are the rules which are considered relevant for the input conditions corresponding to the index j. To distinguish the 'windowed' view of the FAM table from the original table, the first is referred to as the 'Mini' fuzzy associative memory (FAM) table. When the window technique is applied to the FAM table in the Table I, it is observe that number of the mini-FAM tables are identical (e.g. J=1, J=4) out of the sixteen mini–FAM tables, only seven unique tables are formed.

Table-I (FAM Table of the FLC Design)

Ele_car_dist / Ele_no_sto	VS	S	M	L	VL
VS	PVB	PB	P	PS	Z
S	PB	P	PS	Z	NS
M	P	PS	Z	NS	N
L	PS	Z	NS	N	NB
VL	Z	NS	N	NB	NVB

NVB	Negative Very Big
NB	Negative Big
N	Negative
NS	Negative Small
Z	Zero
PS	Positive Small
P	Positive
PB	Positive Big
PVB	Positive Very Big

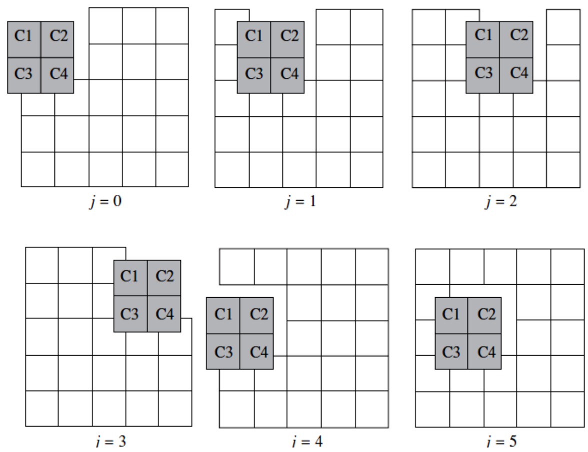


Fig.3 : Mini FAM Table

ISBN:978-81-906109-7-1

C. Defuzzification algorithm :-

The function of the defuzzificaition is to convert the fuzzy output value of the control system into the corresponding crisp value of the membership function shown in fig.4. This is achieved using the weighted average defuzzification method. This defuzzification operation requires several multipliers and a divider. Behavioural modelling in VHDL supports multiplication and divi-sion but these operations are complicated to realise in the systhesis and implementation stages.

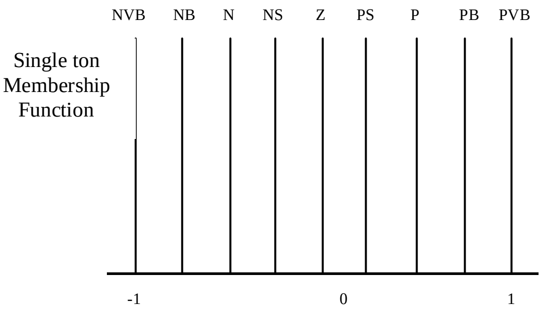


Fig. 4 : Output Fuzzyset

In the proposed approach, only cosider the four significant rules consequents are considered. Therefore, the number of rule-consequnets to be aggregated is reduced but the allocation of correct weightings for the significant output values becomes slightly more complicated. From the tables in Fig.3 it is obvious that regardless of the **WIN** value, the consequents C2 and C3 always point to the same fuzzy value (e.g. when **WIN** = “0000”: C1→PVB, C2→**PB**, C3→**PB**, C4→P). This implies that only C2 and C3 have to be aggregated, hence:

DA = C1
DB = max[C2, C3]
DC = C4

Where DA, DB and DC represent the membership function of the output fuzzy values. Thus the modified output fuzzy set is shown in figure 5,

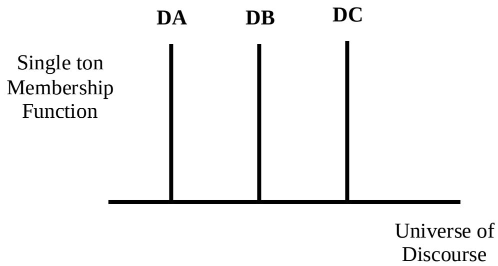


Fig.5 : Modified output fuzzy set

III. DESIGNED METHODOLOGY FOR ELEVATOR GROUP CONTROLS

Figure-6 shows the process of selecting the most suitable car to answer a hall call through the FLC system. This paper considers the up-down call button system when a hall call is registered, relevant data from all cars in the group are needed for computation of the value of the input variables. The data required from every car are, its present position in the building, motion status, speed direction of travel.

Here we use two input variables for fuzzy evaluation they are the car distance and number of stops. Their definitions are as follows : -

1) **Car distance** : The distance travelled by car to move from its present position to a hall call floor when a hall call is registered.

2) **Number of stops** : The number of stops of floors a car has to stop at to load or to unload passengers before a hall call floor is reached.

For every car in the group, the values of the two input variables are calculated based on the data supplied by each car controller. The calculated values of each car are then processed by the FLC and from fuzzy evaluation, a perfor-mance index (PI) is assigned to each car. The PI denotes the suitability of the car to answer a hall call at a particular instant, the car with the highest PI value is considered the car most suitable to attend to the hall call.

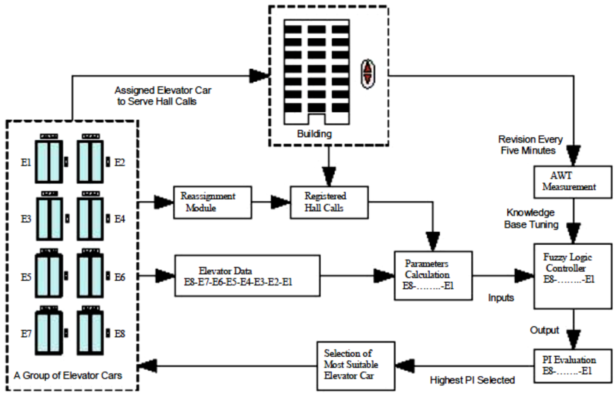


Fig. 6 : The process flow for the elevator dispatching strategy with the use of a fuzzy logic controller

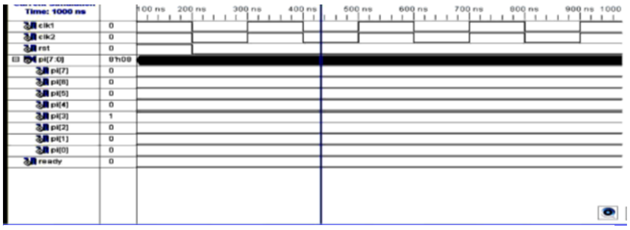
IV. SIMULATION RESULT AND FPGA IMPLEMENTATION

A. Simulation Detail

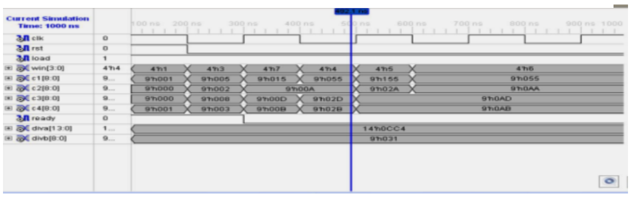
Parameters

Number of floors : 40.
Number of elevator Car : 8.
Floor height is 4 mtrs.
Number passenger per floor in 5 minutes : 40.
Number of FLC run per Traffic stuation : 13.
Number of Stops to hall call floor is 20.
Elevator casr distance from hall call floor is 100mtr.

We consider here two inputs i.e. Elevator Car Distance and Number of Stops. Based on these datas the fuzzy controller can calculate the performance index (PI) of each elevator’s car and evaluate the maximum (PI) of each car, the car which has the largest PI donates the suitable car to answer a hall call at a particular instance. Base on the data given to the input of fuzzifier, elevator car 3 has the highest PI to response the hall calls, which is shown in simulation result in figure-7.



Simulation Result for PI evaluation



De-fuzzification Result

Fig.7 : Output Simulation Result

Based on these data the average waiting time of the passenger become 48 sec for 40 floors, whereas this time was taken to be 52 sec for 35 floors [1]. The average waiting time is calucalted based on the average traffic flow in particular time instance i.e.morning *(8am to 10am)* and evening *(5pm to 7pm)* and computation time of the fuzzy controller. Table-II show the comparison result between proposed approach and 35 floors which was described in [1].

Table-II

AWT	***Time***
Average Waiting Time of proposed approach for 40 floors.	48 Sec
Average Waiting Time of proposed approach for 35 floors described in [1].	52 Sec

B. FPGA Implementation :

The design of fuzzy logic controller for group of elevator control system is implemented using VHDL. Synthesis process has performed using Xilinx tools[6] for synthesizing the compiled VHDL design codes into gate level schematics. The VHDL codes are synthesized for converting into RTL view of the FLC architecture as shown in figure 8. The Technology mapping has chosen in this project from Spartan 3E (xc3s500E) with FG320 package and a speed grade of -4. The synthesized schematic is also simulated to ensure the synthesized design functions. Table-III shows the device utilisation summary of the FPGA based fuzzy logic controller for inteligent control of elevator group system.

Table - III : Device Utilisation Summary

No. of slices	1610 out of 4656	35 %
No. of slices flip flop	1415 out of 9312	15 %
No. of 4 input LUTS	1826 out of 9312	19 %
No. of Bonds IOBs	81 out of 232	35 %
No. of GCLK	1 out of 8	13 %
Max. freuqncy, Total memory uses Minimum period	35.75MHz 206524 kilobyte 28.855 ns	

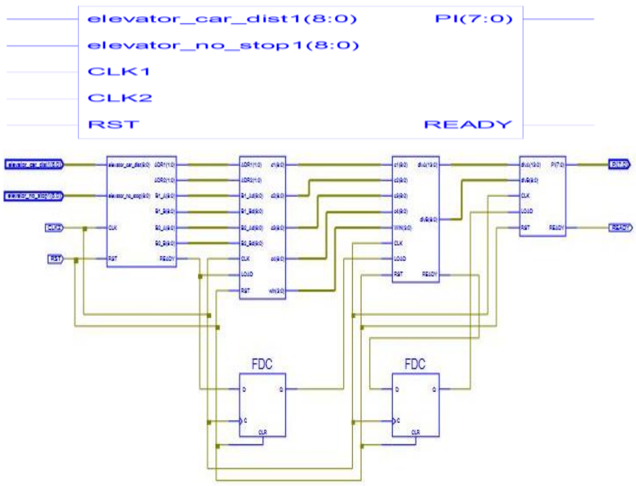


Fig. 8 : RTL view of the FLC Arhitecture

V. CONCLUSION

This paper presents an approach for the implementation of a fuzzy logic controller for elevator group control system on FPGA using VHDL. The controller for elevator group control system is implemented on a Xilinx Spartan-3E FPGA . The implementation of the fuzzy logic controller is very straight forward by coding each component of the fuzzy inference system in VHDL according to the design specifications. The design of the FLC is highly flexible as the membership functions and rule base can be easily changed with reduced rule techniques. Because of the reduced rule techniques the computation time of the fuzzy controller is reduced and elevator group control system gives faster performance by reducing the average waiting time (AWT) of the passenger is reduce upto 48 seconds.

VI. REFERENCE

1) J. Jamaludin, N.A. Rahim, W.P.Hew, “Development of self tunning fuzzy logic controller for intelligence control of elevator system” Journal of Engineering Applications of Artificial Intelligence 22 (2009)1167–1178.

2) Daniel M. Munoz, Carlos H. Llanos, Mauricio Ayala-Rincon, “Distributed Approach to group control of elevator systems using fuzzy logic and FPGA implementation of dispatching algorithms”, Journal of Engineering Applications of Artificial Intelligence 21 (2008)1309–1320.

3) Daijin Kim, member, IEEE “An Implementation of fuzzy Logic Controller on the Reconfigurable FPGA system,” IEEE Transactions on industrial Electronics, Vol.47, No.3, June 2000.

4) Gudwin, R., Gomide, F., Andrade Netto, M., 1998. “A fuzzy elevator group controller with linear context adaptation”. In: Proceedings of FUZZ-IEEE98, WCCI’98—IEEE World Congress on Computational Intelligence, Anchorage. IEEE, Alaska, USA, pp. 481–486.

5) Daniel M. Munoz Carlos H. Lianos, Mauricio Ayala-Rincon Rudi van Els, Renato P. Almeida, “Implementation of Dispatching Algorithms for Elevator Systems using Reconfigurable Architectures” IEEE Conference 2007 February.

6) Xilinx ISE 10.1 Software manuals www.xilinx.com.

7) Fuzzu Control System Design and Analysis : A Linear Matrix Inequality Approach by Kazuo Tanaka, Hua O. Womg, John Wiley and Sons Publicatins.

8) Fuzzy Controller by Leonid Rezmik Victoria University of Technology, Melbourne, Australia, Newnes Publication.