Development of a Fuzzy Chip for Predicting the Confidence level of Soldiers in the Army Vehicle

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Abstract— **The army vehicles have to go to different ranges and different environmental conditions as compared to the conventional vehicles. The safety of soldiers driving army vehicles is a big challenge. It is important to continuously monitor the conditions of the environment so as to give confidence to the soldiers whether they feel safe under those conditions. A fuzzy model is developed to predict the soldiers' confidence. A simplified version of the model is implemented using a fuzzy logic toolbox. The procedure for the development of such a chip is given in this paper. It is hoped that such chips, when put on the dashboard of the army vehicle will guide and advise the soldiers for the upcoming conditions.**

Keywords— **Army Vehicles, Soldiers confidence metrics, Fuzzy logic, Matlab simulations, Soldier safety.**

I. Introduction

Recently, there is an increasing interest in the safety of the soldiers who drive army vehicles. These vehicles have to undergo various environmental conditions as well as go through different ranges. Such vehicles have to undertake different slopes. At any time, it is important to ensure a soldier's safety is maintained under different conditions. Although both electrical and mechanical parts are functioning correctly it may not be advisable for the driver to go under some condition which is unsafe. In this paper, it is suggested that the driver should have an indicator on the dashboard of the vehicle so that the driver can anticipate the prevailing condition. The indicator should give a confidence between zero and 1. If the confidence is less than say 0.8, the driver should try to avoid these conditions and find some alternative path to reach their destination.

In this paper, a Fuzzy logic approach is suggested. Fuzzy logic was proposed by Lotfi Zadeh in a classical paper in 1965 [1]. Soon after this paper, there was an increased application of fuzzy logic. Several conferences regarding fuzzy logic are held at various places across the world. A large number of books and journals have appeared in the literature using fuzzy logic [2]. The applications of fuzzy logic are increasing every day. In this paper, we suggest an approach by which we can predict the confidence of a soldier using fuzzy logic. The mathematical definitions in this area do not work because of the fuzziness in the attributes and hence, fuzzy logic is useful in this research.

There are different Types of Army Vehicles [3]. Some commonly used army vehicles are listed below:

- Main Battle Tank (Kings of Battlefield)
- Modern Combat Tank (The Backbone of Armed Force)
- Infantry fighting vehicle (Bringing the fight to the enemy)
- Armored Personnel Carrier (Riding to war in style)
- Self-Propelled artillery (Ranged Firepower On-the-Move)
- Artillery System (On-Calls Rain of fire) Page Layout

The rest of the paper is organized as follows: Section II gives the procedure we are following for building an integrated chip from the fuzzy rules. All the steps are explained with necessary diagrams. The field programmable gate array (FPGA) implementation and simulation results are given in Section III. Section IV gives concluding remarks.

II. Methodology

The flowchart showing the steps involved in developing the fuzzy integrated chip from the fuzzy rules are given in Fig. 1. The first step is the definition of the fuzzy rules. The confidence of the soldier depends on different attributes such as mobility of the vehicle, radio interference, visibility, the presence of obstacles in the path of the vehicle, and wheel/rail wear. The full model can be defined by considering all the input attributes. A block diagram showing all the inputs and output are shown in Fig. 2. In general, the confidence of the driver will be high when mobility and visibility of the vehicle are high. On the other hand, the confidence will be less, when the radio interference, the presence of obstacles, and wheel/rail wear are high.

For the digital design purpose, only two attributes as shown in Fig. 3, mobility and radio interference were taken. Mobility is defined as how good vehicle moves. The radio interference means the effect of radio waves on the system. In order to define the rules, a set of linguistic variables are defined [4, 5]. These linguistic variables are called membership functions. Seven membership functions were defined for each input and output. All the membership functions were assigned with a trigonometric membership function. The input and output crisp values are used in its normalized form.

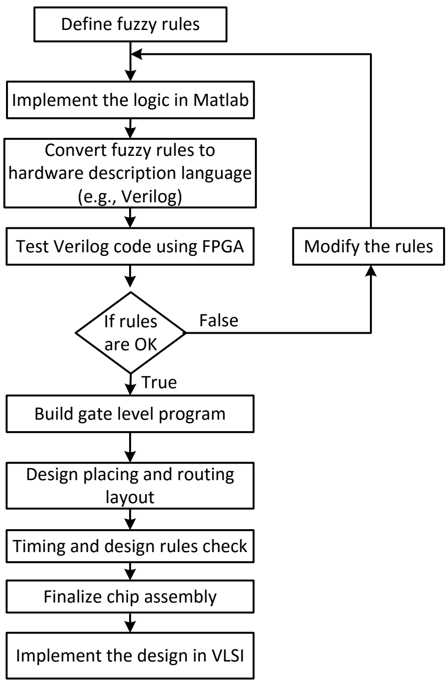


Fig. 1 Flow chart showing the procedure to design the integrated chip from the fuzzy rule set.

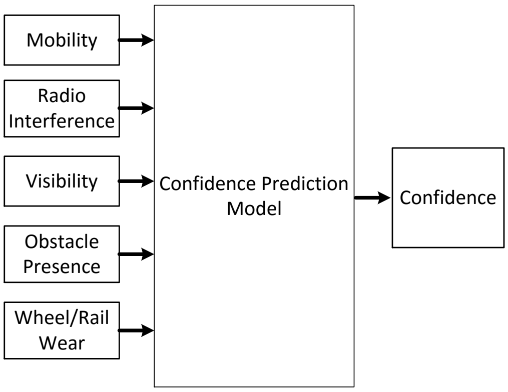


Fig. 2 Full block diagram of the fuzzy system

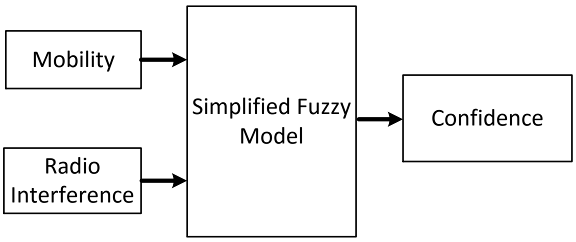


Fig. 3 Block diagram of simplified fuzzy system

The linguistic variables used for inputs and outputs, with corresponding numerical values are shown in Table I and II. A proper mathematical model is difficult to define for the confidence of the army vehicle driver. Here, we are defining a set of rules for defining the confidence by using the linguistic variables.

The rules used to define the confidence of the army vehicle driver are given in Table III. The rules can be written using IF - THEN, AND, and OR logical operators. For example, the first rule could be: “If mobility is very low (VL) and radio interference is very low (VL), then confidence is very low (VL).” Once the rule set is ready, the Matlab model can be designed using the fuzzy toolbox. Since, the fuzzy model to be implemented on an FPGA, the input values are considered in the range 0 to 255, instead of 0 to 1 [6]. Here the input and output are represented by 8 bits while implementing in FPGA. All the membership functions used in the Matlab model are trigonometric. The fuzzy model implemented in Matlab, the membership functions used, the rule set defined, and the surface graph are shown in Fig. 4 (a), (b), (c), and (d) respectively.

TABLE I
INPUT MEMBERSHIP FUNCTIONS

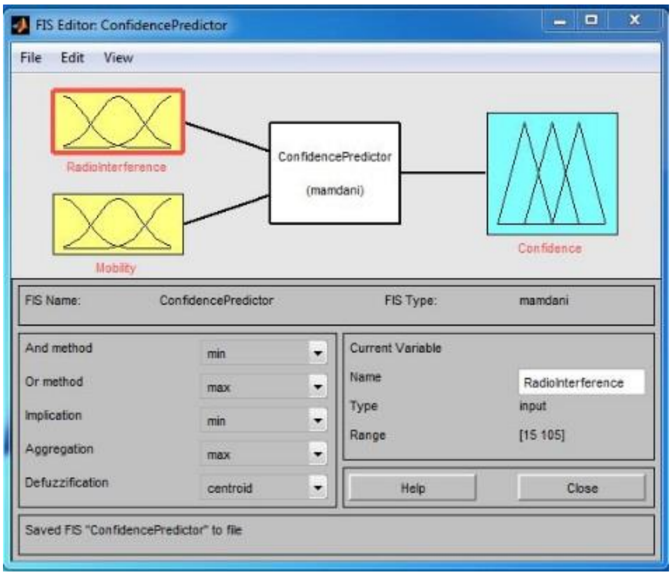
Mobility / Radio Interference	Variable Name	Meaning
< 0.15	VL	Very Low
0.15 - 0.29	L	Low
0.3 - 0.44	LM	Low Medium
0.45 - 0.59	M	Medium
0.60 - 0.74	RN	Far Normal
0.75 - 0.89	LN	Less Normal
> 0.90	N	Normal

TABLE II
OUTPUT MEMBERSHIP FUNCTIONS

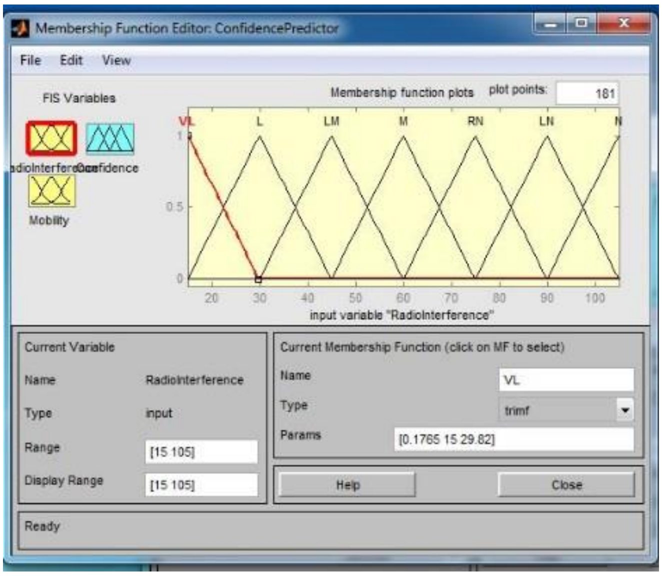
Confidence of the driver	Variable Name	Meaning
< 0.15	VL	Very Low
0.15 - 0.29	L	Low
0.3 - 0.44	LM	Low Medium
0.45 - 0.59	M	Medium
0.60 - 0.74	MH	Medium High
0.75 - 0.89	H	High
> 0.90	VH	Very High

TABLE III
RULE SET FOR FUZZY MODEL

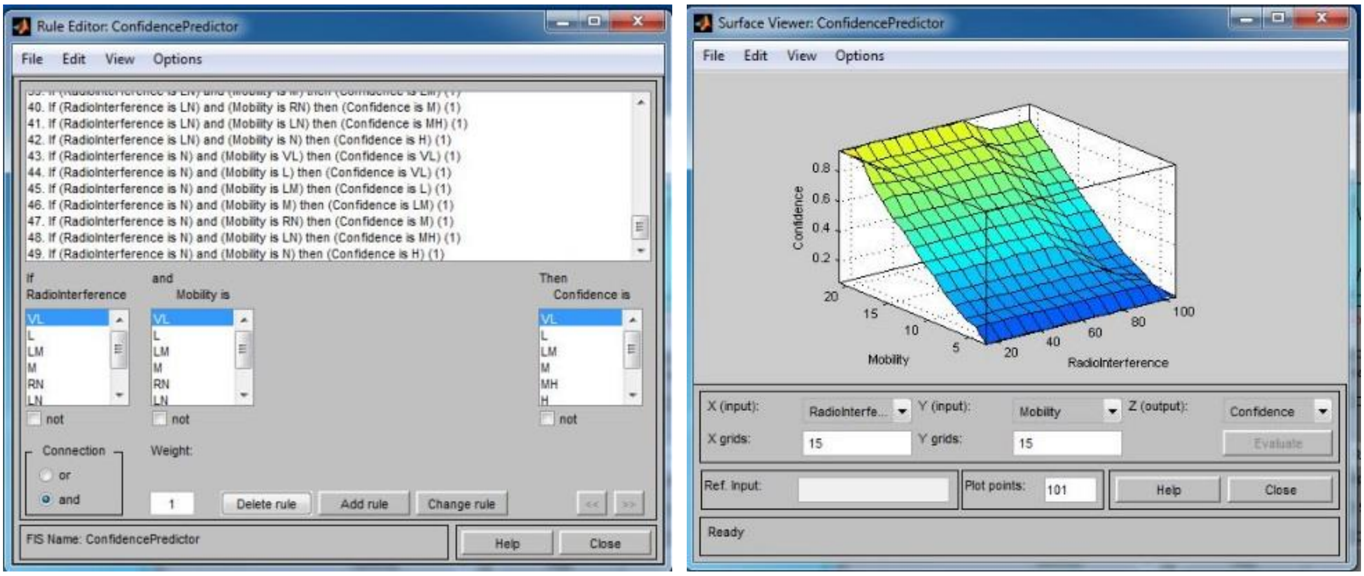
		Mobility						
		VL	L	LM	M	RN	LN	N
Radio interference	VL	VL	L	LM	M	MH	VH	VH
	L	VL	L	LM	M	MH	H	VH
	LM	VL	L	LM	M	MH	H	VH
	M	VL	L	LM	M	MH	H	VH
	RN	VL	L	LM	M	MH	H	VH
	LN	VL	L	L	LM	M	MH	H
	N	VL	VL	L	LM	M	MH	H



(a)



(b)



(c) (d)

Fig. 4 Fuzzy model implementation in Matlab (a) FIS editor showing inputs and output, (b) Membership functions of Radio Interference, (c) Rule set implemented in Fuzzy, and (d) the surface diagram corresponds to the rule set.

Once the fuzzy rules are tested in Matlab, the next step is to convert the fuzzy rule set into a hardware description language such as Verilog. The Verilog code is generated by fuzzifying the crisp inputs into fuzzy inputs, and applying the rule set on it. The inference module will give a fuzzy output, based on the rule set. This fuzzy output is then converted to a crisp output by the defuzzifier. A centroid method [7] is used to find the final crisp output.

III. FPGA Implementation and Final Chip Design

The Verilog code implemented can be tested in FPGA. We are using Spartan 3 starter board with Xilinx XCS200 FPGA [8]. ISE design suite is used to implement the Verilog code in FPGA. The design is simulated by giving different inputs through a test bench program. The results are given in Fig. 5. The synthesized diagram for the circuit is shown in Fig. 6. The Verilog code is now ready for designing an integrated chip. The Verilog code is first converted into a netlist which uses the standard cells from the standard cell library by using a synthesizing program. The synthesized Verilog code is then used in Virtuoso Encounter software to develop the abstract of the integrated chip. A 500nm technology [9] is used for designing the chip. The abstract design is used in Cadence Virtuoso to do the final layout with pad frame to develop the final integrated chip design as shown in Fig. 7. This chip design can be given to IC manufacturers such as MOSIS for fabrication.

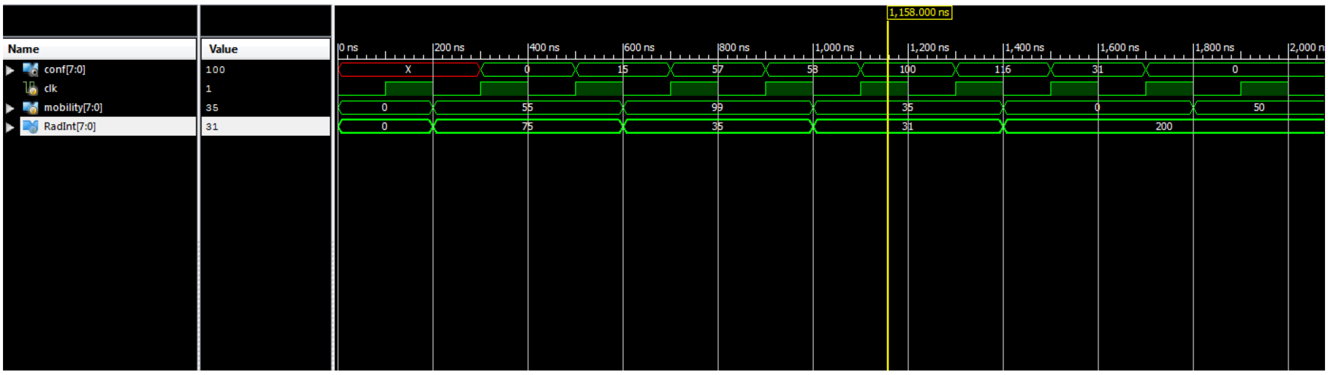


Fig. 5 Simulation results of the proposed fuzzy model with different set of inputs

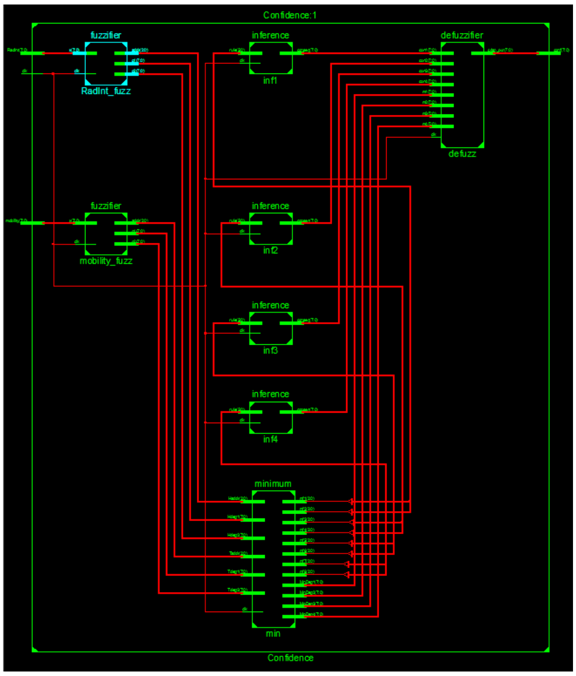


Fig. 6 RTL Schematic of the Verilog code

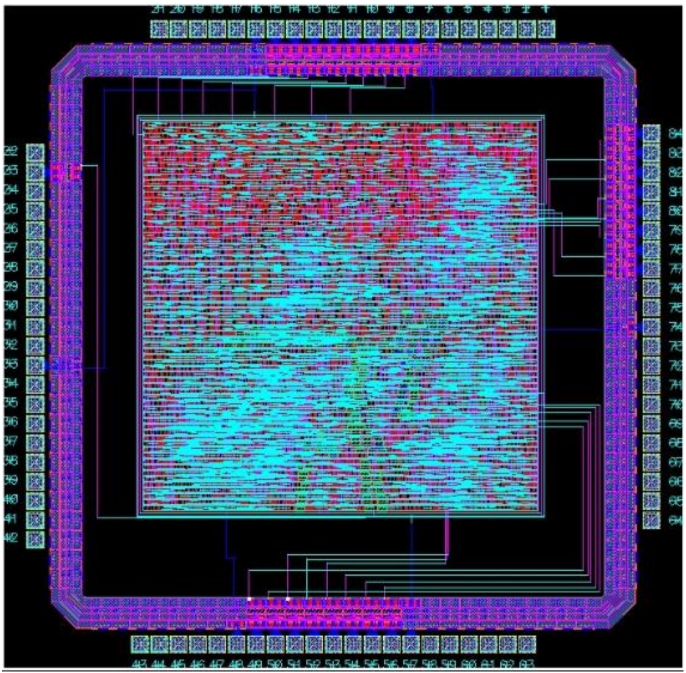


Fig. 7 Fuzzy chip design for predicting confidence of the soldier

IV. Conclusions

In this paper, we developed a fuzzy chip for predicting the confidence level of soldiers in the army vehicle. The fuzzy rules are developed by considering the mobility of the vehicle and radio interferences as input attributes and confidence level as an output. The fuzzy model is first implemented using Matlab fuzzy toolbox. The fuzzy rule set is converted to a Verilog code, and this code is tested in FPGA. The Cadence Virtuoso Layout design suite is used to design the final layout of the design. This is initial research in this area and a great deal of work is needed in order to make this chip as a real life chip which can be used in army vehicles. Future work is needed to develop a chip which could actually be put on army vehicles. The authors feel that such a study will pave a way for future and fruitful research in this important area.

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