

Fuzzy Logic Based Spectrum Sensing Technique for Cognitive Radio

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Abstract.- A cognitive radio is a type of intelligent radio system. It automatically detects available spectrum in a given frequency band. It automatically and intelligently changes its parameters. These parameters include transmission and reception. Therefore, frequent wireless communication is achieved for a given frequency band at specific location. There are multiple techniques used to sense and avail the spectrum in a cognitive radio. Most important among them are spectrum sensing, spectrum mobility, spectrum management and spectrum sharing. Many regulatory bodies in world have found that most radio frequency spectrum is utilized in efficiently. we all know that Cellular network bands are overloaded due excessive use but other bands (like for military and paging frequencies) are insufficiently utilized. Basically utilization of spectrum is dependent on two factors which are time and place. The crux of this research is to design and simulate a controller in MATLAB for SS using FLT. We chose two inputs one is mobility of SU and transmit power. Output is Saa. We defined membership functions for inputs and output. Analyze system and calculate outputs to get minimum percentage error difference between calculated and simulation end results.

Key Words: Ttransceiver (Transmitter & receiver), FL (Fuzzy Logic), FIS (Fuzzy Inference System), Secondary User (SU), FLC(FuzzyLogicController),Saa (SpectrumAccessAvailiability),SS(SpectrumSensing),FLT(FuzzyLogicTechnique)

1: INTRODUCTION

The term "fuzzy logic" was introduced by Lotfi A. Zadeh, Professor while he taught in University of California at Beckley in 1965. Fuzzy logic has been utilized in many sectors like different domestic goods, microwave ovens, vacuum cleaners and other intelligent systems. Unlike ordinary binary system, the range of values would be in between 0 to 1. We designed and implemented a controller which can replace complex algorithms and designs. At present, wireless communication system has allocated and fixed frequency spectrum. And this is not accessible for unlicensed users. Even, this spectrum is not in use. Regulatory bodies in the world have been considering whether to allow unlicensed users in licensed bands if they would not cause any interference to licensed users. Due to above discussion, overall scope of research on cognitive radio in enhanced for dynamic spectrum access

2: LITERATURE REVIEW

2.1 Cognitive Radio

Cognitive radio basically works in such a manner that it automatically adjust/adapts its parameters according to network and user demand. And this is achieved by complete reconfigurable wireless transceiver. Federal Communications Commission in the United States and Ofcom in the United Kingdom have found that most of radio frequency spectrum is inefficiently utilized. Many Cellular network bands are not completely utilized and are overloaded in many parts of the world. Basically, utilization of spectrum is dependent on time and place. Fixed and already allocated frequency bands don't allow other user to use it even when it is not being used. Regulatory bodies in world are considering whether to allow unlicensed users in licensed frequency bands without any interference. This research leads to cognitive radio for dynamic spectrum access. Actually Cognitive Radio systems access spare sections of the radio frequency spectrum. And it keeps monitoring the spectrum to ensure that this does not cause any undue interference. Designed Cognitive radio spectrum should be capable to detect any other transmissions, analyse it. Then it should be informed to central processing unit within the Cognitive Radio so that the required action can be taken [1].

Cognitive radio performs three main tasks. First is spectrum sensing second is spectrum analysis and third is spectrum allocation. The main function of Spectrum sensing is to get spectrum usage characteristics. While having multiple dimensions like space, frequency, time and code and determining what type of signals are occupying the spectrum [2].

In this paper, we propose a novel approach using Fuzzy Logic System (FLS) to control the spectrum access. The linguistic knowledge to access the desired frequency spectrum is based on three main factors. First, how much secondary user has spectrum utilization efficiency, second, its degree of mobility, and third, its distance to the primary user. This technique will choose a frequency spectrum which has maximum possibility to use frequency spectrum [3].

2.2 Spectrum Sensing Technique

Some studies have revealed that utilization of spectrum is dependent on two things. One is time and other is place. Already allocated frequency bands don't allow other users to use this band even when it is not being used. Many regulatory bodies in world are considering this point, whether to allow unlicensed users in licensed frequency bands without any interference. This research leads us to cognitive radio for dynamic spectrum access. Actually, Cognitive Radio systems access spare/unused sections of the radio frequency spectrum. Also, it keeps monitoring the spectrum to make ensure that this does not cause any undue interference. Designed Cognitive radio spectrum should be capable to detect/analyse any other transmissions in region. Then it should be informed to central processing unit within the Cognitive Radio so that the required action can be taken. [4]

In this work, a spectrum sensing controller is designed by using fuzzy logic in MATLAB. Cognitive radio performs following three main tasks. One is spectrum sensing, second is spectrum analysis and third is spectrum allocation. Cognitive Radio presents a technique for utilizing the spectrum holes. Spectrum usage has its characteristics. These characteristics have many dimensions like

1. Time
2. Space
3. Frequency
4. Code
5. Type of signals for spectrum. [5]

The opportunistic spectrum access has become the most feasible approach to achieve near-optimal spectrum utilization. Which is achieved by secondary users to locate and contact available frequency spectrum opportunistically. However, an immature spectrum access for secondary users can make different problems like inefficient spectrum utilization and increase interference to nearby users.

We have to minimize the call blocking and interference. Spectrum access in terms of linguistic knowledge is based on three descriptors namely

1. Spectrum utilization efficiency of the secondary user
2. Its degree of mobility
3. Its distance to the primary user.

The spectrum is chosen for accessing which is based on the maximum possibility for better utilization of the spectrum. [6]

2.3: Fuzzy Logic Technique

In this paper, We design a controller in which we have two inputs and one output fuzzy logic is MATLAB tool which is used to design a controller. Fuzzy logic technique is used to analyse nonlinear systems. It deals with those systems which are difficult to resolve using conventional mathematical models.

The concept of fuzzy logic to solve the problem has been reported first time by Lotfi Zedeh. He also reported the concept of linguistic variables. For designing, here we utilize mamdani model in fuzzy logic tool to control different parameters of cognitive radio.

As shown in figure that two parallel systems doing same control function. One is fuzzy logic base system and other is non fuzzy logic base system. In fuzzy logic design, we deals only three steps:- first is understand physical system. Secondly control requirement and the third is design the controller by using fuzzy rules. Simulate and implement design. Fuzzy logic includes different processes in itself such as

1. fuzzification
2. defuzzification

3. membership functions domain
4. Linguistic variables and rules

Domain determines the range of values in which membership of fuzzy is defined. The basic part of fuzzy sets is membership function. The relation between a domain value and its degree of membership is determined by membership function. Fuzzy logic has many similarities and differences with Boolean logic. Fuzzy logic performs Boolean logic results when all the fuzzy membership functions have range from 0 to 1. FL uses natural/common language techniques and variables. These are based on the degree of truth. And it is easier to understand for human beings.

Fuzzy control is based on fuzzy logic. FL provides us an effective means of confining, approximate, inexact nature of real world. The important part of this logic is linguistic control rules. Rules are defined by our requirements based on if-then statements. Then fuzzy logic controller provides an algorithm which convert linguistic control strategy into an automated control system. Fuzzy logic controller is an approach between mathematical control model and human decision making control/ approach [7].

In this paper work author design a control system for elid grinding . This control system avail fuzzy logic design consist of four inputs and matlab based fuzzy tool having output to control the system[8].

Ahmed .Zahoor. etl narrates the control system in this paper for Automatic night switch to operate the lightning ON/OFF according to the conditions and requirements. Fuzzy Logic tool is used for this designing. In this control system, two inputs light, fog and one output lamp[9] .

Ashraf.waseem.etl describes in this paper about simulation and designing of a fuel consumption control system with the help of fuzzy logic technique. This research can plays a vital role to enhance the performance of the fuelling system of the vehicles depending upon there speed and load. MATLAB based fuzzy-simulation is used to achieve the our goal[10].

Mushtaq.Z.etl explains the control system for liquid level control for many applications. our work is to control the liquid level of a container/boiler. PID and PI also been used to control the level of a tank. We used fuzzy logic technique for liquid .controller consist of two input one is level of fluid in the tank and drain/consumption of fluid from the tank. He used fuzzy inference system with specific defined rules by using valve as output[11].

Khan.saleem.etl describe the system for time control for industrial applications using fuzzy logic based DEV processing system [12].

3: MATLAB SIMULATION

Our (FLC) fuzzy logic controller consists of two input parameters and one output parameter. These parameters used for spectrum sensing technique for cognitive radio, there are many other important parameters that can also be used for the same purpose. We consider mobility of secondary users and transmit power as input for controller and spectrum access availability as an output parameter for FLC

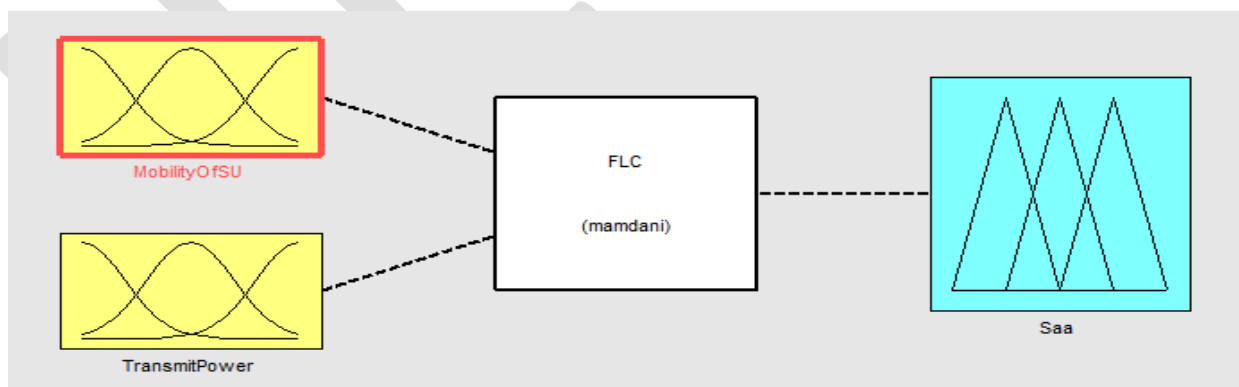


Fig 1: FLC model

Now we discuss input and output parameters separately with their specific ranges and membership functions. Mobility of secondary user having ranges from 0 to 100% .This range defines three membership functions and two regions. Three membership functions are slow from 0 to 50, Adequate (Adeq) from 0 to 100 and fast from 50 to 100. Region 1 having membership functions slow and Adequate and Region 2 Adequate and fast.

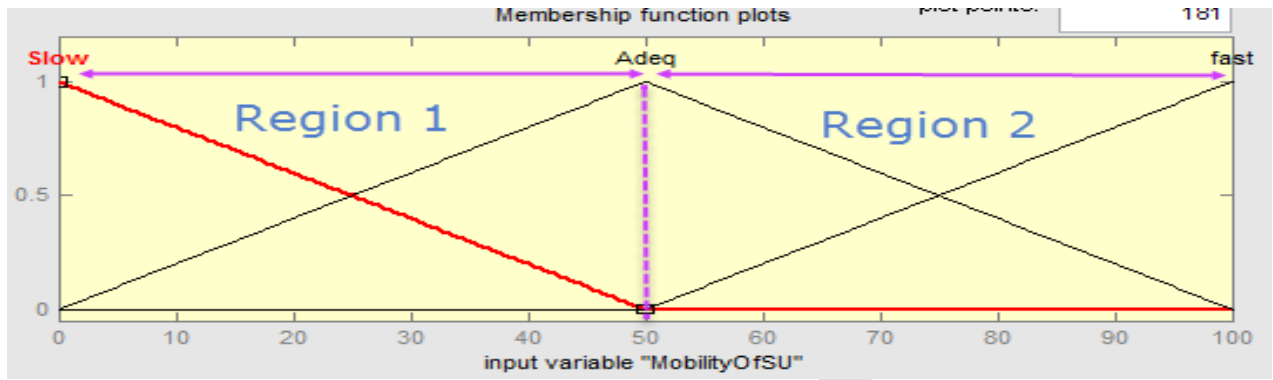


Fig 2: Membership functions of input Mobility of SU.

In second input parameter Transmit Power it consist of two regions and three membership functions. These membership functions are minimum (min) , Medium (med) , maximum (max) , having ranges 0 to 50 and 0 to 100 and 50 to 100. Minimum to Medium are in Region 1 and Medium to Maximum are in Region 2.

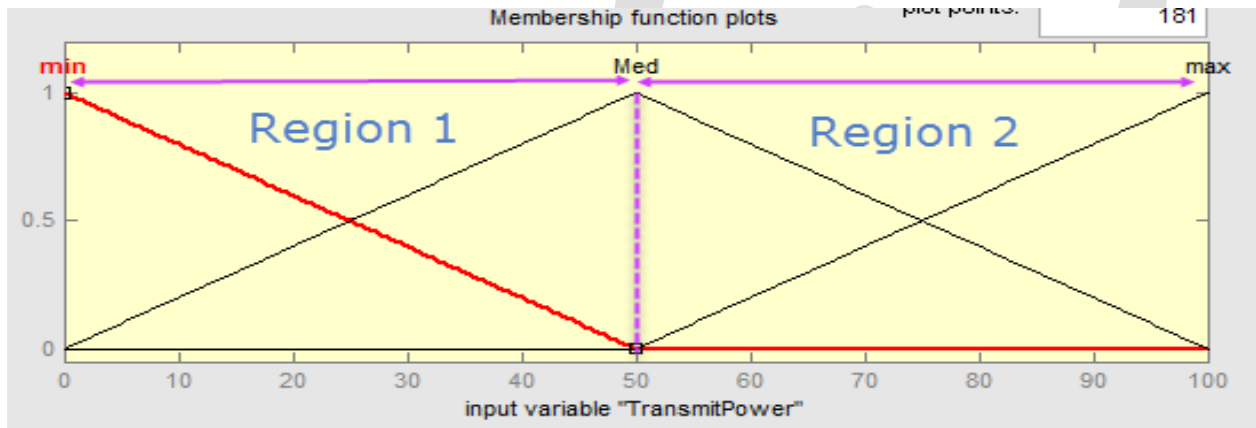


Fig 3: Membership functions of input Transmit Power

Output parameter for spectrum sensing of cognitive radio spectrum access availability. It also consist of three membership functions small, normal and large. Their ranges are from 0 to 50, 0 to 100 and 50 to 100.

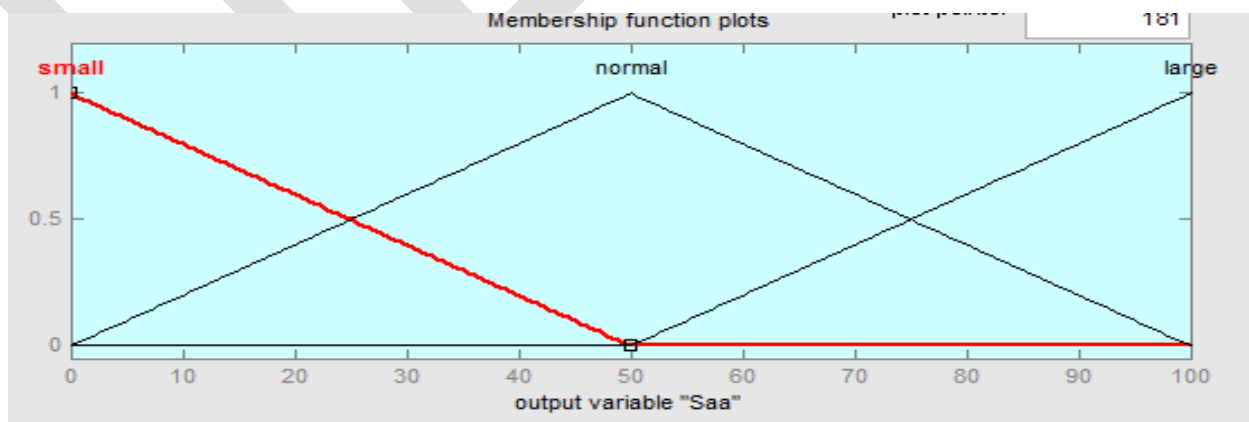


Fig 4: Membership functions of Output Saa.

| Membership functions | Ranges in % | Mobility of SU | Transmit Power | Spectrum Access Availability (Saa) |
|----------------------|-------------|----------------|----------------|------------------------------------|
| MF1 | 0 to 50 | Slow | Minimum(min) | Small |
| MF2 | 0 to 100 | Adequate | Medium (med) | Normal |
| MF3 | 50 to 100 | Fast | Maximum (max) | Large |

Table 1: Ranges of input and output membership functions

4: FUZZY RULES

The fuzzy rules upon which FLC behave depends upon ‘if’ and ‘then’ statements. These fuzzy rules can be find out with the help of formula

$$m^n = 3^2 = 9.$$

Here m = inputs memberships functions.

And n = total number of inputs.

| IF | | | THEN |
|-------|----------------------|---------------------|-----------------------------------|
| Rules | Mobility of SU(MOSU) | Transmit Power (TP) | Spectrum Access Availability(saa) |
| R0 | Slow | Min | Small |
| R1 | Slow | Med | Small |
| R2 | Slow | Max | Normal |
| R3 | Adeq | Min | Small |
| R4 | Adeq | Med | Normal |
| R5 | Adeq | Max | Large |
| R6 | fast | Min | Normal |
| R7 | fast | Med | Large |
| R8 | fast | Max | Large |

Table 2: Rules used in FLC

Fig shown below is fuzzy logic rules editor which is used to edit ,modify and arrange the fuzzy rules that will be used in FLC. We can also made different arrangement regarding the selection of OR & AND logic. Here we used AND logic between the rules. Controller will follow these rules to specify future decisions.

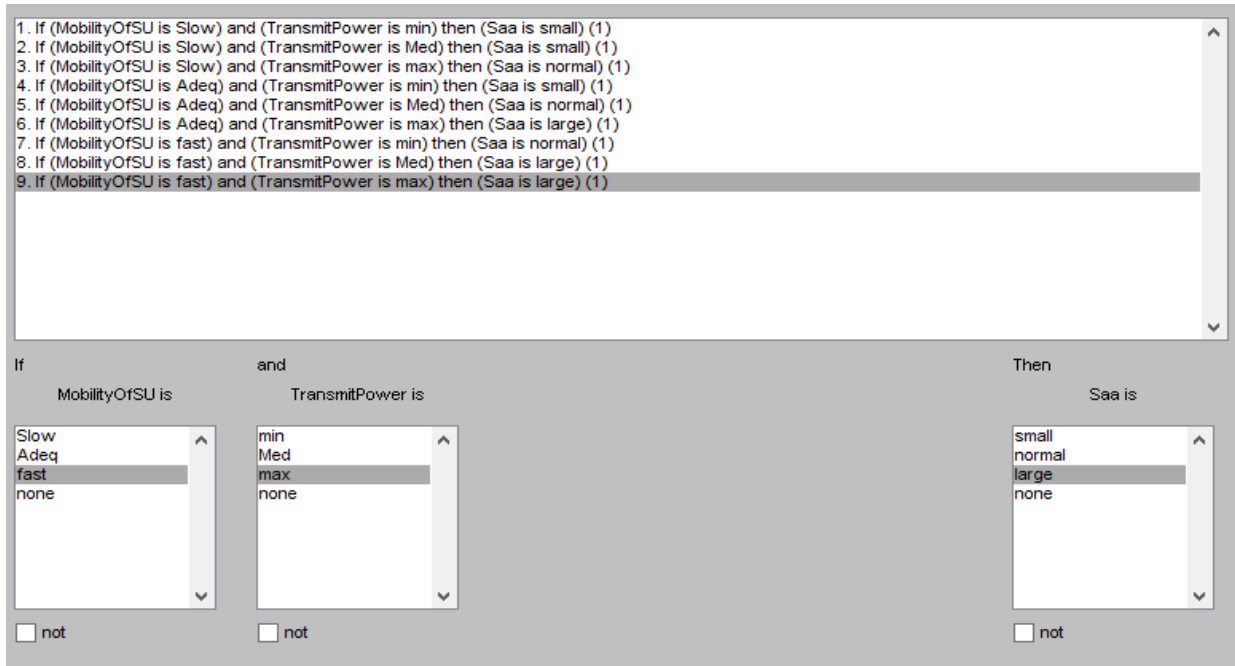


Fig 5: Fuzzy Logic Rules used in editor for FLC

The figure as below shows rule viewer with inputs and outputs values for the fuzzy logic controller. This figure is consider as a Mat lab simulated results for desired output.

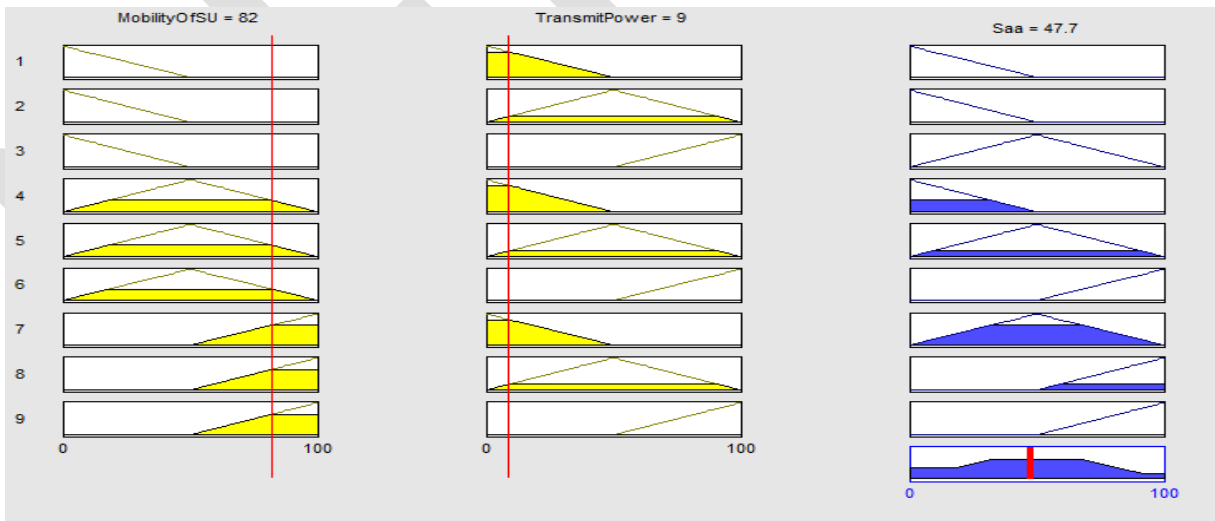


Fig 6: Rule Viewer for FLC.

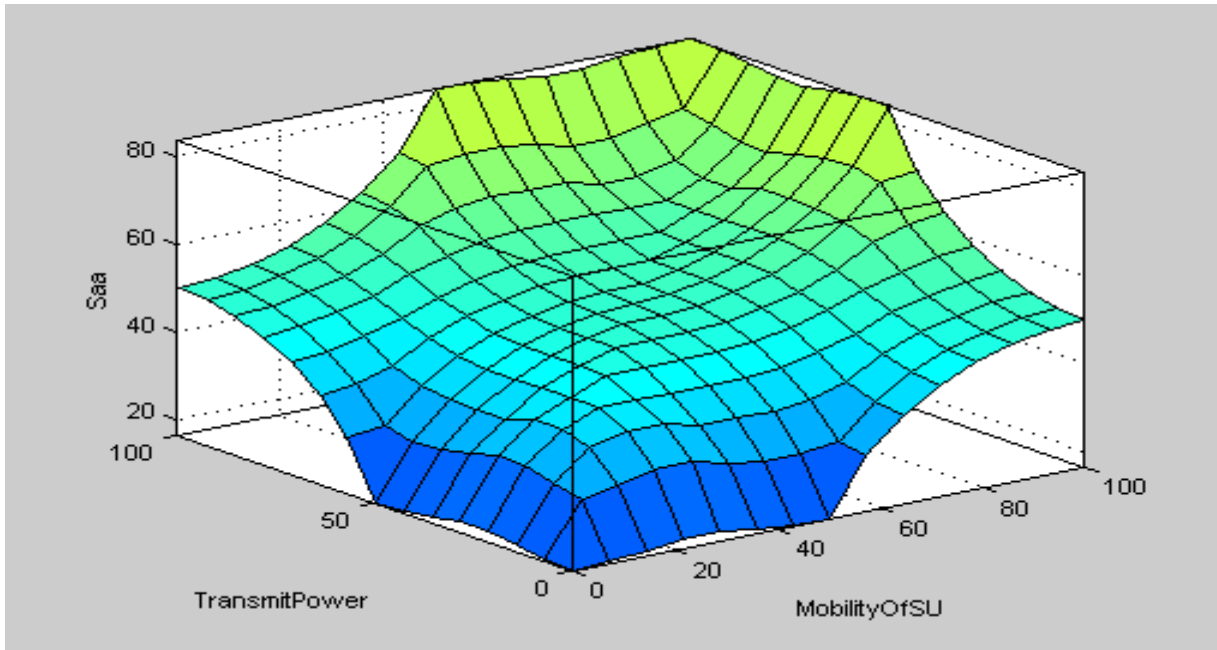


Fig 7: graphical overview of surface of Fuzzy Logic Controller

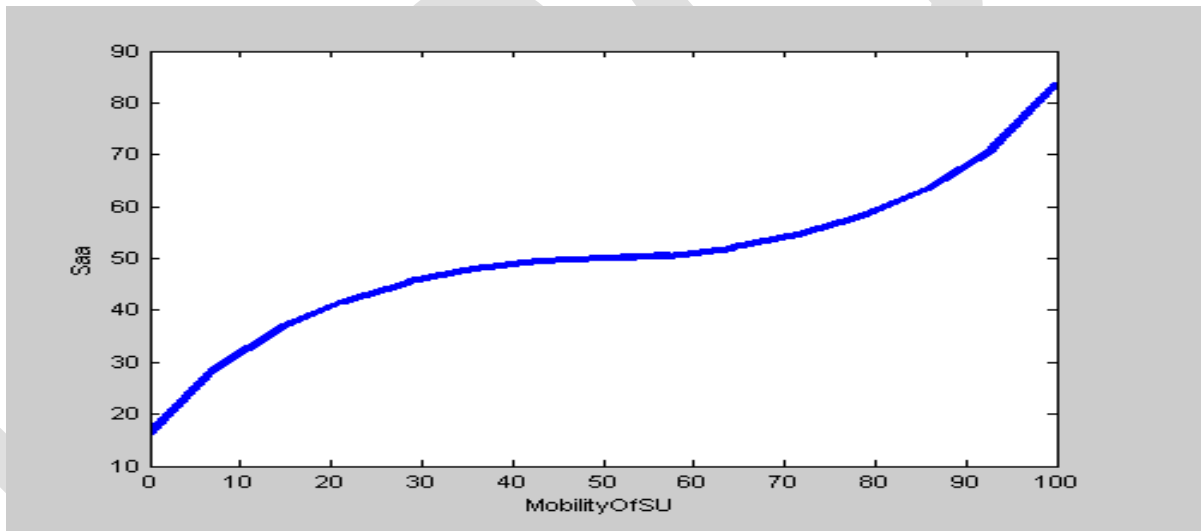


Fig 8: Two dimensional graph of Input w.r.t Output.

5: MATHEMATICAL ALGORITHM DESIGNING FOR FLC

The input and output values are in percentage the software oriented values are as below

MobilityofSU = 82, Transmit Power = 9, and output value = 47.7. As there are two different model in a fuzzy logic system Sugeno and Mamdani we are using Mamdani model for designing most of the nonlinear problems can be achieve by this.

$$(\sum Ri * Si / \sum Ri) * 100.$$

5.1) Mobility of Secondary Users (SU)

It is an input parameter for having values in percentage having two regions and three membership functions slow, Adeq and fast. We consider a value which is in region 2 and the membership functions involve in this region are Adequate (Adeq) and fast. We firstly find the linguistic variables separately for Mobility of Secondary Users its linguistic variables are f1 and f2.

The figure as below is the surface viewer graphical over view of the effects and behaviors of respective inputs with desired output. Here is the figure showing the nonlinear behavior of input without put. Each input behaves in a same manner separately with their output.

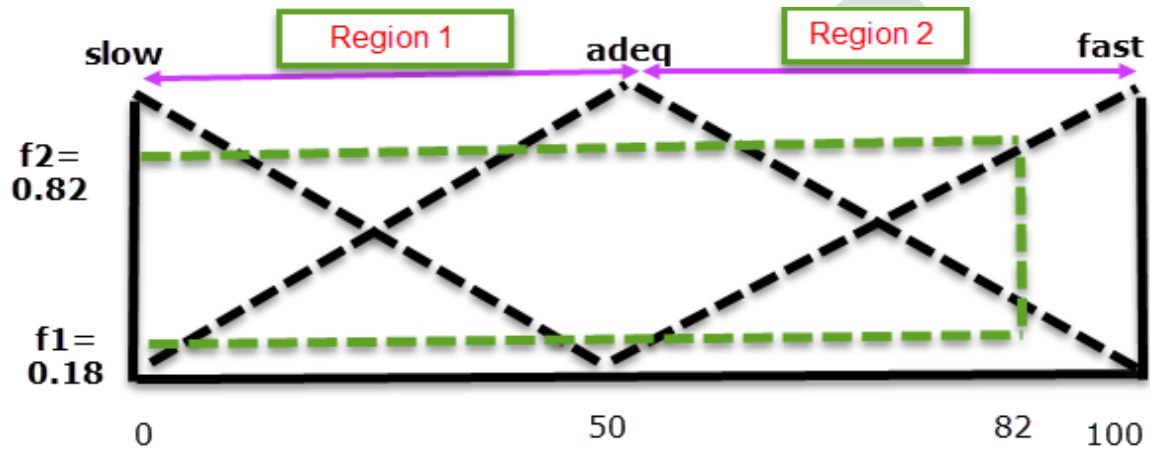


Fig8: Linguistic variables f1 and f2 for Mobility of SU

$$f1 = 100 - 82/100 = 18/100 = 0.18$$

$$f2 = 1 - 0.18 = 0.82$$

5.2) Transmit Power

Second input parameter for the FLC is Transmitted Power having two linguistic variables three membership functions. Specific value used is in region 1 involving two membership functions.

Minimum (min) and medium (med).Linguistic variables involve in this are f3 and f4.

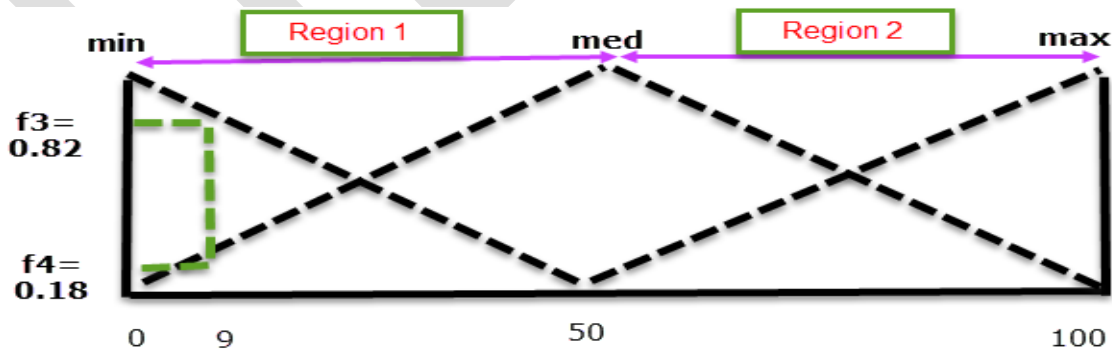


Fig 9: Linguistic variables f3 and f4 for Transmit Power

$$f3 = 50 - 9/50 = 41/50 = 0.82$$

$$f_4 = 1 - 0.82 = 0.18$$

6: RESULTS

After finding the composite rules and their values by using linguistic variables its singleton values calculated.

| Rules Numbers | Membership functions Values |
|---------------|--|
| R0 | $f_1 \wedge f_3 = 0.18 \wedge 0.82 = 0.18$ |
| R1 | $f_1 \wedge f_4 = 0.82 \wedge 0.18 = 0.18$ |
| R2 | $f_2 \wedge f_3 = 0.82 \wedge 0.82 = 0.82$ |
| R3 | $f_2 \wedge f_4 = 0.82 \wedge 0.18 = 0.18$ |

Table 3: Composite Rules Values

| Rules | Mobility of SU | Transmit Power | Saa | Single ton Values |
|-------|----------------|----------------|--------|-------------------|
| R0 | Adeq | min | Small | 0 |
| R1 | Adeq | med | Normal | 0.5 |
| R2 | Fast | min | Normal | 0.5 |
| R3 | Fast | med | Large | 1 |

Table 4: Singleton Values for Composite Rules

Mamdani Model

$$\left(\frac{\sum R_i * S_i}{\sum R_i} \right) * 100$$

$$\sum R_i = 0.18 + 0.18 + 0.82 + 0.18 = 1.36$$

$$\sum R_i * S_i = 0.18 * 0 + 0.18 * 0.5 + 0.82 * 0.5 + 0.18 * 1 = 0 + 0.09 + 0.41 + 0.18 = 0.68$$

After putting values in Mamdani Model formula

$$0.68 / 1.36 * 100 = 50$$

Mat lab simulated value for Spectrum access availability = 47.7

Difference = Mathematically Model value – Mat lab Simulated value

$$= 50 - 47.7 = 2.3$$

$$\text{Error Rate} = 2.3 / 47.7 * 100 = 4.8\%$$

7: ERROR'S

Total error rate between simulated & designed value

| Results | Output Value |
|-------------------------------|--------------|
| Mat lab Simulated Value | 47.7 |
| Mathematically Designed Value | 50 |

| | |
|---------|-----|
| % Error | 4.8 |
|---------|-----|

Table 5: Error Rate

8: DISCUSSION AND CONCLUSIONS

This paper concludes the software and mathematical design base FIS for cognitive radio spectrum sensing. As there are many input parameters use to locate spectrum by sensing its path. We use fuzzy logic technique for this purpose. After simulation and different mathematical calculation the total error rate among them is 4.8% which shows the prove of successful hardware system if implemented.

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