International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 5, July - 2012

An Optimum Decision Making in Cognitive Radio via Fuzzy Neural Network

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Abstract

This paper presents a fuzzy neural network (FNN) structure for optimum decision making operation in cognitive radio (CR). The FNN has the properties of optimal computation scheme, easy to implement, fuzzy logic inference system, and parameters convergence. The novel approach combines the advantages of fuzzy logic systems and neural networks have become a very active subject in many research fields. In the first step, fuzzy inference system is employed in CR to allow secondary user for accessing spectrum effectively. An inference engine having three inputs such as velocity of the secondary user, spectrum to be utilized by secondary user and distance of secondary user from primary user then output is improved spectrum utilization. The membership functions (MFs) and the rules are designed and trained from linguistic information and numeric data. The efficiency of decision making process in CR is based on linguistic knowledge, in which 27 rules are set. The next step is to design neural network structure for achieving a low probability of error in predicting the spectrum allocation, so that we can improve the spectrum utilization. A multilayer perceptron (MLP) model is designed for spectrum predication, which does not require a prior knowledge of the traffic characteristics of the primary user. The performance of the spectrum predictor is analyzed through the simulation results.

1. Introduction

Cognitive radio is a technology for wireless communication in which either a network or a wireless node changes its transmission or reception parameters to communicate efficiently as well as avoiding interference with primary user. Currently, single wireless network technology can to satisfy all of the requirements of mobile users at anywhere and anytime. Due to such requirements CR introduced for utilizing spectrum holes to communicate wherever and whenever needed, thus increasing spectrum utilization efficiency. This technology developed on software defined radio (SDR) platform to support reconfigurability to different physical layer attributes [1]. In order, for secondary user (SU) to communicate using spectrum holes, SU inherits all features of CR where it detects the holes, co-ordinates this information among other SU in its coverage and select one of the vacant bands for its information exchange with a condition that communication of PU is not interrupted.

The major component of CR is spectrum sensing to detect the presence or absence of a primary user in spectrum for a given location. The traditional spectrum sensing technology in CR are matched filtering, waveform based sensing, cyclostationary based sensing , energy detection, FFT detection, correlation detection and radio detection. [2]. These spectrum sensing techniques have different benefits and drawbacks such as energy detection is easy to implement but it lags the capability to differentiate between different signal types and it may have less sensitivity for that, long integration time is required while cyclostationary method is robust to noise like signals and has high sensitivity but it demands excessive A/D converter thus required high signal processing capability due to which large amount of power consumption is needed. Besides it is possible for a single user (SU) to make wrong decision because of server channel fading, hidden nodes and shadowing's. By analyzing drawbacks of single SU detection after that distributed spectrum sensing is well suited for spectrum sensing decision which is based on decision of multiple distributed SUs instead of a single SU alone [3].

The decision making for resource management in future cognitive radio system (CRS) is highly based on the knowledge base of the operational environment for getting information of operational environment based on the collecting the information on the correct resource use and state of nature will be important. In particular information on the present spectrum use with for example; spectrum sensing technology will be crucial for the reliable information in the dynamic and uncertain environment is a true challenge for advance CRS [4].

This paper provides more detail for making real time decision, to deicide the suitable SU which will use the available band. A novel approach employed FNN structure for making optimal decision making in CR management system. In our approach we use the rule based FLS to assign available spectrum to SU efficiently granted that SU is using assigned band will not interfere with its degree of mobility and its distance to PU. The knowledge based spectrum access based on three descriptors is found from groups of network expert. 27 fuzzy rules are setup based on linguistic knowledge. The output of FLS provides probability of each SU, which will use assigned spectrum band.

The paper is organized as following: In Section 2 we briefly introduce FLS for making decision operation in CR. This intelligent spectrum accessing method is based on experience from a group of networks experts. In Section 3, output of FLS is optimized with the help of multilayer perceptron model. We discuss the simulation result in the 4 Section. Conclusions are present in Section 5.

2. Fuzzy Logic System

Fuzzy logic is an attractive technique mainly in case where target problems are difficult to model with traditional mathematical methods, but which are easily understood by human expert. Fuzzy logic resembles human like thinking being, due to that efficient decision making operation can easily done and also it is well suited for multidimensional decision problems. The rule base decision making is achieved by fuzzy logic method in an uncertain condition. Fuzzy logic tool offer good potential to be applied in cognitive radio management system such as cross-layer design with their reconfiguration and cooperative spectrum sensing techniques. The proposed fuzzy decision making technique is based on three factors such as spectrum utilization efficiency, degree of mobility and distance of the PU whereas output is probability of accessing spectrum band for secondary user and user with greatest possibility will be assign the available spectrum band. The main purpose of using fuzzy logic system in cognitive radio is to make decision operation or develop control surface for effective utilization of spectrum[4].

The concept of a control surface or decision surface is central idea in fuzzy logic technique. In this section we illustrate important concept related with decision making operation. The output function P is nonlinear and uncertain in an n-dimensional space for the case of cognitive radio system; we are design rule base depending upon linguistic information of available spectrum utilized by SU. It is generally a hyper plane in an n-dimensional space. The control surface describes the dynamics of spectrum prediction and is generally a time variant non-linear surface. Fuzzy rule based system use a collection of fuzzy conditional statements derived from a knowledge based to approximate and construct the control surface. This scheme acts as identifiers of effective spectrum bands and generally model free paradigms.

In the decision making operation following fuzzy logic system is employed as shown in Fig.1. Three inputs are applied to a FLS, and then converted crisp values of input parameter in fuzzified form value with the help fuzzifier module. The inference engine such as mamdani type FIS determines output from each rule. After that, defuzzifier is employed for getting crisp output from aggregation of rule base.

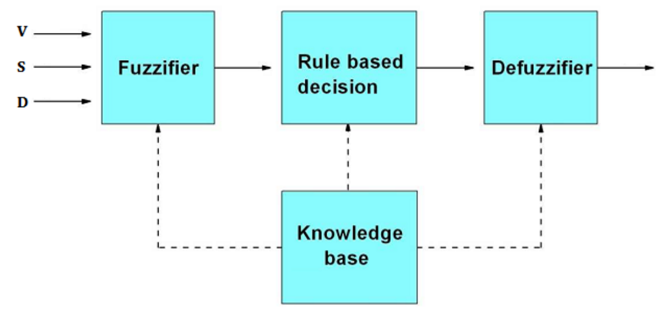

Fig. 1 Basic structure of fuzzy logic system

The rule base consist of 27 fuzzy rules in IF-THEN format such as

R^1 : IF V is MF_l^v and S is MF_l^s and D is MF_l^d then P is G_l^p

In the rule structure antecedent and consequent parameters such as *V*, *S*, *D* and *P* respectively, divided into number of fuzzy subsets which are represented by using linguistic variables. The linguistics variables of velocity and spectrum to be utilized by secondary user are divided into three levels i.e. *small, medium, high*, while the distance is divided into *close, medium and away*. The consequence is divided into five levels which are *very low, low, medium, high and very high*. The membership function employed to represent fuzzy sub sets of input and output parameters are define by using trapezoidal and triangular membership function as shown in Fig. 2 (a), (b), (c) and (d).

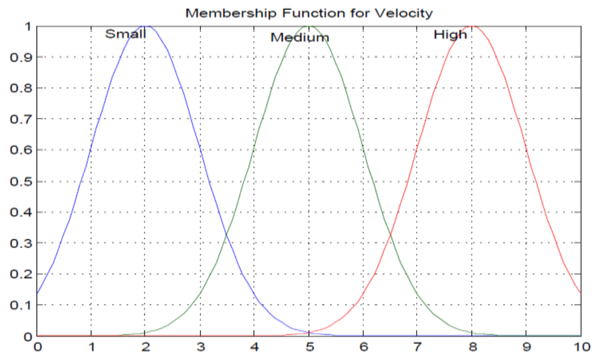

Fig. 2(a) Membership Function of Velocity

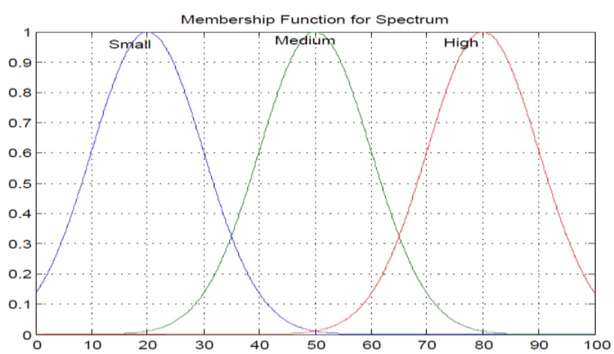

Fig. 2(b) Membership Function of Available Spectrum

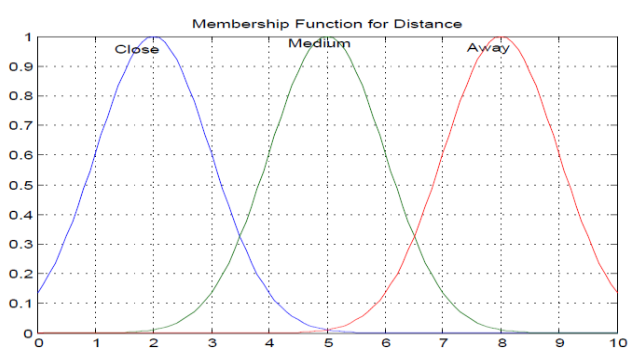

Fig. 2(c) Membership Function of Distance

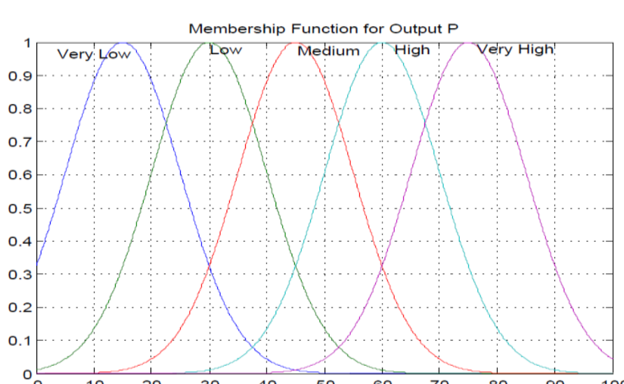

Fig. 2(d) Membership Function of Output

Since we have 3 antecedents and 3 consequences so we need to setup 3^3=27 rules in FLS are given in Table 1. In this paper centroid defuzzifer is used to compute crisp output from firing of each rule.

$$z^* = \frac{\int \mu_c(z).zdz}{\int \mu_c(z)dz} \qquad (1)$$

The crisp output of FLS is nothing but probability of effective spectrum utilization in cognitive radio, then we can easily develop decision surface. The optimum spectrum utilization in effective manner determine by using neural network model.

Table 1: Rule base for Fuzzy Logic

Rule	Antecedent	Antecedent	Antecedent	Consequence
1	Small	Small	Close	Very Low
2	Small	Small	Medium	Low
3	Small	Small	Away	Low
4	Small	Medium	Close	Very Low
5	Small	Medium	Medium	Low
6	Small	Medium	Away	Medium
7	Small	High	Close	Very Low
8	Small	High	Medium	Low
9	Small	High	Away	Medium
10	Medium	Small	Close	Very Low
11	Medium	Small	Medium	Medium
12	Medium	Small	Away	High
13	Medium	Medium	Close	Very Low
14	Medium	Medium	Medium	Medium
15	Medium	Medium	Away	High
16	Medium	High	Close	Very Low
17	Medium	High	Medium	Low
18	Medium	High	Away	High
19	High	Small	Close	Low
20	High	Small	Medium	High
21	High	Small	Away	Very High
22	High	Medium	Close	Low
23	High	Medium	Medium	High
24	High	Medium	Away	Very High
25	High	High	Close	Very Low
26	High	High	Medium	Low
27	High	High	Away	Low

3. Neural Network

Neural network applied to cognitive radio management system in several different aspects such as dynamic channel selection, channel sensing, spectrum prediction and learning. In most of the application neural network models are employed for the intelligent computation are based on statistical estimation, optimization and control theory. Neural network is made up of interconnected artificial neurons which are having similar properties of biological neurons such a network can be utilized for solving artificial intelligence problems for e.g. Machine learning [5].

In the decision making operation output of FLS is applied to the multilayer perceptron. The MLP is feed forward neural network. It is composed of an interconnection of basic neuron processing units. The basic structure of the multilayer peceptron is shown is in Fig.3. It mainly consists of three-layer peceptron model since there are three stages of neural processing between the inputs and outputs. More layers can be added by concatenating additional hidden layers of neurons.

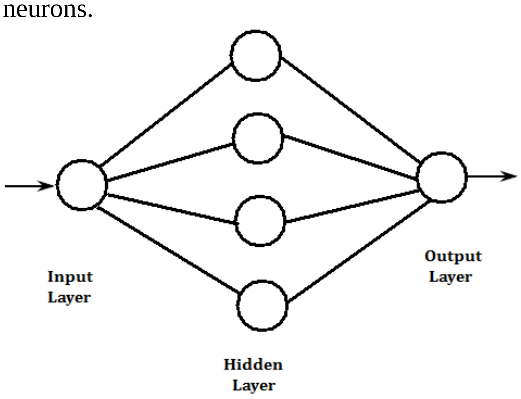

Fig. 3 Basic structure of multilayered perceptron model

The multilayer perceptron has inputs x_i where i = 1, 2 …… n and outputs y_p where p =1, 2….l. The number of neurons in the hidden layer is m_j where j =1, 2…… k. The neurons in the first layer of the multilayer perceptron perform computation and the outputs of these neurons are given by second stage of neural network model.

$$m_j^{(1)} = f_j(\sum_{i=1}^{n} w_{ij}x_i) - \theta_j \qquad (2)$$

with j=1,2…… k. The neurons in the second layer of multi perceptron performer computation and the outputs of these neurons are given by

$$y = f_p(\sum_{j=1}^{k} v_{jp}m_j - \theta_j) \qquad (3)$$

The parameters w_{ij} are called the weights in between hidden layer and input. The v_{jp} are called the weights in between hidden layer and output. The parameter θ_j is called the bias of the first stage. The parameter θ_p is called the bias of the second stage of neural network. The functions f_j and f_p represents the activation functions. The activation function can be different from each neuron in the multilayer perceptron (e.g. the first layer could have one type of sigmoid, while the next two layers could have different sigmoid functions or threshold functions) [5].

The generalized equation of the sigmoid function as

$$f(y) = \frac{1}{1+\exp(-by)} \qquad (4)$$

The output of multilayered perceptron model is nothing but optimum spectrum band value, used for secondary user. The MLP did not required a prior knowledge of the traffic characteristics of the licensed user system. The performance of the spectrum predictor is analyzed through FNN model with the help of extensive simulation.

4. Simulation Results

To validate our approach, we have to simulate FLS in first stage due to simulate FLS in first stage due to which we can provide decision making surface in the spectrum accessing for the cognitive user with fixed distance to the primary user.

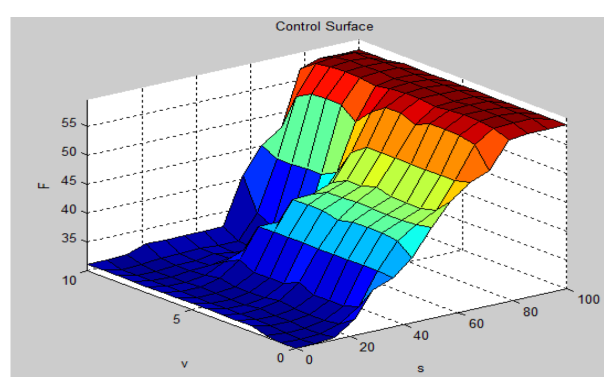

Fig. 4 Decision Control surface of velocity and spectrum

The control surfaces of FLS are shown in Fig. 4, 5 and 6. By observing control surface it is clear that probability of taking decision if the distance of primary and secondary user is low and enough free spectrum or channels is available. The velocity of the secondary user increases then spectrum accessing is more but the distance between PU and SU is reasonably small.

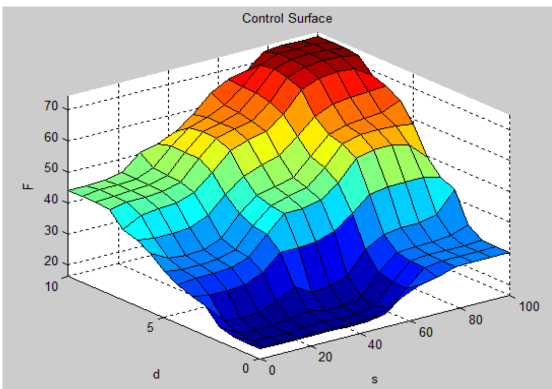

Fig. 5 Decision surface of distance and spectrum

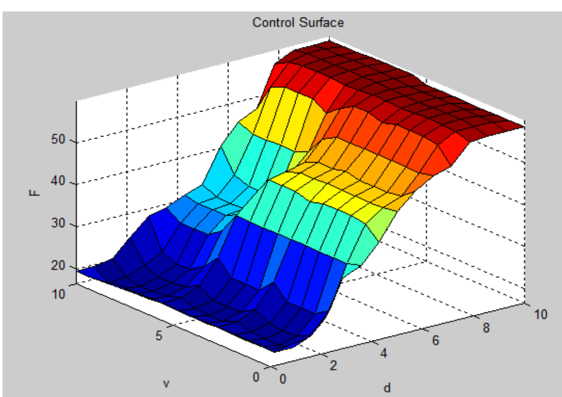

Fig. 6 Decision surface of velocity and distance

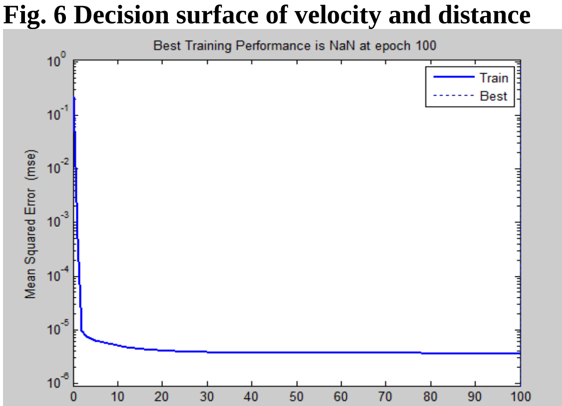

Fig.7 Performance of Neural Network

The output values of FLS according to the 27 rules with their operating values are mentioned in Table 2. Fig. 7 shows the performance of the neural networks. The output of first stage is applied to the feed forward neural network to get optimized results in Table 2 in which effective utilization of spectrum.

Table 2 Result of Fuzzy logic and FNN sytems

Rule	Fuzzy	Fuzzy Neural
1	18.7674	0.0092
2	28.2382	0.0049
3	33.9476	0.0049
4	17.2946	0.0138
5	30.3949	0.0049
6	44.7584	0.0052
7	19.6476	0.0065
8	33.074	0.0049
9	45.1843	0.0051
10	16.7981	0.0143
11	34.3264	0.0049
12	44.3333	0.0052
13	21.092	0.0051
14	41.9543	0.0051
15	55.6813	0.0052
16	26.6397	0.0049
17	45.0672	0.0052
18	58.6113	0.0052
19	28.4052	0.0049
20	44.2672	0.0052
21	65.3148	0.0052
22	30.1901	0.0049
23	57.8057	0.0052
24	73.153	0.0052
25	28.6174	0.0049
26	60.5755	0.0052
27	59.9402	0.0052

5. Conclusion

We propose novel approach using FNN structure for effective utilization of spectrum for secondary users in cognitive radio network. FLS required expert information for the formulation of the rule base, combination of the fuzzy sets and the defuzzification module. The fuzzy logic tool is very helpful for complex or uncertain process where it is difficult to develop mathematical model. The result of FLS exhibits that chance of decision increases if the distance between primary and secondary is low while velocity of the SU is more. The decision making surface enables the CRS to access effective spectrum. The decision making operation in CRS is based on 27 rule base which are created by knowledge of spectrum access is based on experiences form a group network expert due to that correct decision can be taken. In our approach we can modify the output of FLS by using MLP model, which is employed for determining optimum values of spectrum band.

10. References

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