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Soft computing techniques for mobile networks

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***Abstract*— In the paper it has been proposed to use a fuzzy-controller in CDMA mobile networks for improving the process of power control. An architecture of the fuzzy-controller was developed. Linguistic variables, terms and membership functions for input and output values have been defined. Rules base has been developed. The operation of the fuzzy-controller has been simulated. The neuro-fuzzy system has been developed. The genetic algorithm has been proposed.**

Keywords*— mobile; control; fuzzy logic; neural network; genetic algorithm

I. INTRODUCTION (HEADING 1)

The third generation of CDMA systems must be able to support integrated services applications and guarantee all requirements for quality-of-service.

Power control is an important element in CDMA systems, because in order to maximize capacity and quality of service all mobile station transmissions should be received at the base station with equal power [1]. The main parameter to characterize the system performance in CDMA is the signal-to-interference ratio (SIR). Many works regard the signal to interference ratio as a measure to control powers [2-4].

Fuzzy systems, neural networks, and genetic algorithms have replaced conventional techniques in many engineering applications [5]. In modern telecommunication networks, the control techniques [6] are widely used.

Fuzzy logic refers to a logical system that generalizes classical logic for reasoning under uncertainty. In general sense, fuzzy logic refers to all the theories and techniques employing fuzzy sets, i.e. classes with rough confines. Fuzzy logic implements human experiences by means of membership functions and fuzzy rules. Fuzzy logic can be used when dealing with uncertain information while a network shows dynamic nature.

Artificial neural networks are physical cellular systems which can acquire, store and utilize experiential knowledge. One may say that they function as parallel distributed computing networks. But, they are not programmed to perform specific task, they to be taught, or trained. Also they can learn new associations and patterns. Neural networks can change their weights to optimize their work.

Genetic algorithm is optimization technique of iterative search and finding solutions to problems by a process based on natural selection, mutation, crossover and reproduction. Genetic algorithms are successfully used to solve many combinatorial optimization problems.

Hybrid systems combining fuzzy logic, neural networks, and genetic algorithms have proved their effectiveness in a wide variety of problems [7-9].

So, it is suggested to use a fuzzy controller for power control in CDMA mobile netwoks. The fuzzy controller's operation may be improved by using neural system and genetic algorithm.

II. FUZZY CONTROLLER

We propose to use in mobile CDMA networks a fuzzy controller having two input and one output linguistic variables (fig.1). Input linguistic variables of the fuzzy controller are a signal-to-interference ratio error R and a difference between the measured SIR and the target SIR D, its output variable is power increment P.

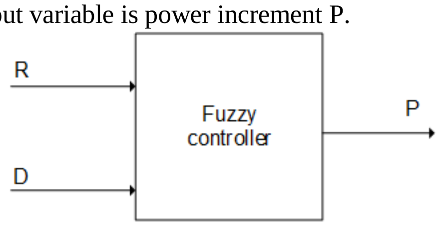

Figure 1. The architecture of the neuro-fuzzy controller

For defining the measured SIR the terms "very positive", "positive", "zero", "negative", "very negative" are used. Thus, the term set of R is:

$$T(R) = \{Very\ Negative\ (VN),\ Negative\ (N),\ Zero\ (Z),\ Positive\ (P),\ Very\ Positive\ (VP)\}.$$

Membership functions for T(R) are shown on fig. 2.

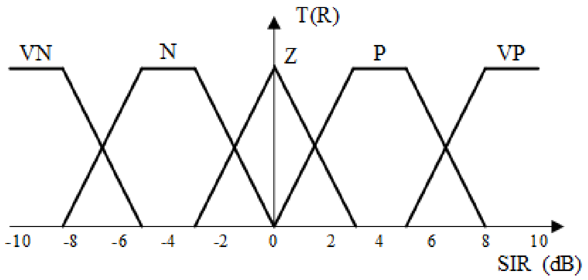

Figure 2. Membership functions for the R linguistic variable

For defining the difference between the measured SIR and the target SIR the terms ”positive”, “zero”, ”negative”, are used. Thus, the term set of D is:

$$T(D) = \{Negative\ (N),$$
$$Zero\ (Z),\ Positive\ (P)\}.$$

Membership functions for T(D) are shown on fig. 3.

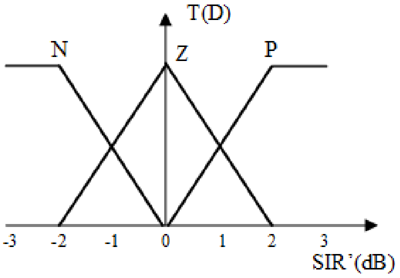

Figure 3. Membership functions for the D linguistic variable

For defining the power increment the terms ”very positive”, ”positive”, “zero”, ”negative”, ”very negative” are used. Thus, the term set of P is:

$$T(P) = \{Very\ Negative\ (VN),$$
$$Negative\ (N),\ Zero\ (Z),$$
$$Positive\ (P),\ Very\ Positive\ (VP)\}.$$

Membership functions for T(P) are presented on fig. 4.

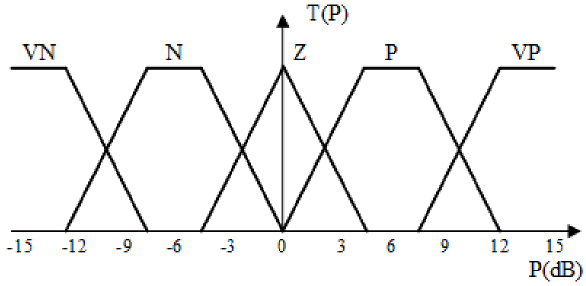

Figure 4. Membership functions for the P linguistic variable

The proposed neuro-fuzzy controller works according to a rule base consisting of fifteen rules:

1. $If\ \ R = VN\ \ and\ \ D = N\ \ then\ \ P = VN;$
2. $If\ \ R = VN\ \ and\ \ D = Z\ \ then\ \ P = VN;$
3. $If\ \ R = VN\ \ and\ \ D = P\ \ then\ \ P = N;$
4. $If\ \ R = N\ \ and\ \ D = N\ \ then\ \ P = VN;$
5. $If\ \ R = N\ \ and\ \ D = Z\ \ then\ \ P = N;$
6. $If\ \ R = N\ \ and\ \ D = P\ \ then\ \ P = N;$
7. $If\ \ R = Z\ \ and\ \ D = N\ \ then\ \ P = N;$
8. $If\ \ R = Z\ \ and\ \ D = Z\ \ then\ \ P = Z;$
9. $If\ \ R = Z\ \ and\ \ D = P\ \ then\ \ P = P;$
10. $If\ \ R = P\ \ and\ \ D = N\ \ then\ \ P = P;$
11. $If\ \ R = P\ \ and\ \ D = Z\ \ then\ \ P = P;$
12. $If\ \ R = P\ \ and\ \ D = P\ \ then\ \ P = VP;$
13. $If\ \ R = VP\ \ and\ \ D = N\ \ then\ \ P = P;$
14. $If\ \ R = VP\ \ and\ \ D = Z\ \ then\ \ P = VP;$
15. $If\ \ R = VP\ \ and\ \ D = P\ \ then\ \ P = VP.$

III. NEURAL NETWORK

Combining fuzzy logic and neural network it is possible to get a hybrid neuro-fuzzy system that can be learned.

So, we can transform the proposed fuzzy-controller into a neuro-fuzzy system (fig.5).

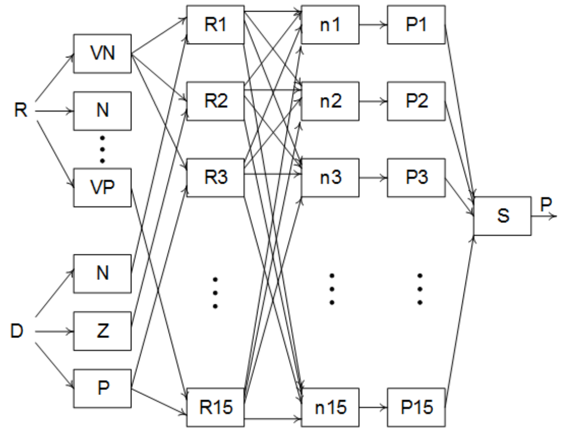

Figure 5. The neuro-fuzzy system block diagram

The neuro-fuzzy system operates as follows.

In layer 1 each input gets a corresponding fuzzy value:

$$R \Rightarrow R_{VN}, R_N, R_Z, R_P, R_{VP}\ ;$$

$$D \Rightarrow D_N, D_Z, D_P\ .$$

In layer 2 each node represents firing strength of a rule:

$$w_1 = \min[R_{VN}, D_N];$$

$$w_2 = \min[R_{VN}, D_Z];$$

$$\ldots$$

$$w_{15} = \min[R_{VP}, D_P].$$

Layer 3 normalizes the firing strength:

$$w_1^n = \frac{w_1}{w_1 + w_2 + \ldots + w_{15}};$$

$$w_2^n = \frac{w_2}{w_1 + w_2 + \ldots + w_{15}};$$

$$\ldots$$

$$w_{15}^n = \frac{w_{15}}{w_1 + w_2 + \ldots + w_{15}}.$$

In layer 4 crisp values are obtained:

$$P_1 = w_1^n \cdot P_{VN},$$

$$P_2 = w_2^n \cdot P_{VN};$$

$$\ldots$$

$$P_{15} = w_{15}^n \cdot P_{VP}.$$

The output of layer 5 is an overall output:

$$P = \sum_{i=1}^{15} P_i .$$

IV. GENETIC ALGORITHM

The genetic algorithm may be applied for updating the rule base and the membership function shape.

The first step when optimizing the fuzzy system is encoding the fuzzy sets into chromosomes (fig.6).

MF shape	Position of R	Position of D	Position of P	Rules

Figure 6. The chomosome

The fitness function is minimum of the mean difference between the measured power and the target power:

$$M = \frac{P_M - P_T}{N},$$

where N is a quantity of information.

The second step of the genetic algorithm is selection. The third and the fourth ones are mutation and crossover respectively.

The procedures of selection, mutation and crossover are performed until convergence.

V. SIMULATION

In order to confirm the operability of the controller we can use the Matlab 6.5 program. The simulated fuzzy-controller is shown on fig.7.

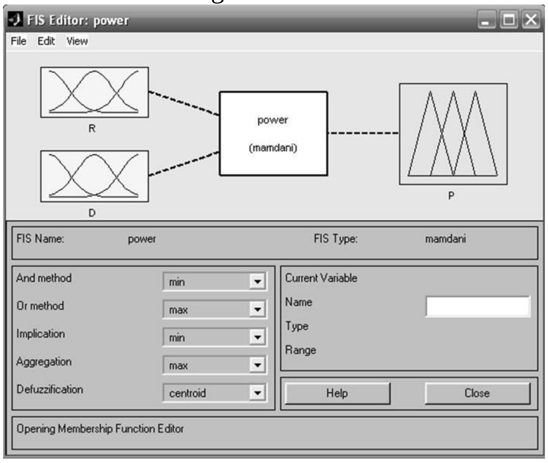

Figure 7. The fuzzy-controller in Matlab 6.5

Specifying the R linguistic variable is shown on fig.8.

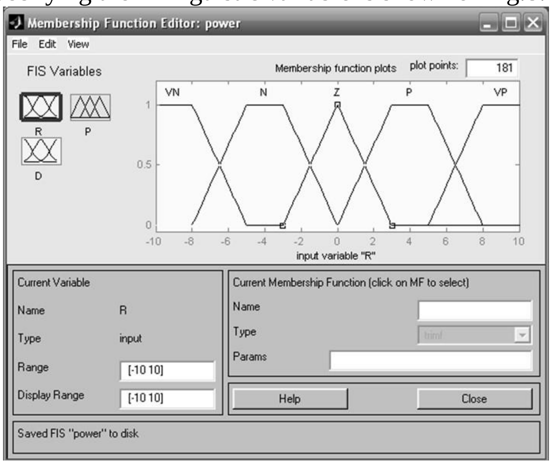

Figure 8. Specifying of the R input variable

Specifying the D linguistic variable is shown on fig.9.

Specifying of the output linguistic variable is shown on fig.10.

Specifying of the rule base is shown on fig.11.

Let the measured SIR is R=-5 and the difference between the measured SIR and the target SIR is D=0. According to fig. 12 we get the power increment of P=-6.

So, according to the simulation results, the proposed fuzzy-controller can be applied in mobile networks.

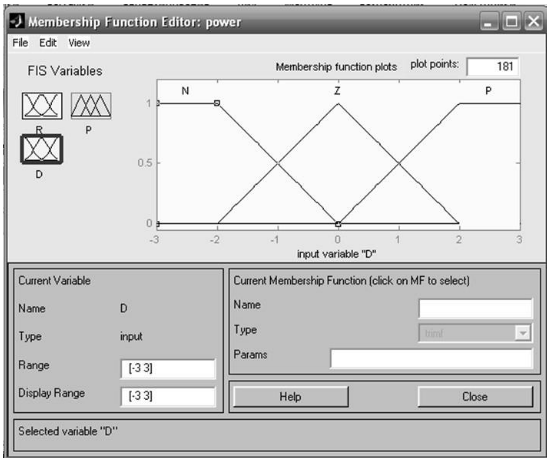

Figure 9. Specifying of the D input variable

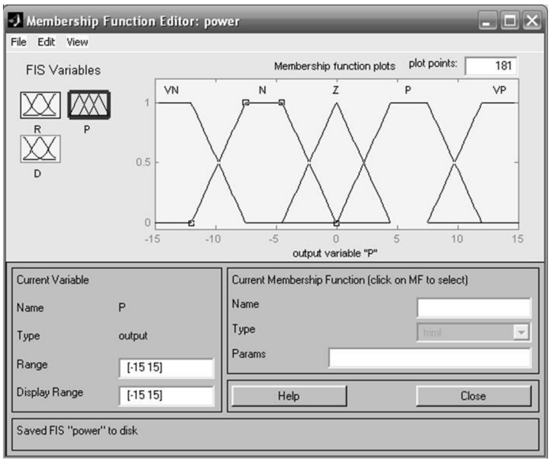

Figure 10. Specifying of the P output variable

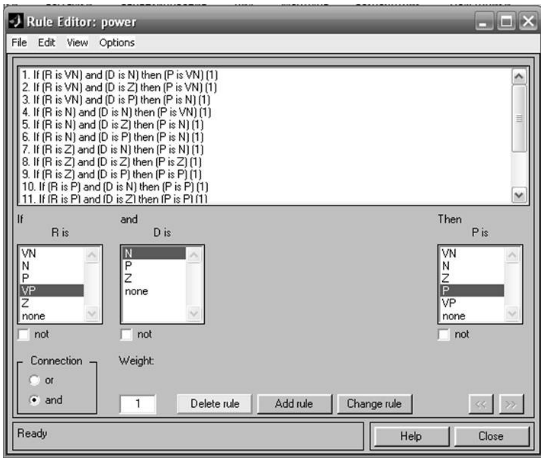

Figure 11. The rule base

VI. Conclusion

So, the fuzzy controller for power control in the CDMA-network was designed. The fuzzy controller was transformed into a neuro-fuzzy system and updated with a genetic algorithm.

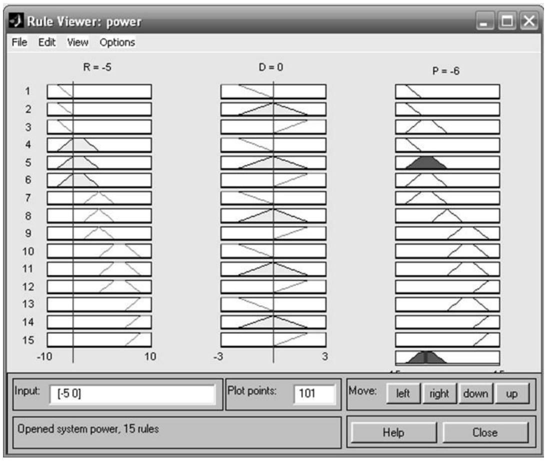

Figure 12. The simulation result

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