Fuzzy-Controller for Handover in Mobile Networks

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***Abstract*— In the paper it is proposed to use a fuzzy-controller in mobile networks for improving the handover process. An architecture of the fuzzy-controller was developed. Linguistic variables, terms and membership functions for input and output values were defined. A rules base was developed. The operation of the fuzzy-controller was simulated.**

***Keywords*— fuzzy; mobile; handover**

I. INTRODUCTION

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

The handover in mobile systems is a quite essential operation. Handover is the process of changing the channel while a call is being served. It is initiated either when crossing a cell boundary or when a quality of the signal in the channel reduces. Performance of the handover mechanism is important to maintain the appropriate Quality of Service (QoS) . So, new and better handover algorithms are required to keep QoS as high as possible. It is necessary to provide that handover should be performed reliably and without disruption of calls.

The conventional handover algorithm compares the received signal strength (RSS) of the serving base station with those of the other base stations and selects the base station with the strongest received signal. However, some other metrics to support handover decisions are to be used for increasing the mobile system efficiency.

Handover algorithms, based on soft computing techniques such as fuzzy logic, neural networks and genetic algorithms can be used for that purpose[1-6].

Fuzzy systems, neural networks, and genetic algorithms have replaced conventional techniques in many engineering applications, especially in control systems [7-9]. In modern telecommunication networks, the soft-computing-based control techniques [10-22] 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 [23-25].

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 an 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 [26-28].

So, the purpose of this paper is to develop a fuzzy logic based handover controller.

II. ARCHITECTURE OF THE FUZZY-CONTROLLER

Generally, a fuzzy controller consists of four main blocks: a fuzzifier, defuzzifier, inference engine, and fuzzy rule base. The fuzzifier transforms each input variable to the membership functions values. The inference engine calculates the fuzzy output depending on the rule base. The defuzzifier converts the fuzzy output to crisp value using mathematical formulas.

After having studied the problem of designing a fuzzy-controller [29-32], we propose to use in mobile networks a fuzzy-controller having three input and one output linguistic variables (fig.1). Input linguistic variables of the fuzzy-controller are a bit error rate (BER) [33], a received signal strength indicator (RSSI), and a load in the cell, its output variable is a handover indicator.

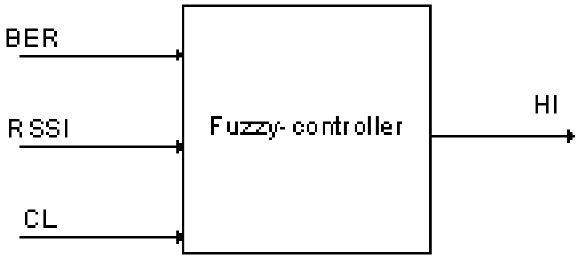


Fig. 1. The architecture of the fuzzy-controller

For defining bit error rate (BER) terms ”low”, ”moderate”, and “high” are used. Thus, the term set of BER is:

T(BER)={Low (L), Medium (M), High (H)}.

Membership functions for T(BER) are presented on fig. 2.

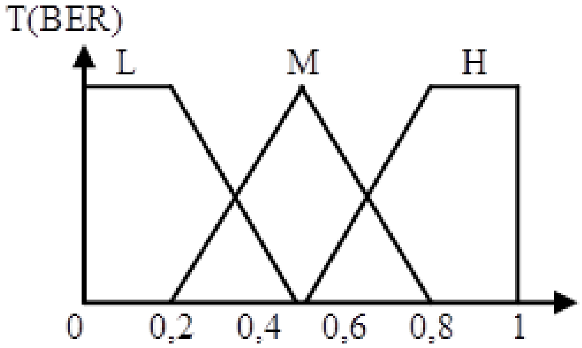


Fig. 2. Membership functions for the BER linguistic variable

For defining the received signal strength indicator RSSI terms ”weak”, ‘medium” and “strong” are used. Thus, the term set of RSSI is:

T(RSSI)={Weak (W), Medium (M), Strong (S)}.

Membership functions for T(RSSI) are presented on fig. 3.

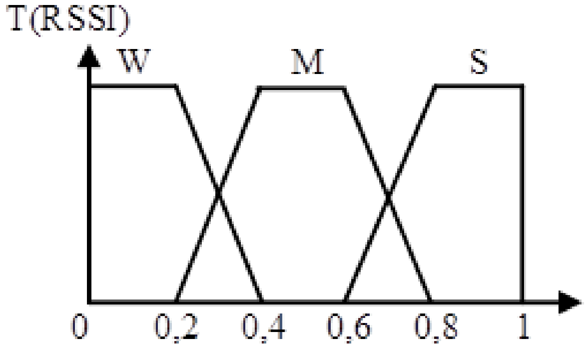


Fig. 3. Membership functions for the RSSI linguistic variable

For defining the cell load (CL) terms ”small”, ”medium”, and “big” are used. Thus, the term set of CL is:

T(CL)={Small (L), Medium (M), Big (B)}.

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

For defining the handover indicator (HI) terms ”no handover”, ”wait”, “ready” and “handover” are used. Thus, the term set of HI is:

T(HI)={No (N), Wait (W), Ready (R) Handover (H)}.

Membership functions for T(HI) are presented on fig. 5.

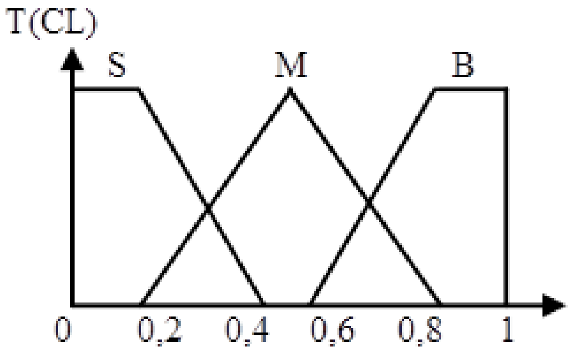


Fig. 4. Membership functions for the CL linguistic variable

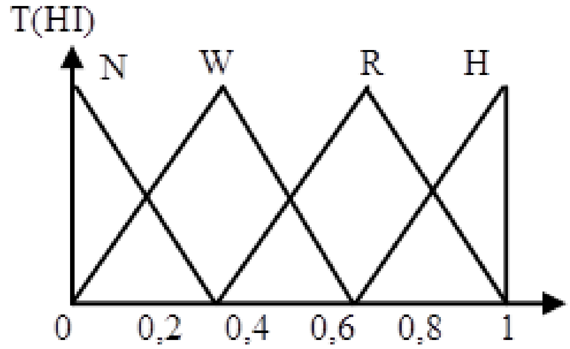


Fig. 5. Membership functions for the HI linguistic variable

III. Rules of The Fuzzy-Controller

The proposed fuzzy-controller works according to a rule base consisting of twenty-seven rules:

If BER=L and RSSI=W and CL=S than H=W;

If BER=L and RSSI=W and CL=M than H=W;

If BER=L and RSSI=W and CL=B than H=W;

If BER=L and RSSI=M and CL=S than H=N;

If BER=L and RSSI=M and CL=M than H=N;

If BER=L and RSSI=M and CL=B than H=W;

If BER=L and RSSI=S and CL=S than H=N;

If BER=L and RSSI=S and CL=M than H=N;

If BER=L and RSSI=S and CL=B than H=N;

If BER=M and RSSI=W and CL=S than H=R;

If BER=M and RSSI=W and CL=M than H=R;

If BER=M and RSSI=W and CL=B than H=R;

If BER=M and RSSI=M and CL=S than H=W;

If BER=M and RSSI=M and CL=M than H=W;

If BER=M and RSSI=M and CL=B than H=R;

If BER=M and RSSI=S and CL=S than H=W;

If BER=M and RSSI=S and CL=M than H=W;

If BER=M and RSSI=S and CL=B than H=W;

If BER=H and RSSI=W and CL=S than H=H;

If BER=H and RSSI=W and CL=M than H=H;

If BER=H and RSSI=W and CL=B than H=H;

If BER=H and RSSI=M and CL=S than H=R;

If BER=H and RSSI=M and CL=M than H=H;

If BER=H and RSSI=M and CL=B than H=H;

If BER=H and RSSI=S and CL=S than H=R;

If BER=H and RSSI=S and CL=M than H=R;

If BER=H and RSSI=S and CL=B than H=R.

IV. Operation of The Fuzzy-Controller

The proposed fuzzy-controller acts as follows.

In the fuzzyfier each input variable gets a corresponding fuzzy value:

$$BER \Rightarrow BER_L,\ BER_M,\ BER_H;$$

$$RSSI \Rightarrow RSSI_W,\ RSSI_M,\ RSSI_S;$$

$$CL \Rightarrow CL_S,\ CL_M,\ CL_B.$$

Then in the inference engine the minimum operations are performed:

$$w_1 = \min[BER_L, RSSI_W, CL_S],$$

$$w_2 = \min[BER_L, RSSI_W, CL_M],$$

$$\cdots$$

$$w_{27} = \min[BER_H, RSSI_S, CL_B].$$

In the defuzzyfier the crisp value is obtained:

$$HI = \frac{\sum_{i=1}^{27} w_1 \cdot HI_1}{\sum_{i=1}^{27} w_1}.$$

V. Simulation

In order to confirm the operability of the fuzzy-controller we can use the Matlab 6.5 program. It is a multi-paradigm numerical computing environment and fourth-generation programming language. The simulated fuzzy-controller is shown on fig.6.

Specifying the bit error rate input linguistic variable is shown on fig.7.

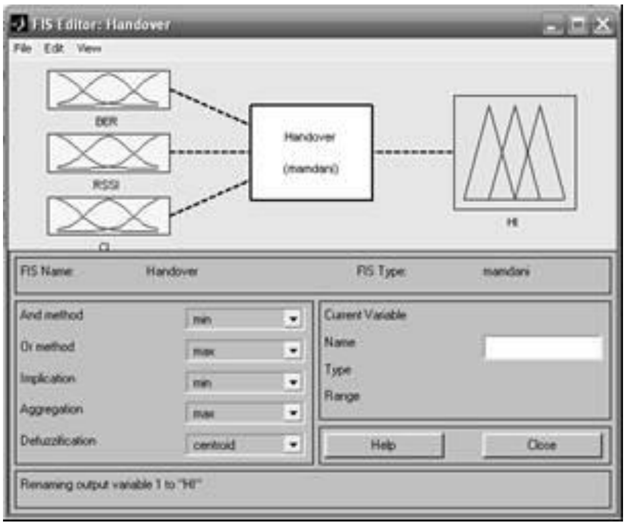
Specifying the received signal strength indicator input linguistic variable is shown on fig.8.

Specifying the cell load input linguistic variable is shown on fig.9

Specifying the handover indicator output linguistic variable is shown on fig.10.

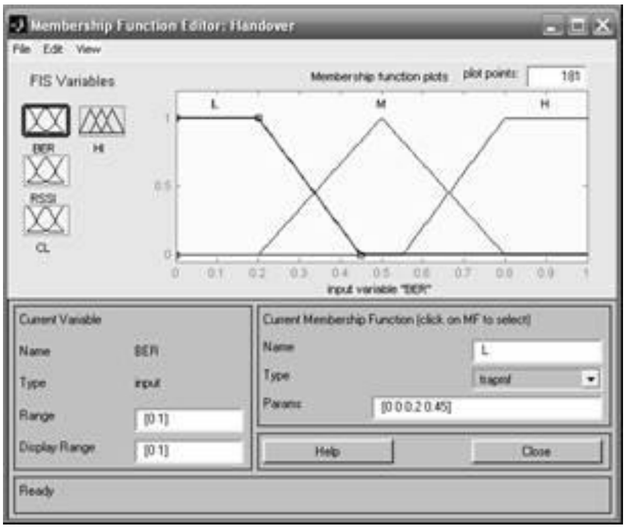
Specifying the rule base is shown on fig.11.

The rule surfaces are shown on fig.12–14.



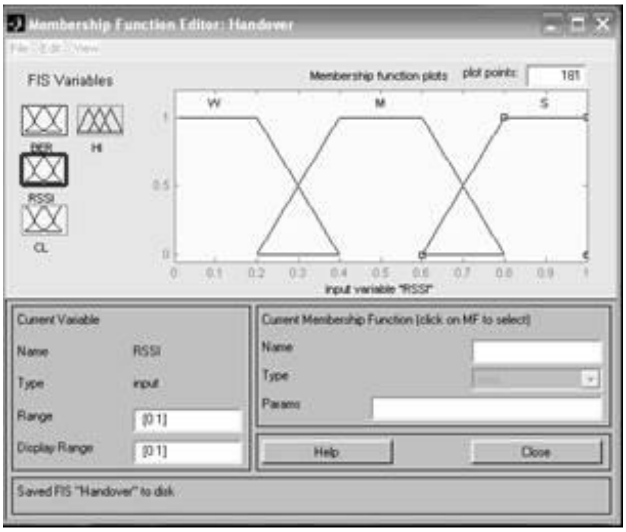
FIS Name: Handover
FIS Type: mamdani
And method: min
Or method: max
Implication: min
Aggregation: max
Defuzzification: centroid
Current Variable
Name
Type
Range
Renaming output variable 1 to "HI"

Fig. 6. The fuzzy-controller in Matlab 6.5



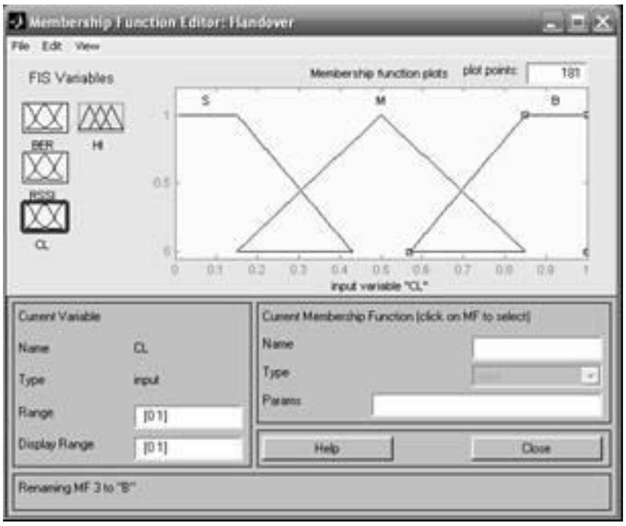
Current Variable
Name: BER
Type: input
Range: [0 1]
Display Range: [0 1]
Current Membership Function (click on MF to select)
Name: L
Type: trapmf
Params: [0 0 0.2 0.45]
Ready

Fig. 7. Specifying the BER input variable



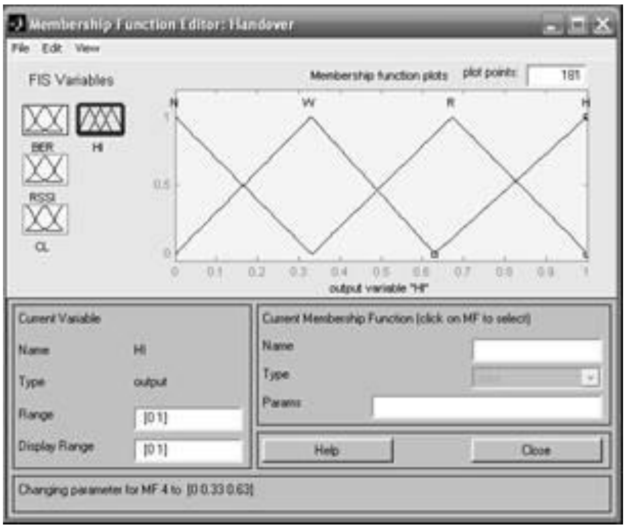
Current Variable
Name: RSSI
Type: input
Range: [0 1]
Display Range: [0 1]
Current Membership Function (click on MF to select)
Name
Type
Params
Saved FIS "Handover" to disk

Fig. 8. Specifying the RSSI input variable



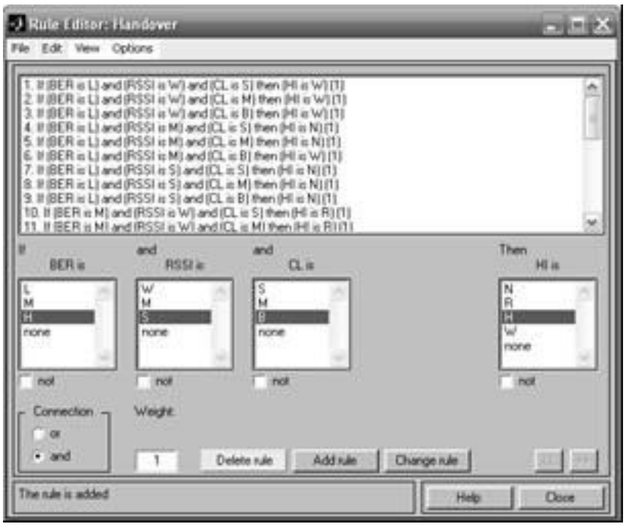
Current Variable
Name: CL
Type: input
Range: [0 1]
Display Range: [0 1]
Current Membership Function (click on MF to select)
Name
Type
Params
Renaming MF 3 to "B"

Fig. 9. Specifying the CL input variable



Current Variable
Name: HI
Type: output
Range: [0 1]
Display Range: [0 1]
Current Membership Function (click on MF to select)
Name
Type
Params
Changing parameter for MF 4 to [0 0.33 0.63]

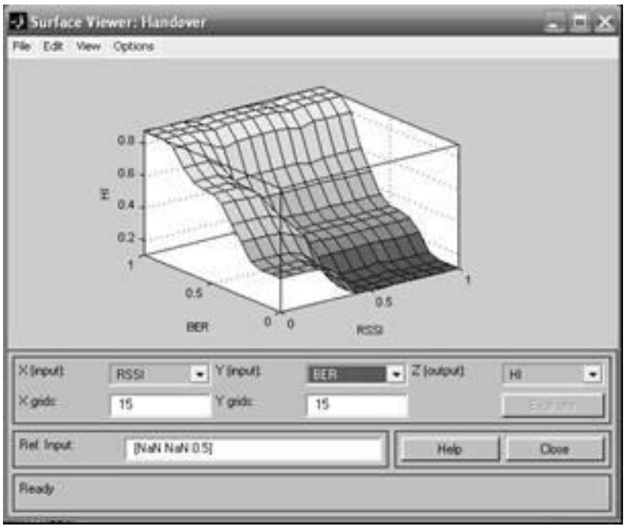
Fig. 10. Specifying the HI output variable



1. If (BER is L) and (RSSI is W) and (CL is S) then (HI is W) (1)
2. If (BER is L) and (RSSI is W) and (CL is M) then (HI is W) (1)
3. If (BER is L) and (RSSI is W) and (CL is B) then (HI is W) (1)
4. If (BER is L) and (RSSI is M) and (CL is S) then (HI is N) (1)
5. If (BER is L) and (RSSI is M) and (CL is M) then (HI is N) (1)
6. If (BER is L) and (RSSI is M) and (CL is B) then (HI is W) (1)
7. If (BER is L) and (RSSI is S) and (CL is S) then (HI is N) (1)
8. If (BER is L) and (RSSI is S) and (CL is M) then (HI is N) (1)
9. If (BER is L) and (RSSI is S) and (CL is B) then (HI is N) (1)
10. If (BER is M) and (RSSI is W) and (CL is S) then (HI is R) (1)
11. If (BER is M) and (RSSI is W) and (CL is M) then (HI is R) (1)

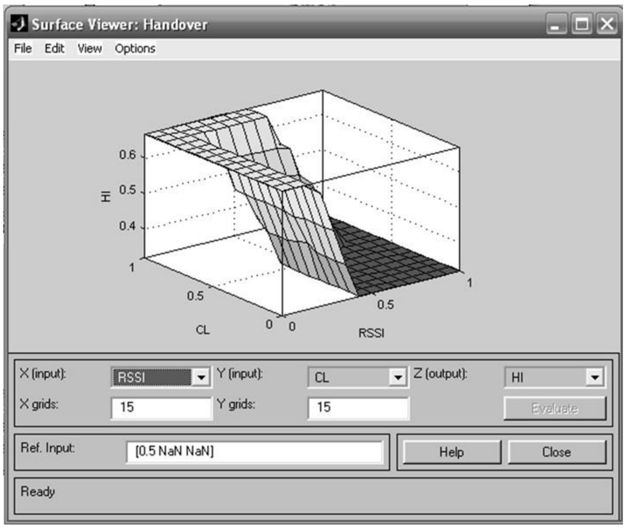
Weight: 1
The rule is added

Fig. 11. The rule base



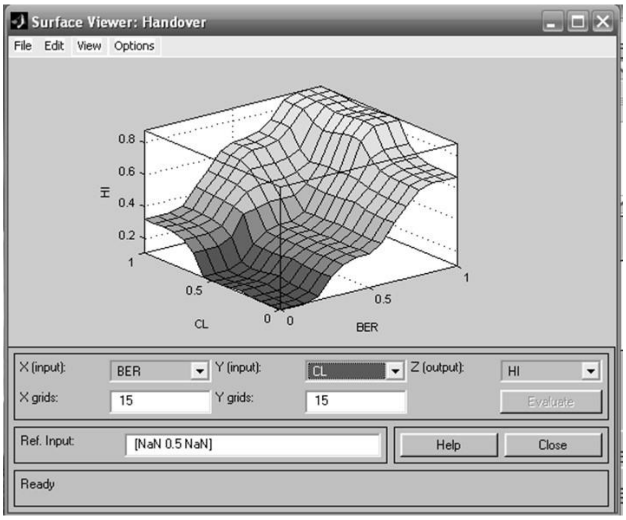
X (input): RSSI
Y (input): BER
Z (output): HI
X grids: 15
Y grids: 15
Ref. Input: [NaN NaN 0.5]
Ready

Fig. 12. The rule surface, RSSI–BER–HI



X (input): RSSI
Y (input): CL
Z (output): HI
X grids: 15
Y grids: 15
Ref. Input: [0.5 NaN NaN]
Ready

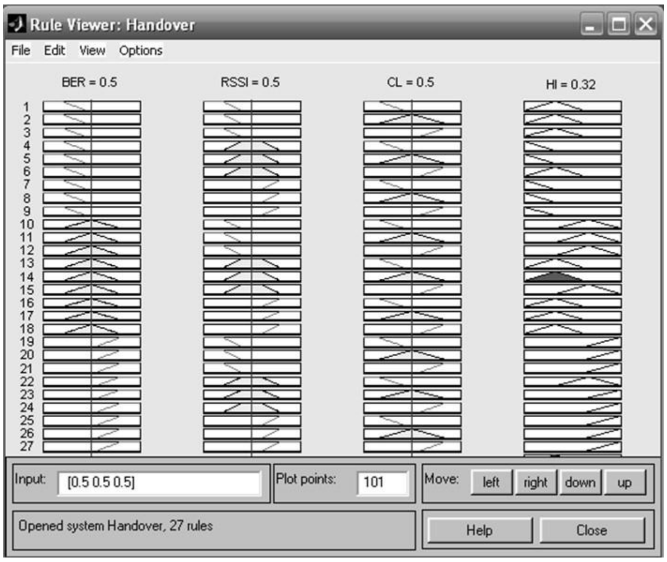
Fig. 13. The rule surface, RSSI–CL–HI



X (input): BER
Y (input): CL
Z (output): HI
X grids: 15
Y grids: 15
Ref. Input: [NaN 0.5 NaN]
Ready

Fig. 14. The rule surface, BER–CL–HI

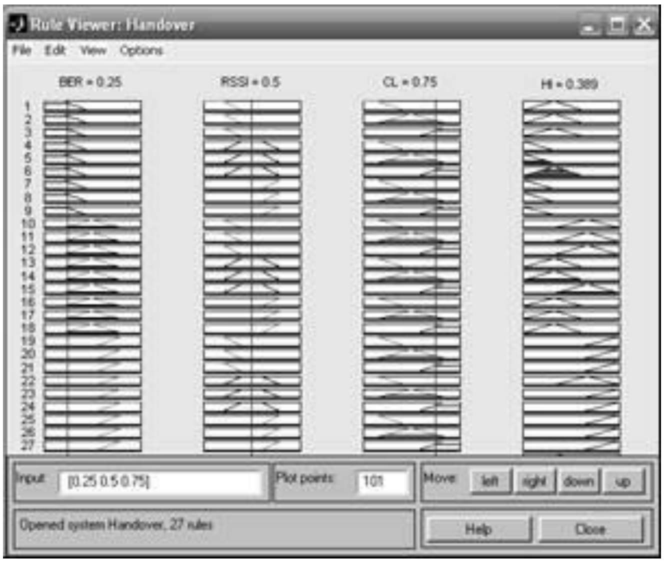
Let the bit error rate BER=0.5, the received signal strength indicator RSSI=0.5, and the cell load CL=0.5. According to fig. 15, we get the handover indicator value HI=0.32.



BER = 0.5
RSSI = 0.5
CL = 0.5
HI = 0.32
Input: [0.5 0.5 0.5]
Plot points: 101
Opened system Handover, 27 rules

Fig. 15. The simulation result giving HI=0.32

Let the bit error rate BER=0.25, the received signal strength indicator RSSI=0.5, and the cell load CL=0.75. According to fig. 16, we get the handover indicator value HI=0.389.



BER = 0.25
RSSI = 0.5
CL = 0.75
HI = 0.389
Input: [0.25 0.5 0.75]
Plot points: 101
Opened system Handover, 27 rules

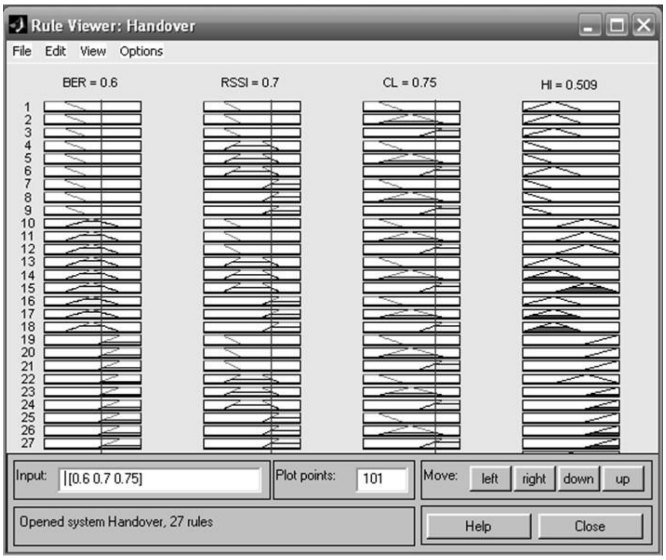
Fig. 16. The simulation result giving HI=0.389

Let the bit error rate BER=0.6, the received signal strength indicator RSSI=0.7, and the cell load CL=0.75. According to fig. 17, we get the handover indicator value HI=0.509.

Let the bit error rate BER=0.5, the received signal strength indicator RSSI=0.1, and the cell load CL=0.9. According to fig. 18, we get the handover indicator value HI=0.669.

Let the bit error rate BER=0.8, the received signal strength indicator RSSI=0.1, and the cell load CL=0.6. According to fig. 19, we get the handover indicator value HI=0.872.

Let the bit error rate BER=0.8, the received signal strength indicator RSSI=0.05, and the cell load CL=0.5. According to fig. 20, we get the handover indicator value HI=0.88.

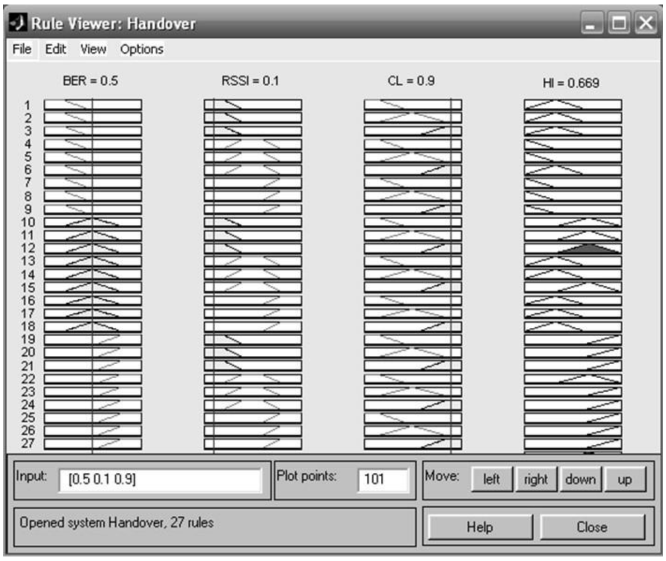


Input: [0.6 0.7 0.75]

Plot points: 101

Opened system Handover, 27 rules

Fig. 17. The simulation result giving HI=0.509



Input: [0.5 0.1 0.9]

Plot points: 101

Opened system Handover, 27 rules

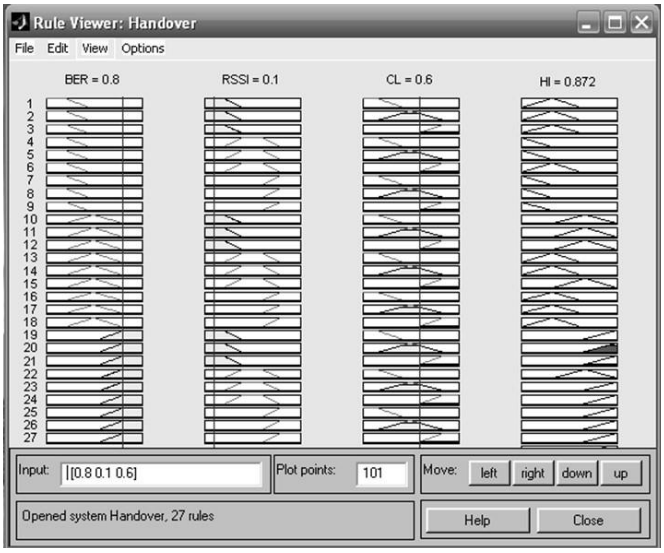
Fig. 18. The simulation result giving HI=0.669

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

The application of the fuzzy-controller can improve the process of base station selection and unnecessary handovers avoiding.

The proposed fuzzy-controller can be improved by considering some other parameters.

In future works, handover mechanism is to be optimized by combining the multicriterial method with other soft computing techniques such as neural networks and genetic algorithms.

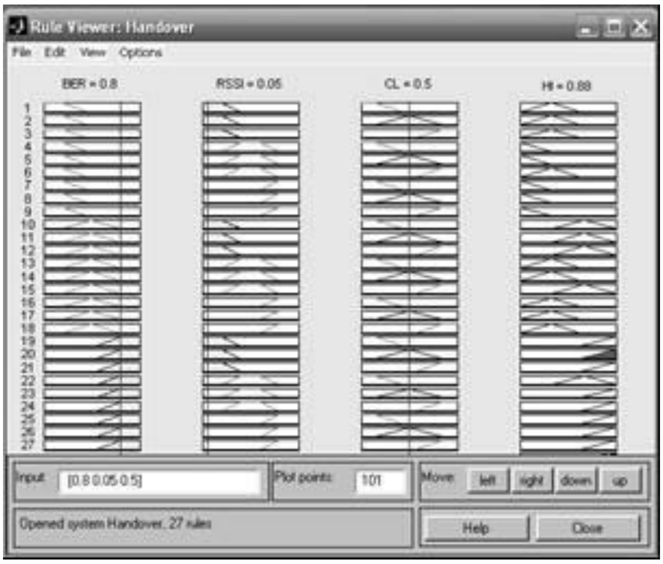


Input: [0.8 0.1 0.6]

Plot points: 101

Opened system Handover, 27 rules

Fig. 19. The simulation result giving HI=0.872



Input: [0.8 0.05 0.5]

Plot points: 101

Opened system Handover, 27 rules

Fig. 20. The simulation result giving HI=0.88

VI. CONCLUSION

In mobile networks the procedure of handover is necessary for maintaining the communication quality. However, it is rather complex to make handover decision in mobile networks because multiple criteria should be considered. So, in this work the fuzzy-controller for mobile networks with several criteria in addition to RSSI was developed to improve the handover decision process: the first one is a bit error rate and the second one is a load in the cell. The proposed handover technique is well suited for high-speed applications.

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