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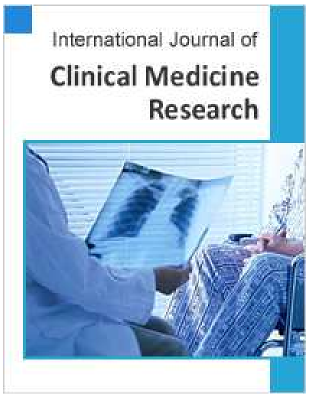

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Fuzzy Medical Expert Systems for Clinical Medicine Learning Through the Fuzzy Neural Network

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Abstract
Computer programs are playing key role in Medicine not only in Medical Information Systems but also in Medical Diagnosis and Surgery. Artificial Intelligence in Medicine particularly Expert Systems are used for diagnosis and robotics are used in surgery. The Robotics will assist the surgeon in Surgery. The Medical Expert Systems will assist the physician in Diagnosis. The information available to the medical diagnosis is incomplete. The medical diagnosis needs commonsense. The fuzzy logic deals incomplete information with commonsense rather than likelihood (probability). In this paper, fuzzy conditional inference is discussed for incomplete information. The neural networks are used to learn the fuzzy rules of Medical care. Some methods of fuzzy conditional inferences are studied. The fuzzy neural networks are used to learn fuzzy rules of medical diagnosis for incomplete information. The fuzzy medical expert system is discussed for medical diagnosis. The Generalized fuzzy certainty factor is discussed for medical diagnosis. The EMYCIN medical expert system shell is discussed for Eye diseases asan example.

1. Introduction

The clinical medicine is the reasoning processes to take appropriate decision in the form of structured approach "if symptoms then diagnosis" in various clinical areas of expertise. The consultation process with medical expert systems is acceptable because the physician has to define expertise in the expert system. The Medical Expert Systems are computer programs that assist the physician for Medical Diagnosis when the Medical diagnosis contains incomplete information. The fuzzy logic [12] deals incomplete information with belief rather than likelihood. An Expert System is a Computer Program in which knowledge is embedded in certain domain. MYCIN medical expert system is written in general scheme whereas. EMYCIN is defined with production system "IF … THEN" for medical diagnosis [1]. The Medical Diagnosis Medical Expert Systems are acceptable because the medical diagnosis in the form of "if symptoms then diagnosis" is defined by the physician. Physician can update or increase or delete medical knowledge. EMYCIN is expert systems shell in which physician can define diagnostic rules. Final decision maker is physician.

Zadeh [12] formulated incomplete information as fuzzy set with single membership function**.** The fuzzy set with two membership functions will give more evidence than single membership function. The two fold fuzzy set may be defined with fuzzy membership functions “True” and “False”. Zadeh [12], Mamdani [5], TSK [6] and Reddy [7] have studied fuzzy conditional inference. Zadeh and Mamdani fuzzy conditional inference needs both fuzziness of precedent part and consequent part in fuzzy rule “if (precedent part) then (consequent part)”. The medical diagnosis rules are formed on the the basis “if symptoms then diagnosis”. Usually in medical diagnosis, the diagnosis will be made from symptoms. Reddy [7] studied fuzzy conditional inference for medical diagnosis where information is not known for consequent part.

In MYCIN [1], there are two factors MB [h,e] and MD [h,e] for representation of incomplete medical information. The Certainty Factor is defined by CF [h,e]=MB[h,e] – MD[h.e], where “e” is the evidence for given hypothesis and “h” as probabilities. The two fold fuzzy set of “True” and “False” are considered instead of Probability. The two fold fuzzy set is considered for medical diagnosis.

In the following, different fuzzy conditional inferences are studied. The fuzzy neural networks are the one of the learning techniques. Different fuzzy conditional inference methods are learned through the neural networks. The fuzzy medical expert system architecture is also discussed. The Generalized fuzzy certainty factor is studied. An EMYCIN is discussed for eye diseases using fuzzy conditional inferences.

2. Fuzzy Logic

Various theories are studied to deal with imprecise, inconsistent and inexact information and these theories deal with likelihood whereas fuzzy logic with commonsense. Zadeh [12] has formalized fuzzy set as a model to deal with incomplete information. The fuzzy set is a class of objects with a continuum of grades of membership.

Definition The set A of X is characterized by its membership function $\mu_A(x)$ and ranging values in the unit interval [0, 1]

$\mu_A(x)$: X →[0, 1], x Є X, where X is Universe of discourse.

A = $\mu_A(x_1)/x_1 + \mu_A(x_2)/x_2 + \ldots + \mu_A(x_n)/x_n$, “+” is union

For example, the fuzzy proposition “x has fever”

$$\text{fever}=\{.2/99+0.3/100+0.5/101+0.7/102+0.8/103\}$$

$$\text{not fever}=\{.8/99+0.7/100+0.5/101+0.3/102+0.2/103\}$$

For instance “Rama has fever” and the fuzziness of “fever” is0.8 The Graphical representation for the fever and not fever is shown in fig.1

For example, Consider the fuzzy proposition “x has mild Headache”

The fuzzy setof type 2 for“Headache” is defined as

$$\text{Headache} = \{0.4/\text{mild} + 0.6/\text{moderate} + 0.8/\text{Serious}\}$$

For instance “Rama has mild headache” with Fuzziness 0.4

The fuzzy logic is defined as combination of fuzzy sets using logical operators[11]. Some of the logical operations are given below

Consider fuzzy sets A, B and C. The operations on fuzzy sets are

Negation

If x is not A

$$A' = 1-\mu A(x)/x$$

Conjunction

x is A and y is B→ (x, y) is A x B

$$A \text{ x } B=\min(\mu_A(x)), \mu_B(y)\}(x,y)$$

if x=y

x is A and x is B→ x is AΛB

$$A\Lambda B=\min(\mu_A(x)), \mu_B(x)\}/x$$

x is A or y is B→ (x, y) is A' x B’

$$A' \text{ x } B'=\max(\mu_A(x)), \mu_B(y)\}(x,y)$$

If x=y

x is A and x is B→ x is A V B

$$AVB=\max(\mu_A(x)), \mu_B(x)\}/x \text{ Disjunction}$$

Implication

if x is A then y is B =A→B = min{1, 1- $\mu_A(x)) + \mu_B(y)\}/(x,y)$

if x= y

$$A\rightarrow B= \min \{1, 1- \mu_A(x)) +\mu_B(x)\}/x$$

If x is A then y is B else y is C= A x B + A' x C

The fuzzy proposition “If x is A then y is B else y is C” may be divided into two clause “If x is A then y is B “ and “If x is not A theny is C” [9]

If x is A then y is B else y is C =A→B= min {1, 1-$\mu A(x) + \mu B(y)\}/(x,y)$

If x is not A then y is B else y is C =A'→ C = min $\{1,\mu_A(x)) +\mu_C(y)\}/(x,y)$

Composition

$$A \text{ o } B= A \text{ x } B=\min\{\mu_A(x)), \mu_B(y)\}/(x,y)$$

If x = y

$$A \text{ o } B==\min\{\mu_A(x)), \mu_B(x)\}/x \text{ Composition}$$

The fuzzy propositions may contain quantifiers like “Very”, “More or Less”. These fuzzy quantifiers may be eliminated as

Concentration

x is very A

$$\mu_{\text{very } A}(x)),=\mu_A(x)^2$$

Diffusion

x is very A

$$\mu_{\text{more or less } A}(x) =\mu_A(x)^{0.5}$$

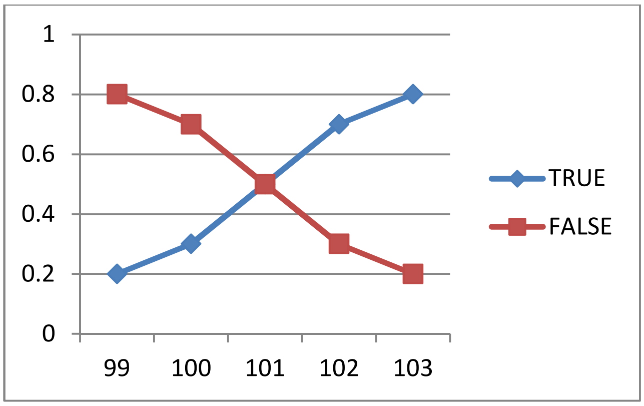

Fig. 1. *Fuzzy membership function.*

3. Fuzzy Neural Network

The neural network concept is taken from the Biological activity of nervous system [2]. The neuron passes information to other neurons. There are many models described for neural networks. The McCulloch-Pitts model [3] contributed in understanding neural network and Zedeh explain that activity of neuron is fuzzy process [13].

The McCulloch and Pitt's model consist of set of inputs, processing unit and output and it is shown in Fig.2

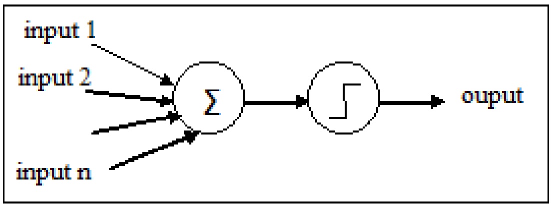

Fig. 2. *McCulloch and Pitt's model.*

The fuzzy neuron model for fuzzy conditional inference for
if x_1 is A_1 and/or x_2 is A_2 and/or … and/or x_n is A_n then x_0 is B may be defined as fuzziness and computational function and shown in Fig.3.

Where $f(A_1,A_2,\ldots A_n,B)$ and $A_1,A_2,\ldots A_n$, B are fuzzy sets.

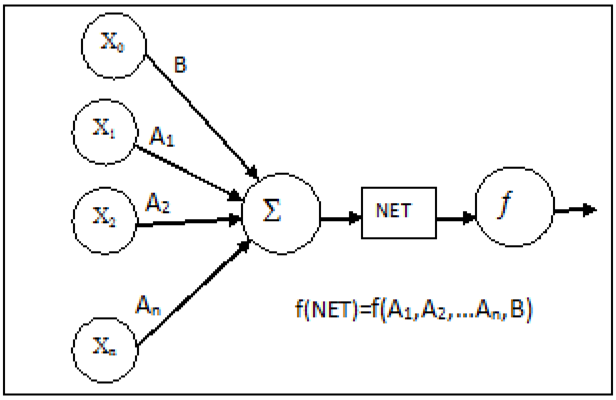

Fig. 3. *Fuzzy neuron model.*

The multilayer fuzzy neural net work is shown in Fig.4.

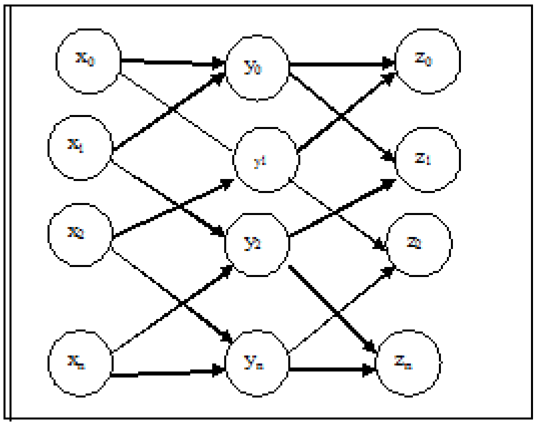

Fig. 4. *Multilayer fuzzy neural net.*

4. Methods for Fuzzy Conditional Inference

There are many fuzzy conditional inference methods, among those Zadeh, TSK and Mamdani methods are popular for many applications like fuzzy control systems. These fuzzy conditional inferences shall be used for fuzzy medical expert systems. Consider the Zadeh fuzzy conditional inference.

If x is A theny is B =min (1, 1- $\mu_A(x)+ \mu_B(y)$)

Let A1, A2,…… An and Bbe the fuzzysets. The fuzzy nested condition is given by

If x_1 is A_1 and x_2 isA_2….. and x_n is A_n theny is B

$$=\min\{1,1-\min(\mu_{A1}(x_1),\mu_{A2}(x_2),\ldots,\mu_{An}(x_n))+\mu_B(y)\} \quad (4.1)$$

The fuzzy neuron for Zadehfuzzy conditional inference is represented as in Fig.5

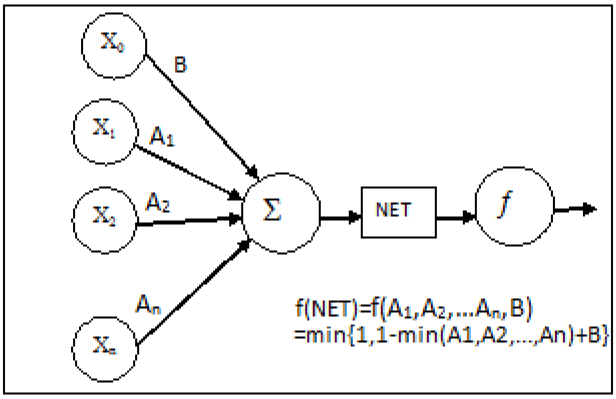

Fig. 5. *Zadeh method.*

Mamdani [5] proposed the inference for fuzzy conditional proposition in which prior information is also known for Consequent part. i.e., the relationship between president part and consequent part is known.

if x is A then y is B= min($\mu_A(x)$, $\mu_B(x)$,)

if x_1 is A_1 and $x_2$isA_2….. and x_n is A_n then y is B

$$=\min(\mu_{A1}(x), \mu_{A2}(x),\ldots,\mu_{An}(x), \mu_B(y)) \quad (4.2)$$

The fuzzy neuron for fuzzy conditional inference is represented as in Fig.6.

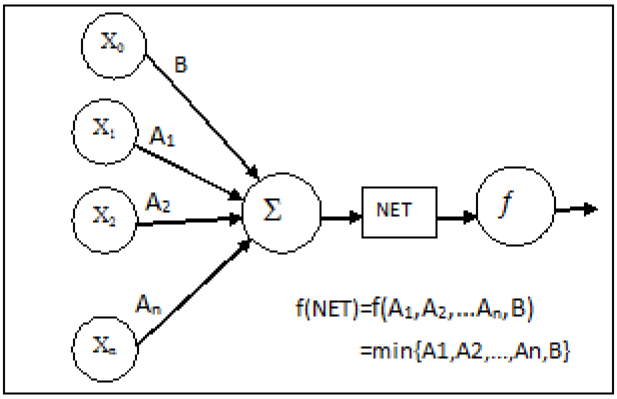

Fig. 6. *Mamdani method.*

The fuzzy inferenceneeds prior information forthe precedence part and consequentpart. i.e., the relationship between president part and consequent part is known The modified method is proposedwhen relationship between president part and consequent part is not known.

The fuzzy conditional inference for TSK method [6] is given as $x_0=f(x_1,x_2,\ldots,x_n)$ and is shown in fig.7a.

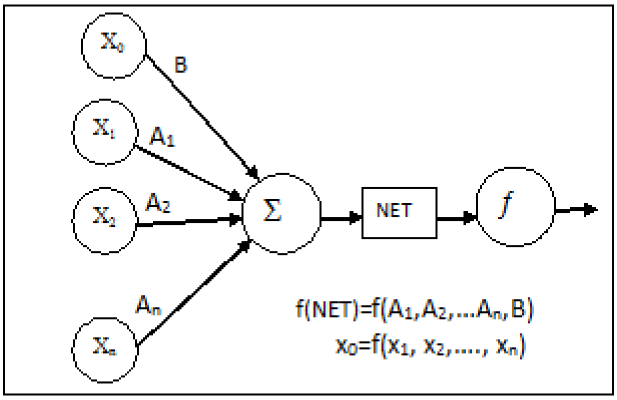

Fig.7a. *TSK method.*

The TSK method is difficult to compute and modified method is proposed instead of TSK method.

The TSK model is difficult to compute. The modified method is proposed.

Consider fuzzy sets Instead of variable for fuzzy rule and the fuzzy rule may be given as

if x_1 isA_1 and x_2 is A_2 and … and x_n is A_n then B =f(A_1, A_2, …, A_n)

The fuzzy inference may be derived in the following way.

The additivemapping f: R→R is called derivation if

$$f(x+y)=f(x)+f(y)$$

t-norm is used in several fuzzy classification system[2]

$$t(x+y)<=\max(t(x),t(y))$$

$$t(x*y)<=\min(t(x),t(y))$$

Substitute fuzzy sets A_1 and A_2 with x and yrespectively

$$f(A_1 + A_2)<=\max(f(A_1),f(A_2))$$

$$f(A_1 * A_2)<=\min(f(A_1),f(A_2))$$

The fuzzy conditional inference is given by

if x_1 isA_1 and x_2 is A_2 and … and x_n is A_n then B =min(A_1, A_2, …, A_n), where A_1 +$A_2$is A_1orA_2, A_1 * $A_2$is A_1+A_2

The fuzzy neuron for fuzzy conditional inferenceis represented as

$$B= f(A_1,A_2,\ldots,A_n) =\min(A_1,A_2,\ldots,A_n) \quad (4.3)$$

and is shown in Fig.7b

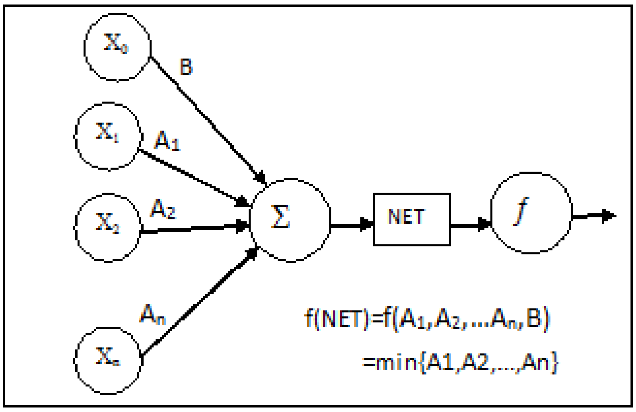

Fig. 7b. *Reddy method.*

5. Fuzzy Medical Expert Systems

Expert Systems has been a rapidly developing field in AI. A recent trend in Expert Systems is the development of Fuzzy Medical Expert Systems for solving Medical diagnosis. The object of the medical expert systems is to capture the knowledge of an expert in medical problem domain, represent it in a modular, expandable structure, and transform it to their users in the same problem domain. Many times knowledge available to the medical expert system fall under uncertain, imprecise, vague, incomplete, inconsistent and inexact. Zadeh introduced fuzzy logic to deal such information which is based on True rather than probable.

An Expert System is called Fuzzy Expert System if it reasons for fuzzy information. The components of fuzzy expert system are shown in fig.8.It is necessary to understand the components of fuzzy Expert system. The Fuzzy Expert System contains Fuzzy knowledge base (Fuzzy rule based), Interference engine, Working memory, Explanation subsystem, Natural language interference and knowledge acquisition. In this paper, mainly concentrate on fuzzy knowledge bases because the others are vastly developed.

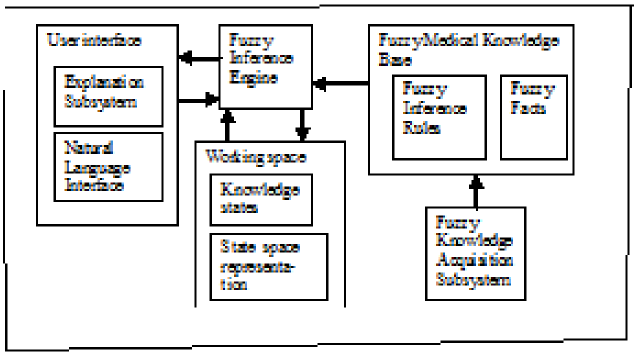

Fig. 8. *Fuzzy expert system.*

Domain expert

Whose knowledge and experience have been used to produce information about specific area of interest and to store it in the fuzzy expert system is given by domain expert.

Knowledge Engineering

The knowledge engineering is the problem solving strategy consists of problem solution such as control architecture (search strategies), Fuzzy knowledge representation and problem solution strategy, which determine what knowledge to apply.

Inference engine

It is responsible for interpreting the contents of the Fuzzy knowledge base in order to reach a goal or conclusion. The inference engine can be divided into three parts.

Context Block

This part contains the current state of the problem and solution.

Inference (Reasoning) Mechanism

The inference mechanism finds appropriate set of knowledge with the help of context block in order to reach a goal or conclusion.

Explanation Facility

The facility helps the user to understand the line of reasoning.

Knowledge acquisition facility

New knowledge is generated with the assistance of this facility.

Work Space

It is storage structure of problem description and the levels of problem states (knowledge sources). The Fuzzy rule based knowledge to be stored can be schematically represented in a net form.

User Interface

The module of the Fuzzy expert system permits the user to benefit from the system.

6. Generalized Fuzzy Certainty Factor

The Generalized fuzzy set A of X is characterized as its membership function A = $\{\mu_A^{true}(x), \mu_A^{false}(x)\}$ and ranging values in the unit interval[0, 1]

The Certainty factor in MYCIN [1] is defined as CF[h,e]=MB[h,e]-MD[h,e], where MB[h,e] and MD[h,e] are Probabilities.

The Generalized Fuzzy Certainty Factor (GFCF) is defined as

$$GFCF[x,A]=MB[x,A]-MD[x,A],$$

$$\mu_A^{GFCF}(x) = \mu_A^{True}(x) - \mu_A^{False}(x)$$

$$MB[x, A] = \mu_A^{True}(x) \text{ and } MD[x,A\} = \mu_A^{False}(x)$$

Where MB[x,A] and MD[x,B] are fuzzy functions

The Generalized Fuzzy Certainty Factor (GFCF) will compute the conflict of evidence in the Uncertain Information.

$$\mu_A^{GFCF}(x) = \mu_A^{True}(x) - \mu_A^{False}(x)\mu_A^{True}(x) \geq \mu_A^{False}(x)$$

$$0\mu_A^{True}(x) < \mu_A^{False}(x)$$

The fuzzy certainty factor becomessingle fuzzy membership function.

$\mu_A^{GFCF}(x)$:X→[0, 1], x€ X,where X is Universe of discourse.

The Generalized fuzzy certainty factor becomes single fuzzy membership function.

For instance " x has fever"

The GFCF for fever given as

$$\mu_{fever}^{FCF}(x) = \{ \mu_{fever}^{True}(x) - \mu_{fever}^{False}(x) \}$$

The operations on GFCF are similar to fuzzy logic operations with single membership function.

Consider the rule in medical diagnosis

If the patient has Red Eye

And Purulent Discharge

and matting of Eye lashes

Then the patient has Conjunctivitis Eye

For instance, 'True" and "False" Fuzziness maybe given for symptoms and diagnosis as

IF the patient has Red Eye (0.9, 0.1)

AND Purulent Discharge(0.8, 0.1)

AND Matting of Eye lashes(0.9, 0.1)

THEN the patient ConjunctivitisEye (0.9, 0.3)

The GFCF may be given as

IF the patient has Red Eye (0.8)

AND Purulent Discharge(0.7)

AND Matting of Eye lashes(0.8)

THEN the patient Conjunctivitis Eye(0.6)

EMYCIN Programming the GFCF may be computed as

Zadeh [11] fuzzy conditional inference(4.1) is given by

(defrule10

If: Red-Eye

and Purulent-Discharge

and matting –of- Eye-lashes

then: identity diagnosis is Conjunctivitis-Eye (0.9)

The EMYCIN will diagnose Conjunctivitis-Eye with fuzzy certainty factor 0.9.

Mamdani[5]fuzzy conditional inference (4.2) is given by

(defrule 11

If: Red-Eye

and Purulent-Discharge

and Matting-of-Eye-lashes
then: identity diagnosis Conjunctivitis-Eye (0.6)

The EMYCIN will diagnose chicken-pox with fuzzy certainty factor 0.6.

Reddy fuzzy conditional inferenceis given by
(defrule 12
If: Red-Eye
and Purulent-Discharge
and Matting-of-Eye-lashes
then: identity diagnosis is Conjunctivitis-Eye (0.7)

The EMYCIN will diagnose Conjunctivitis-Eye with fuzzy certainty factor 0.7.

The Graphical representationfor Zaheh, Mamdani and Reddyfuzzy conditional inference is shown in Fig.9a and 9b

Similarly, there are some fuzzy medical rules may be defined in EMYCIN.

If the patient has Defective vision
and Headache
and watering
then patient has Myopia

If the patient has Unilateral Headache
and Nausea vomiting
and defective vision
then patient has migraine.

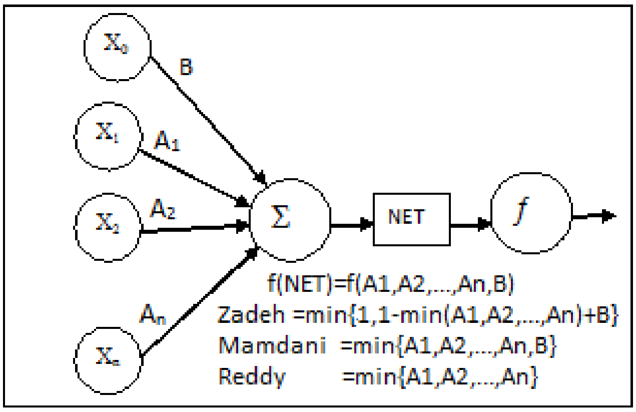

Fig. 9a. *Fuzzy neural net for diagnosis.*

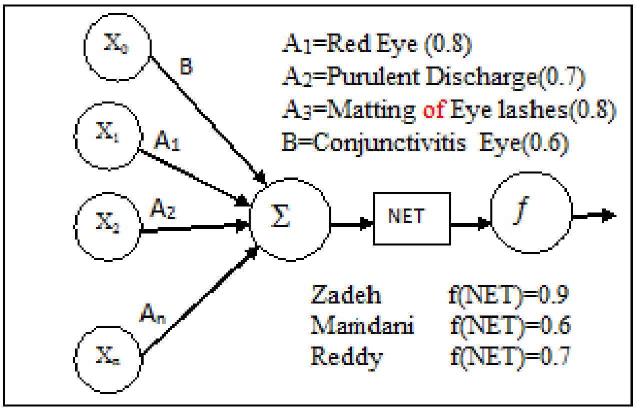

Fig. 9b. *Fuzzy medical diagnosis.*

7. Conclusion

The medical expert systems are emerging area for medical diagnosis because they act as Doctors in diagnosis. The medical diagnosis has to deal with incomplete information. The fuzzy logic will deal incomplete information with belief rather than probability (likelihood).Different fuzzy conditional inferences are discussed and learned through neural networks. The fuzzy medical expert system shell is a tool for medical diagnosis in which physician can define medical diagnosis. The EMYCIN fuzzy medical expert system is discussed for eye disease as an example. The fuzzy medical expert systems may be developed even using JAVASCRIPT for medical diagnosis.

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