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Fuzzy Reinforcement Learning using Neural Network: An Application to Medical Diagnosis and Business Intelligence

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Abstract- The information available to the system is incomplete in many applications, particularly in Decision Support Systems. The fuzzy logic deals incomplete information with belief rather than likelihood (probability). Sometimes the decision has to be taken with fuzzy information. In this paper, fuzzy machine learning is studied for decision support systems. The fuzzy Decision set is defined with two-fold fuzzy set. The fuzzy inference is studied with fuzzy neural network for fuzzy Decision sets. Business application is given as application.

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FUZZYREINFORCEMENTLEARNINGUSINGNEURALNETWORKANAPPLICATIONTOMEDICALDIAGNOSISANDBUSINESSINTELLIGENCE

Strictly as per the compliance and regulations of:

Fuzzy Reinforcement Learning using Neural Network: An Application to Medical Diagnosis and Business Intelligence

Poli Venkata Subba Reddy

Abstract- The information available to the system is incomplete in many applications, particularly in Decision Support Systems. The fuzzy logic deals incomplete information with belief rather than likelihood (probability). Sometimes the decision has to be taken with fuzzy information. In this paper, fuzzy machine learning is studied for decision support systems. The fuzzy Decision set is defined with two-fold fuzzy set. The fuzzy inference is studied with fuzzy neural network for fuzzy Decision sets. Business application is given as application.

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I. Introduction

Information available to many applications like Business, Medical, Geological, Control Systems, etc is incomplete or uncertain. The fuzzy logic will deal with incomplete information with belief rather than likelihood (probable). Zadeh formulated uncertain information as fuzzy set with a single membership functions. The fuzzy set with two membership functions will give more evidence than a single membership function. The two-fold fuzzy set is with fuzzy membership functions "Belief" and "Disbelief". Usually, in Medical and Business applications, there are two opinions like "Belief" and "Disbelief" about the information and decision has to be taken under risk. For instance, in Mycin[1], the medical information is defined with belief and disbelief i.e./, CF[h,e]=MB[h,e] – MD[h.e], where "e" is the evidence for given hypothesis "h". The fuzzy set is used instead of Probability to define fuzzy certainty factor.

The fuzzy neural networks are one of the learning techniques to study fuzzy problems. In the following, some methods of fuzzy conditional inference are studied through fuzzy neural network and before that preliminaries of fuzzy logic and neural network are discussed.

In the following fuzzy logic [10] and Generalized fuzzy logic [9] are studied briefly. The fuzzy Certainty Factor is studied and fuzzy Decision set is proposed. The fuzzy inference and fuzzy reasoning are studied for fuzzy Decision set. The Business applications are studied as applications of fuzzy Decision set.

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II. Fuzzy Logic

Various theories are studied to deal with imprecise, inconsistent and inexact information and these theories deal with likelihood whereas fuzzy logic with belief. Zadeh [10] has introduced fuzzy set as a model to deal with uncertain information as single membership functions. The fuzzy set is a class of objects with a continuum of grades of membership. The set A of X is characterized by its membership function $\mu A(x)$ and ranging values in the unit interval [0, 1].

$\mu A(x)$: $X \rightarrow [0, 1]$, $x \in X$, where X is Universe of discourse.

$A = \mu A(x1)/x1 + \mu A(x2)/x2 + \ldots + \mu A(xn)/xn$, "+" is union

For example, the fuzzy proposition "x is young"

Young={.95/10+0.9/20+0.8/30+0.6/40+0.4/50+0.3/60+0.2/70+0.15/80+0.1/90}

Not young={ 0.05/10 + 0.1/20 + 0.2/30+0.4/40 +0.6/50 + 0.8/60+0.7/70 +0.95/80+0.9/90 }

For instance "Rama is young" and the fuzziness of "young" is 0.8 The Graphical representation of young and not young is shown in fig.1

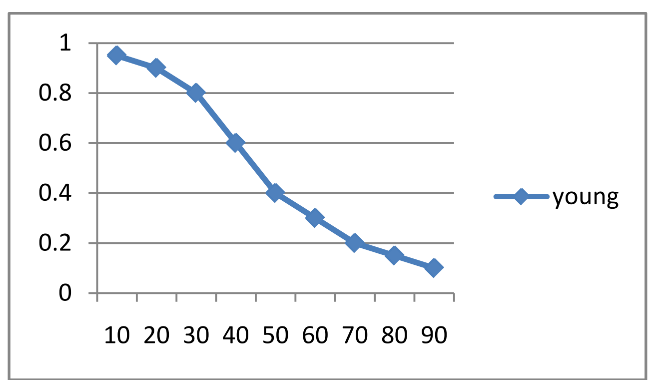

Fig. 1: fuzzy membership function

The fuzzy set of type 2 "Headache" is defined as

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

For example, consider the fuzzy proposition "x has mild Headache"

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For instance “Rama has mild headache” with Fuzziness 0.4

The fuzzy logic is defined as combination of fuzzy sets using logical operators [21]. Some of the logical operations are given below

Let A, B and C are fuzzy sets. 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

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

If x=y

x is A and y is B→ (x, y) is AΛB

$$A \Lambda B = \min(\mu_A(x)), \mu_B(y)\}/x$$ x is A or y is B→ (x, y) is A' x B'

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

If x=y

x is A and x is B→ (x, x) is A V B

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

Implication

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

if x= y

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

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 then y is C” [15]

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

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

Composition

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

If x = y

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

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

III. Generalized Fuzzy Logic with two-Fold Fuzzy Set

Since formation of the generalized fuzzy set simply as two-fold fuzzy set and is extension Zadeh fuzzy logic.

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

Suppose A, B and C are fuzzy sets. The operations on fuzzy sets are given below for two-fold fuzzy sets.

Since formation of the generalized fuzzy set simply as two-fold fuzzy set, Zadeh fuzzy logic is extended to these generalized fuzzy sets.

Negation

$$A' = \{1-\mu_A^{Belief}(x),\ 1-\mu_A^{Disbelief}(x)\ \}/x$$

Disjunction

$$AVB = \{\max(\mu_A^{Belief}(x), \mu_A^{Belief}(y)),\ \max(\mu_B^{Disbelief}(x), \mu_B^{Disbelief}(y))\}(x,y)$$

Conjunction

$$A\wedge B = \{\min(\mu_A^{Belief}(x), \mu_A^{Belief}(y)),\ \min(\mu_B^{Disbelief}(x), \mu_B^{Disbelief}(y))\}/(x,y)$$

Implication

$$A\rightarrow B = \{\min(1,\ 1-\mu_A^{Belief}(x) + \mu_B^{Belief}(y)),\ \min(1, 1-\mu_A^{Disbelief}(x) + \mu_B^{Disbelief}(y)\}(x,y)$$

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

If x is A then y is B else y is C $= A\rightarrow B = \{\min(1, 1-\mu_A^{Belief}(x) + \mu_B^{Belief}(y)),\ \min(1, 1-\mu_A^{Disbelief}(x) + \mu_B^{Disbelief}(y)\}/(x,y)$

if `A

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

Composition

$$A\ o\ R = \{\min_x(\mu_A^{Belief}(x), \mu_A^{Belief}(x)),\ \min_x(\mu_R^{Disbelief}(x), \mu_R^{Disbelief}(x))\}/y$$

The fuzzy propositions may contain quantifiers like "very", "more or less". These fuzzy quantifiers may be eliminated as

Concentration

"x is very A

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

Diffusion

"x is more or less A"

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

For instance, Let A, B and C are

$$A = \{0.8/x_1 + 0.9/x_2 + 0.7/x_3 + 0.6/x_4 + 0.5/x_5,\ 0.4/x_1 + 0.3/x_2 + 0.4/x_3 + 0.7/x_4 + 0.6/x_5\}$$

$$B = \{0.9/x_1 + 0.7/x_2 + 0.8/x_3 + 0..5/x_4 + 0.6/x_5,\ 0.4/x_1 + 0.5/x_2 + 0.6/x_3 + 0.5/x_4 + 0.7/x_5\}$$

$$A\ V\ B = \{0.9/x_1 + 0.9/x_2 + 0.8/x_3 + 0.6/x_4 + 0.6/x_5,\ 0.4/x_1 + 0.5/x_2 + 0.6/x_3 + 0.7/x_4 + 0.7/x_5\}$$

$$A\wedge B = \{0.8/x_1 + 0.7/x_2 + 0.7/x_3 + 0.5/x_4 + 0.5/x_5,\ 0.4/x_1 + 0.3/x_2 + 0.4/x_3 + 0.5/x_4 + 0.6/x_5\}$$

$$A' = \text{not } A = \{0.2/x_1 + 0.1/x_2 + 0.3/x_3 + 0.4/x_4 + 0.5/x_5,\ 0.6/x_1 + 0.7/x_2 + 0.6/x_3 + 0.3/x_4 + 0.4/x_5\}$$

$$A\rightarrow B = \{1/x_1 + 0.8/x_2 + /x_3 + 0.9/x_4 + 1/x_5,\ 1/x_1 + 1/x_2 + 1/x_3 + 0.8/x_4 + 1/x_5\}$$

$$A\ o\ B = \{0.8/x_1 + 0.7/x_2 + 0.7/x_3 + 0.5/x_4 + 0.5/x_5,\ 0.4/x_1 + 0.3/x_2 + 0.4/x_3 + 0.5/x_4 + 0.6/x_5\}$$

$$\mu_{Very\ A}(x) = \{\mu_A^{Belief}(x)^2,\ \mu_A^{Disbelief}(x)\mu_A(x)^2\}$$

$$= \{0.64/x_1 + 0.81/x_2 + 0.49/x_3 + 0.36/x_4 + 0.25/x_5,$$

$$0.16/x_1 + 0.09/x_2 + 0.16/x_3 + 0.49/x_4 + 0.36/x_5$$

$$\mu_{\text{More or Less A}}(x) = (\mu_A^{\text{Belief}}(x)^{1/2}, \mu_A^{\text{Disbelief}}(x)\mu_A(x)^{1/2}\}$$

$$= \{\ 0.89/x_1 + 0.94/x_2 + 0.83/x_3 + 0.77/x_4 + 0.70/x_5,$$

$$0.63/x_1 + 0.54/x_2 + 0.63/x_3 + 0.83/x_4 + 0.77/x_5\}$$

IV. Fuzzy Neural Network

The neural network concept is taken from the Biological activity of nervous system. The neurons passes information to other neurons. There are many models described for neural networks. The McCulloch-Pitts model 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

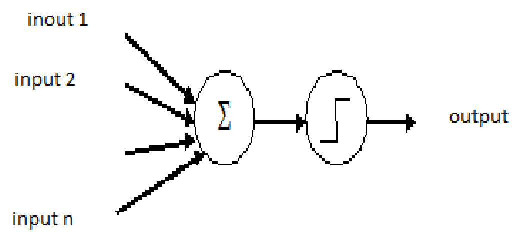

Fig. 2: McCulloch and Pitt's model

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 B may be defined as set of individuals of the universe of discourse, fuzziness and computational functional function and shown in Fifg.3.

Where $B=f(A_1,A_2,\ldots A_n)$

This fuzzy neuron fit for where the relation between president part and consequent part of fuzzy conditional inference is not known

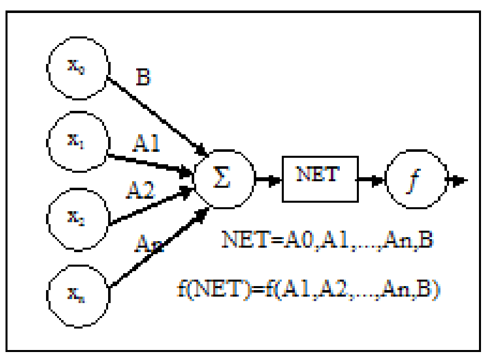

Fig. 3: Fuzzy neuron model

The multilayer fuzzy neural net work is shown in Fig.3

The fuzzy neuron for Defuzzification for Centre of Gravity (COG) is shown in fig.4

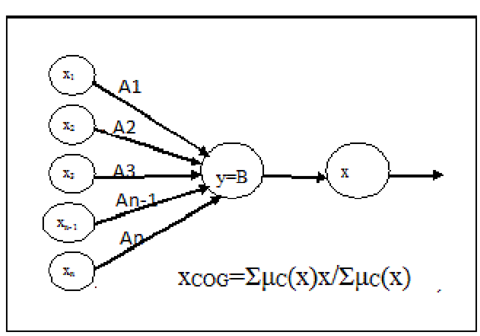

Fig. 4: Defuzzification

V. Fuzzy Decision Set

Zadeh[10] proposed fuzzy set to deal with incomplete information. Generalized fuzzy set with two-fold membership function $\mu_A(x) = \{\mu_A^{Belief}(x), \mu_A^{Disbelief}(x)\}$ is studied [18]

The fuzzy Certainty Factor may be defined as (FCF)

$$\mu_A^{FCF}(x) = \mu_A^{Belief}(x) - \mu_A^{Disbelief}(x)\text{, where}$$

$$\mu_A^{FCF}(x) = \mu_A^{Belief}(x) - \mu_A^{Disbelief}(x) \qquad \mu_A^{Belief}(x) \geq \mu_A^{Disbelief}(x)$$

$$= 0 \quad \mu_A^{Belief}(x) < \mu_A^{Disbelief}(x)$$

Fuzzy Decision set R is defined based on convex fuzzy set [10]

$$R = \{A,\ \mu_A^{FCF}(x) \geq \alpha\}\text{, where } \alpha \in [0,1]$$

For instance,

$$\text{Demand} = \{ 0..8/x1+0.7/x2+0.86/x3+0.75/x4+0.88/x5,\ 0.2/x1+0.3/x2+0.25/x3+0.3/x4+0.2/x5 \}$$

$$\mu_{Demand}^{FCF}(x) = 0.6/x1+0.4/x2+0.61/x3+0.45/x4+0.68/x5$$

The Generalized fuzzy set for Demand for the Items and fuzzy certainty factor is shown in Fig5.

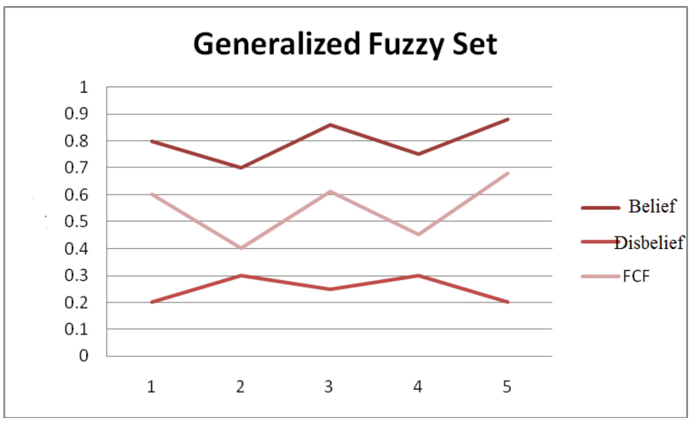

Fig. 5: Generalized fuzzy set

Suppose fuzzy Decision set is defined

$$\mu_{Demand}^{FCF}(x) \geq 0.5$$

$$= 1/x1+0/x2+1/x3+0/x4+1/x5$$

Decision may be taken under Decision shown in Fig.6.

Fig. 6: Fuzzy Decision set

The fuzzy logic is combination of logical operators. Consider the logical operations on fuzzy Decision sets r1, R2 and R3

Negation

If x is not R1

$$R1' = 1 - \mu_{R1}(x)/x$$

Conjunction

$$x \text{ is } R1 \text{ and } y \text{ is } R2 \rightarrow (x, y) \text{ is } R1 \times R2$$

$$R1 \times R2 = \min(\mu_{R1}(x)), \mu_{R2}(y)\}(x,y)$$

$$\text{If } x = y$$

$$x \text{ is } R1 \text{ and } y \text{ is } R2 \rightarrow (x, y) \text{ is } R1 \wedge R2$$

$$R1 \wedge R2 = \min(\mu_{R1}(x)), \mu_{R2}(y)\}/x \; x \text{ is } R1 \text{ or } y \text{ is } R2 \rightarrow (x, y) \text{ is } R1' \times R2'$$

$$R1' \times R2' = \max(\mu_{R1}(x)), \mu_{R2}(y)\}(x,y)$$

$$\text{If } x = y$$

$$x \text{ is } R1 \text{ and } x \text{ is } R2 \rightarrow (x, x) \text{ is } R1 \vee R2$$

$$R1 \vee R2 = \max(\mu_{R1}(x)), \mu_{R2}(y)\}/x \text{ Disjunction}$$

Implication

$$\text{if } x \text{ is } R1 \text{ then } y \text{ is } R2 = R1 \rightarrow R2 = \min\{1, 1 - \mu_{R1}(x)) + \mu_{R2}(y)\}/(x,y)$$

$$\text{if } x = y$$

$$R1 \rightarrow R2 = \min\{1, 1 - \mu_{R1}(x)) + \mu_{R2}(y)\}/x$$

Composition

$$R1 \circ R2 = R1 \times R2 = \min\{\mu_{R1}(x)), \mu_{R2}(y)\}/(x,y)$$

$$\text{If } x = y$$

$$R1 \circ R2 == \min\{\mu_{R1}(x)), \mu_{R2}(y)\}/x$$

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

Concentration

$$x \text{ is very } R1$$

$$\mu_{\text{very } R1}(x)), \; = \mu_{R1}(x)^{2}$$

Diffusion

$$x \text{ is very } R1$$

$$\mu_{\text{more or less } R1}(x) = \mu_{R1}(x)^{0.5}$$

Zadeh[10] fuzzy conditional inference is give as

If x_1 is R1 and x_2 is R2 and … and x_n is Rn then y is B =f(R1,R2,…,Rn,B)=min(1,1-R1+R2+…+Rn+B)

The fuzzy neural network for Zadeh is shown in fig.7

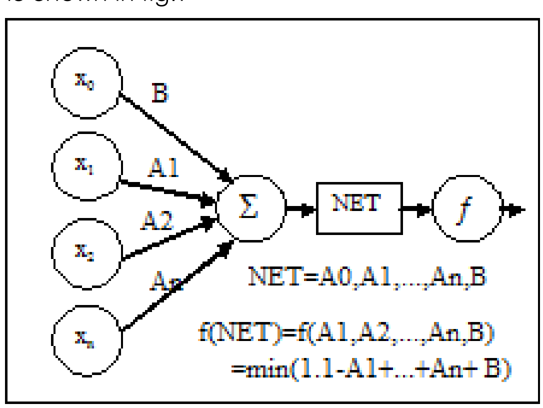

Fig. 7: Zadeh fuzzy conditional inference

Mamdani [2] fuzzy conditional inference is give as

If x_1 is R1 and x_2 is R2 and … and x_n is Rn then y is B =f(R1,R2,…,Rn,B)=min(R1,R2,…,Rn,B)

The fuzzy neural network for Mamdani is shown in fig.8

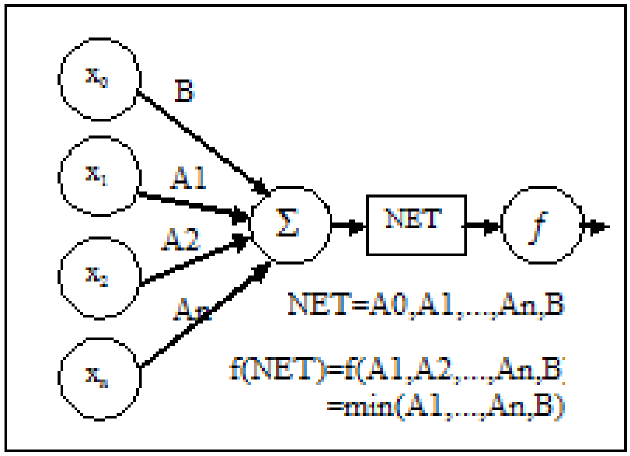

Fig. 8: Mamdani fuzzy conditional inference

Reddy [8] fuzzy conditional inference is give as
If x_1 is R1 and x_2 is R2 and … and x_n is Rn then y is B =f(R1,R2,…,Rn,B)=min(R1,R2,…,Rn)

The fuzzy neural network for Reddy is shown in fig.9

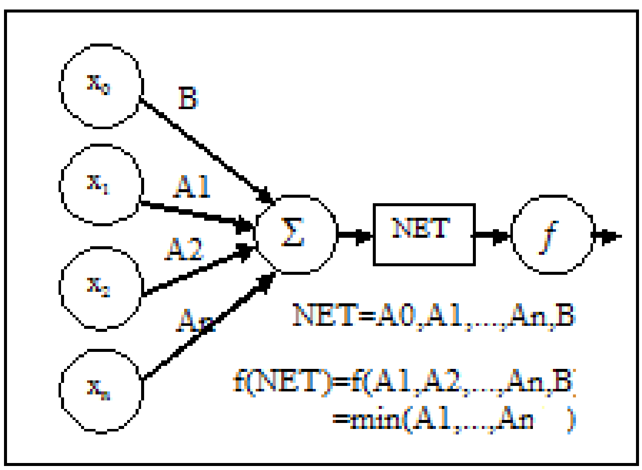

Fig. 9: Reddy fuzzy conditional inference

VI. Fuzzy Conditional Infrence in Decision Making

Decision management is usually happens in Decision Support Systems.

Example 1
Consider Business rule
If x is Demand of the product then x is High Price
Let x1, x2, x3, x4, x5 be the Items.
The Generalized fuzzy set

Demand ={ 0.56/x1+0.48/x2+0.86/x3+0.36/x4+0.88/x5, 0.06/x1+0.04/x2+0.07/x3+0.03/x4+0.2/x5 }

$$\mu_{Demand}^{FCF}(x) = 0.5/x1+0.44/x2+0.79/x3+0.33/x4+0.68/x5$$

High Price = 0.49/x1+0.52/x2+0.35/x3+0.4/x4+0.3/x5,
0.09/x1+0.02/x2+0.06/x3+0.02/x4+0.1/x5 }

$$\mu_{High\ Price}^{FCF}(x) = 0.4/x1+0.5/x2+0.29/x3+0.38/x4+0.2/x5$$

Zadeh inference is given as A→B= min{1, 1-μ_A(x) + μ_B(x)}

$$\mu_{Demand \rightarrow High\ Price}{}^{FCF}(x) = 0.9/x1+1/x2+0.5/x3+1/x4+0.52/x5$$

$$\mu_{Demand \rightarrow High\ Price}{}^{FCF}(x) \geq 0.6 = 1/x1+1/x2+0/x3+1/x4+0/x5$$

Mamdani inference is given as A→B= min{μ_A(x) , μ_B(x)}

$$\mu_{Demand \rightarrow High\ Price}{}^{FCF}(x) = 0.4/x1+.44/x2+0.29/x3+.33/x4+0.2/x5$$

$$\mu_{Demand \rightarrow High\ Price}{}^{FCF}(x) \geq 0.6 = 1/x1+1/x2+0/x3+1/x4+0/x5$$

Mamdani inference is given as A→B= min{μ_A(x) }

$$\mu_{Demand \rightarrow High\ Price}{}^{FCF}(x) = 0.4/x1+.44/x2+0.29/x3+.33/x4+0.2/x5$$

$$\mu_{Demand \rightarrow High\ Price}{}^{FCF}(x) \geq 0.6 = 1/x1+1/x2+0/x3+1/x4+0/x5$$

Example 2

Consider Medical Diagnosis

If x has infection in the leg then surgery

Let x1, x2, x3, x4, x5 are the Patients.

The fuzzy set

$$\mu_{Infection}{}^{FCF}(x) = 0.76/x1+0.78/x2+0.46/x3+0.86/x4+0.58/x5,$$

$$0.16/x1+0.12/x2+0.06/x3+0.14/x4+0.05/x5\}$$

$$= 0.6/x1+0.64/x2+0.4/x3+0.72/x4+0.53/x5$$

$$\mu_{Surgery}{}^{FCF}(x) = 0.59/x1+0.26/x2+0.55/x3+0.24/x4+0.35/x5,$$

$$0.09/x1+0.06/x2+0.05/x3+0.04/x4+0.03/x5\ \}$$

$$= 0.5/x1+0.2/x2+0.5/x3+0.2/x4+0.32/x5$$

Using inference rule A→B= min{1, 1-μ_A(x) + μ_B(x)}

$$\mu_{Infection \rightarrow Surgery}{}^{FCF}(x) = 0.9/x1+0.56/x2+0.9/x3+1/x4+1/x5$$

$$\mu_{Infection \rightarrow Surgery}{}^{R}(x) = 1 \quad \mu_{Infection \rightarrow Surgery}{}^{FCF}(x) \geq 6$$

$$0 \quad \mu_{Infection \rightarrow Surgery}{}^{FCF}(x) < 6$$

The fuzzy risk set R is

$$1/x1+0/x2+1/x3+1/x4+1/x5$$

The decision is to take for surgery is Yes for x1, x3, x4, x5 and No for x2.

The fuzzy reasoning under Risk management in Decision Support Systems may be Consider the fuzzy rule and fuzzy fact

If x has Infection of the product then x is to go for Surgery

x has very Infection

x is very Infection o Infection→Surgery

$$\mu_{Infection \rightarrow Surgery}{}^{FCF}(x) = 0.9/x1+0.56/x2+0.9/x3+1/x4+1/x5$$

$$\mu_{very\ Surgery}{}^{FCF}(x) = 0.25/x1+0.2\backslash 04/x2+0.25/x3+0.04/x4+0.1/x5$$

x is very Demand o Demand→Increase Price

$$=0.35/x1+0.66/x2+0.35/x3+0.04/x4 + 0.1/x5$$

Suppose Fuzzy risk set for **α**≥.5, the decision is Yes for x2 and No for x1, x4, x4 and x5.

VII. Conclusion

The decision has to be taken under incomplete information in many applications like Business, Medicine etc. The fuzzy logic is used to deal with incomplete information The fuzzy Decision set is defined with two-fold fuzzy set. The fuzzy logic is discussed with two-fold fuzzy set. The fuzzy Decision set, inference and reasoning are studied. The Business applications is discussed for fuzzy Decision set.

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