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***Abstract*— Knowledge Representation (KR) is key factor to solve AI problem particular incomplete problems. The fuzzy logic deals with incomplete information, The KR with single fuzzy membership function is not sufficient to deal with incomplete problems. The two fold fuzzy set will give more evidence than the single fuzzy membership function. In this paper, FUZZY PROLOG is discussed for to KR with a two fold fuzzy set. FUZZY PROLOG is higher order representation of predicate logic for incomplete problems. Logic programming is discussed for FUZZY PROLOG by taking examples.**

Key words-fuzzy logic, twofold fuzzy set, fuzzy knowledge representation, logic programming

I. INTRODUCTION

Various theories are proposed to deal with incomplete information. Most of the theories are based on probability and randomized... Fuzzy logic is dealing with the commonsense and mind. Zadeh [10] propose single membership function to deal with incomplete information. Fuzzy Set with two membership functions will give more evidence to deal with the incomplete information. The Many-Valued Logic is considered to discuss the Fuzzy Logic with two membership functions. The fuzzy Set may be defined by two Fuzzy membership functions based on "Belief and Disbelief" to deal with incomplete, inconsistent, inexact and Incomplete information.

The AI problems may contain incomplete information. The KR is key factor to solve the AI problems. The KR is necessary to deal with incomplete problems. The FKR is studied to design incomplete problems. This FKR later used for logic programming to solve in complete AI problems.

II. GENERALIZED FUZZY LOGIC WITH TWO FOLD FUZZY SETS

Zadeh[10] considered a single Fuzzy membership function to define the Fuzzy set to deal the incomplete information.

The proposition " x is A" is defined by

A= $\mu_A(x)$, Where A is Fuzzy Set and x Є X, $\mu A(x)$ is Fuzzy membership function.

The propositions " x is A" may represent the evidence with "Belief" and Disbelief" to deal the Incomplete information.

Given some Universe of discourse X, the proposition " x is A" is defined by its two Fuzzy membership functions

$\mu_A(x) = \{\mu_A^{Belief}(x), \mu_A^{Disbelief}(x)\}$

or

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

$A = \{ \mu_A^{Belief}(x_1)/x_1 + \mu_A^{Belief}(x_2)/x_2 + \ldots + \mu_A^{Belief}(x_n)/x_n,$
$\mu_A^{Disbelief}(x_1)/x_1 + \mu_A^{Disbelief}(x_2)/x_2 \ldots + \mu_A^{Belief}(x_n)/x_n\}$

$\mu_A^{Belief}(x) + \mu_A^{Disbelief}(x) < 1,$

$\mu_A^{Belief}(x) + \mu_A^{Disbelief}(x) > 1$

and $\mu_A^{Disbelief}(x) + \mu_A^{Disbelief}(x) = 1$

are interpreted as redundant, insufficient and sufficient Knowledge respectively.

For example,

Consider the Fuzzy proposition "x has Cold" and The Fuzzy set 'Cold" may be defined

Cold = { $0.8/x_1 + 0.6/x_2 + 0.4/x_3 + 0.6/x_4 + 0.75/x_5$, $0.4/x_1 + 0.5/x_2 + 0.5/x_3 + 0.4/x_4 + 0.35/x_5$}

For instance "Rama has Cold" with Fuzziness {0.8, 0.4}.

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

Suppose A, B, C are Fuzzy sets, and The operations on Fuzzy sets are given below

$A \vee B = \{ \mu_A^{Belief}(x) \vee \mu_A^{Belief}(x), \mu_B^{Disbelief}(x) \vee \mu_B^{Disbelief}(x)\}$

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

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

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

$A1oR = \{\min_x (\mu_{A1}^{Belief}(x), \mu_{A1}^{Belief}(x)), \min_x(\mu_R^{Disbelief}(x), \mu_R^{Disbelief}(x))\}/x$

For instance

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 Λ 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' = 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→ 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 = { $0.8/x_1 + 0.7/x_2 + 0.7/x_3 + 0.5/x_4 + 0.5/x_5$, $0.4/x_1 + 0.3/x_2 + 0.4/x_3 + 0.5/x_4 + 0.6/x_5$}

The Fuzzy propositions [8] may contain quantifiers like "very" (Concentration), "more or less" (Diffusion) . These Fuzzy quantifiers may be eliminated as

For instance

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

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

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

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

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

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

III. FUZZY CERTAINITY FACTOR

The fuzzy certainty Factor FCF) may be defined with the "belief " and "disbelief "

.

In MYCIN [1], the certainty factor(CF) is defined as the deference between belief [MB] and disbelief [MD] of probabilities.

CF[h,e]=MB[h,e]-MD[h,e]

Where "e' evidence and "h" is hypothesis

The certainty factor (CF) may defied by fuzzy certainty factor (FCF) by considering fuzziness instead of probability.

$\mu_A^{FCF}(x) = \mu_A^{belief}(x) - \mu_A^{disbelief}(x)$

where "belief" and "disbelief" are fuzzy sets.

For instance

$\mu_{vision\ clarity}^{disbelief}(x) = 0..7/x_1 + 0.6/x_2 + 0.4/x_3 + 0.3/x_4 + 0.2/x_5$

$\mu_{vision\ clarity}^{FCF}(x) = 1 - \mu_{vision\ clarity}^{disbelief}(x)$

$= 0..3/x_1 + 0.4/x_2 + 0.6/x_3 + 0.7/x_4 + 0.8/x_5$

Fig2. Fuzzy certainty factor

IV. FUZZY KNOWLEDGE REPRESENTATION LANGUAGE

Fuzzy Modulations is a type of Knowledge representation for Fuzzy propositions. These Fuzzy modulations are used to study Fuzzy Logic and Inference for two membership functions for understanding.

. Fuzzy Modulations are a type of Knowledge representation for Fuzzy propositions .

The Fuzzy Modulation for the position " x is A" is defined by

[A]R(x), where A is Fuzzy Set, R is relation and x Є X

Fuzzy reasoning is discussed for the Fuzzy sets with two membership functions Fuzzy modulations in the following

For instance,

"Rama has Cold" is modulated as

[Cold] Symptom(Rama)

The Fuzzy position "Rama has Headache" may be modulated as

[Headache] Symptom(Rama)

From the above propositions infer

Rama has Cold or Headache

This may be modulated as

[Cold V Headache Symptom(Rama)

For instance, consider the Fuzziness for Fuzzy Sets

Rama has cold

Cold = [0.6, 03]

Rama has Headache

Headache = {0.4, 0.5]

Rama has Cold or Headache

[Cold V Headache]Symptom(Rama)

[[0.6, 03]V{0.4, 0.5]]Symptom(Rama)

[[0.6, 0.5]]Symptom(Rama)

Rama has Cold or Headache with fuzziness [0.6, 0.5]

An Example of Fuzzy Reasoning with two membership functions is given bellow

Rama has Cold

If Rama has Cold Then Rama has Sneezing

If Rama has Cold Then Rama has Headache

The above Fuzzy facts may be modulated as

F1:[Cold] Symptom(Rama)

F2:If [Cold] Symptom(Rama) Then [Sneezing] Symptom(Rama)

or

F2: [(Cold → Sneezing] Symptom(Rama)

F3: If [Cold] Symptom(Rama) Then [Headache] Symptom(Rama)

Or

F3: [(Cold → Headache] Symptom(Rama)

From F1 and F2 infer using R5

F4: [Cold o (Cold → Sneezing] Symptom(Rama)

From F1 and F3 infer using R5

F5: [Cold o (Cold → Headache] Symptom(Rama)

If Rama has Sneezing Then Rama has Fever

If Rama has Headache Then Rama has Body pains

The above Fuzzy facts may be modulated as

F6: If [Sneezing] Symptom(Rama) Then [Fever] Symptom(Rama)

Or

F6: [Sneezing →Fever] Symptom(Rama)

F7: If [Headache] Symptom(Rama) Then [Body pains] Symptom(Rama)

Or
F7: [Headache →Body pains] Symptom(Rama)

From F4 and F6 infer

F8: [Cold o (Cold → Sneezing] o [Sneezing→fever] Symptom(Rama)

From F5 and F7 infer

F9:[Cold o (Cold→Headache]o [Headache→.Body pains] Symptom(Rama)

From F8 and F9 infer

F10: [Cold o (Cold → Sneezing] o [Sneezing → fever] [Sneezing] Symptom(Rama)
V
[Cold o (Cold → Headache] o [Headache →Body pains] [Sneezing V Body pains] Symptom(Rama)

For example,

Consider Fuzziness for the above propositions

Cold = [0.6, 03]
Fever = [0.4, 0.5]
Sneezing =[0.7, 0.2]
Headache= [0.4, 0.6]
Body pains = [0.7, 0.2]

F1:[Cold] Symptom(Rama)
[0.6, 03] Symptom(Rama)
F2: [Cold → Sneezing] Symptom(Rama)
[[0.6, 03] → [0.7, 0.2] Symptom(Rama)
[1, 0.9] Symptom(Rama)
F3: [Cold → Headache]Symptom(Rama)
[[0.6, 03]→ [0.4, 0.6]]Symptom(Rama)
[0.8,1] Symptom(Rama)

From F1 and F2 infer using R5

F4: [Cold o (Cold → Sneezing] Symptom(Rama)
[0.6, 03]o [1, 0.9] Symptom(Rama)
[0.6, 0.3]Symptom(Rama)

From F1 and F3 infer using R5

F5: [Cold o (Cold → Headache] Symptom(Rama)
[0.6, 03] o [0.8,1] Symptom(Rama)
[0.6, 0.3]Symptom(Rama)
F6: [Sneezing →Fever] Symptom(Rama)
F7: [Headache →Body pains] Symptom(Rama)

From F4 and F6 infer

F8: [Cold o (Cold → Sneezing] o [Sneezing→fever] Symptom(Rama)

[[0.6, 03]o ([0.6, 03]→ [[0.7, 0.2]) o [[0.7, 0.2]→ [0.4, 0.5]] Symptom(Rama)
[[0.6, 03]o [1, 0.9]] o [0.7, 1] Symptom(Rama)
[[0.6, 03]o [0.7, 1] Symptom(Rama)
[0.6, 03] Symptom(Rama)

From F5 and F7 infer

F9: [Cold o (Cold→Headache]o [Headache→.Body pains] Symptom(Rama)
[[0.6, 03]o ([0.6, 03]→ [0.4, 0.6]]o [[0.4, 0.6]→ [0.7, 0.2]] Symptom(Rama)
[[[0.6, 03]o [0.8,1]]o [[1,0.6] Symptom(Rama)
[0.6, 03]o [1,0.6] Symptom(Rama)
[0.6, 03] Symptom(Rama)

From F8 and F9 infer

F10: [Cold o (Cold → Sneezing] o [Sneezing → fever] [Sneezing] Symptom(Rama)
V
[Cold o (Cold → Headache] o [Headache →Body pains] [Sneezing V Body pains] Symptom(Rama)
=[0.6, 03] Symptom(Rama) V[0.6, 03] Symptom(Rama)
=[0.6, 0.3]V[0.6, 03] Symptom(Rama)
=[0.6, 03] Symptom(Rama)

The inference is given by

Rama has symptoms Cold , Fever , Sneezing , Headache and Body pains with uncertainty [0.6, 0.3], where Belief is 0.6 and Disbelief is 0.3.

IV. APPLICATOION TO MEDICAL INTELLIGENCE

The medical intelligence is nothing but doing better medical diagnosis. The medical intelligence is needed second opinion. Medical expert systems are used for medical intelligence

Consider the rule in medical diagnosis
If the patient has Red Eye
and Purulent Discharge
Then the patient has Conjunctivitis Eye

For instance, Fuzziness may be given for symptoms and diagnosis as
IF the patient has Red Eye (0.9, 0.2)
AND Purulent Discharge0(.7, 0.2)
THEN the patient has Conjunctivitis Eye (0.8, 0.2)

The FCF may be given as
IF the patient has Red Eye (0.7)
AND Purulent Discharge(0.5)
THEN the patient has Conjunctivitis Eye Eye(0.6)

The fuzzy rule may be interpreted in EMYCIN (empty MYCIN) as using Mamdani [2] fuzzy conditional inference
(defrule 10
If: Red-Eye

and Purulent-Discharge
then : identity organism is Conjunctivitis-Eye (0.7)

- LOGIC PROGRAMMING FOR FUZZY KNOWLEDE REPRESENTATION

The Prolog is used mainly used for Predicate Logic. The Prolog is a Logic Programming language. It contains mainly predicates and Clauses.

A predicate is a relation with name of the relation and arguments . The arguments may be containing variables or constants.

for instance

simptom(x,y)

symptom(patient, headache)

where father is name of the relation, x and y are variables, and raama and dasaradha are constants.

A clause is combination of and/ or more predicates for the rules.

For instance

If patient has cold then patient has headache

Suppose, we want to find grand children of Dasaradha

The Prolog programming may be written as

predicates

symptom(Patient, cold)

clauses

symptom(Patient, headache):- symptom(Patient, cold)

run the system for

symptom(Patient, headache)

it gives

yes

The FPL is a type of Predicate Logic in which fuzzy set may be defined.

The Logic Programming may be written in SWI-Prolog as

symptom(Patient, headache):- symptom(Patient, cold)

fuzzy(cold,headache,M) :- symptom(Patient, headache, A), symptom(Patient, cold, B), M is min(A,B).

fuzzy(A,B,M) :- M=1.

symptom(Patient, headache, 8).

symptom(Patient, cold, 0.6).

The fuzzy inference is given by

?-.fuzzy(cold,headache,M)

M=0.6

Yes.

V. FUZZY PROLOG FOR HIGHER ORDER

There are some quantifiers may contain in predicate logic like most, usuall, very, more or less ect.

For instance ,

IF the patient has very Red Eye (0.7)
AND more or less Purulent Discharge(0.5)
THEN the patient has Conjunctivitis Eye Eye(0.6)

The quantifiers may reduced as

IF the patient has very Red Eye (0.49)
AND more or less purulent Discharge (0.70)
THEN the patient has Conjunctivitis Eye Eye(0.6)

“there exist a symptom which causes disease is give by

Symptom: Purulent Discharge(0.5)
Disease: Conjunctivitis Eye Eye(0.6)
there exists is minimum of symptoms.

“for every symptom which causes disease is give by

Symptom: Red Eye (0.7)
Disease: Conjunctivitis Eye Eye(0.6)
for every is maximum of symptoms...

VI. CONCLUSION

The Knowledge Representation is key factor to solve the AI problems. The Fuzzy Knowledge Representation will solve the AI problems with incomplete information. Fuzzy Set with two Fuzzy membership functions will give more information than the single membership function. The FUZZY PROLOG is representation of predicate logic for incomplete problems. This is also deal with the higher order predicate logic for incomplete information. The medical diagnosis is studded as an example.

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