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Fuzzy Conditional Inference and Application to Wireless Sensor Network

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I. Introduction

There are many theories to approximate incomplete information. Until recently, probability theory was the only existing theory to the approximate incomplete formation. Zadeh [11] proposed to deal with incomplete information. n Fuzzy set allows us to represent membership function aspossibility distribution. Fuzzy theory is the most effective than the other theory because fuzzy theory depends on the degree of belief rather than likelihood (Probability). Fuzzy conditional propositions are of the type if (precedent part) then (consequent part). There are different methods of fuzzy conditional inference to approximate uncertain information [2,3,4,6,7]. The Zadeh and Mamdani inferences are needed prior information for both precedent and consequent part. There are some applications like fuzzy control systems that do not have prior information to the consequent part. The TSK fuzzy conditional inference need not know prior information to the consequent part, but it is difficult to compute.

The Sensors are able to sense and process the data. The Sensors are used to collect the data or information for many application like Wireless Sensor Networks and Contro Systems. The Wireless Sensor Network (WSN) and fuzzy control systems are give an an examples for proposed fuzzy conditional inference. It is necessary to give a brief description of fuzzy logic and WSN.

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II. Fuzzy Logic

Zadeh [11] introduced the concept of a fuzzy set as a model of a vague fact. Fuzzy set theory for control systems is accepted because it is very convenient and believable. The fuzzy set may be defined with membership function or commonsense.

Definition: Given some universe of discourse X, a fuzzy set A of X is defined by its membership function μA taking values on the unit interval[0,1] i.e

μ_A:X→[0,1]

Suppose X is a finite set. The fuzzy set A of X may be represented as

$$A= \mu_A(x_1)/x_1 + \mu_A(x_2)/x_2 + \ldots\ldots\ldots\ldots\ldots\ldots + \mu_A(x_n)/x_n$$

Where "+" is union

For instance, fuzzy set may be defined with commonsense

TALL =0.00/5'0'' + 0.08/5'4'' + 0.32/5'8''+ 0.50/6'0'' + 0.82/6'4''

There is an alternative way to defined fuzzy subset with function and is given by [7]

For instance, fuzzy set may be defined with m**embership function

YOUNG = { μ_{YOUNG}(x)/x=1

if x∊[0,25] =[1+((x-25)2)]-1

if x∊[25,100]

Let A and B be the fuzzy sets, and the operations on fuzzy sets are given below

AVB=max(μ_A(x) , μ_B(y)}	Disjunction
AΛB=min(μ_A(x) , μ_B(y)}	Conjunction
A′=1- μ_A(x)	Negation
A→B=min {1, (1- μ_A(x) +μ_B(y)}	Implication
AXB=min { μ_A(x) , μ_B(y)}/(x,y)	Relation
AoR=min $_x${ μ_A(x) , μ_R(x,y)}/y	Composition

Implication

The Zadeh fuzzy condition inference s given by

if x_1 is A_1 and x_2 is A_2 and … and x_n is A_n then y is B

= min {1, (1-min(μ_{A1}(x), μ_{A2}(x), …, μ_{An}(x)) +μ_B(y)}

For Example

A_1= 0.2/x_1 + 0.6/x_2 + 0.9/x_3 + 0.6/x_4 +0.2/x_5

$A_2 = 0.5/x_1 + 0.7/x_2 + 0.9/x_3 + 0.7/x_4 + 0.3/x_5$

$B = 0.1/x_1 + 0.4/x_2 + 0.6/x_3 + 0.4/x_4 + 0.1/x_5$

The Graphical representation of A1, A2 and b are shown in fig.1

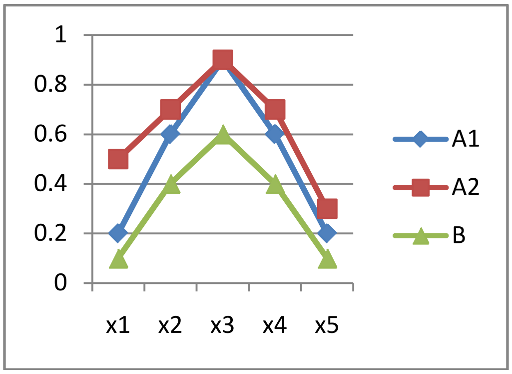

Fig. 1: Implication

Zadeh fuzzy inference is given as

$=\min(1, 1-(A_1, A_2) + B)$

$= 0.9/x_1 + 0.8/x_2 + 0.7/x_3 + 0.8/x_4 + 0.9/x_5$

Mamdani fuzzy inference is given as

$\min(A_1, A_2, \ldots, A_n, B)$

$= 0.1/x_1 + 0.4/x_2 + 0.6/x_3 + 0.4/x_4 + 0.1/x_5$

Mamdani inference is given as

if x_1 is A_1 and x_2 is A_2 and … and x_n is A_n then y is B

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

Reddy[7] fuzzy inference is given as

if x_1 is A_1 and x_2 is A_2 and … and x_n is A_n then y is B

$=\min(A_1, A_2, \ldots, A_n)$

The "consequent" part is derived from "president" part of fuzzy conditions.

$\min(A_1, A_2, \ldots, A_n) = 0.2/x_1 + 0.6/x_2 + 0.9/x_3 + 0.7/x_4 + 0.3/x_5$

The Graphical representation of fuzzy inference is shown in Fig.2.

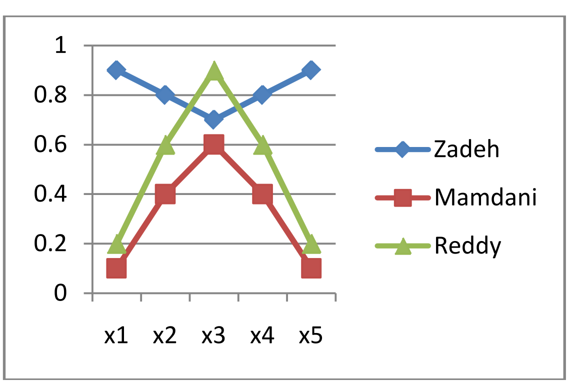

Fig. 2: Composition

Composition

If some relation R between A and B is known and some value A1 then B1 is to infer from R

$B1=A1 \circ R= \min_x \{\mu_{A1}(x), \mu_R(x,y)\}/(x,y)$, where $R=A \rightarrow B$

If x = y

$B1=A \circ R=\min\{\mu_{A1}(x), \mu_R(x)\}/x$

According to Zadeh fuzzy conditional inference

$B1=A1 \circ R=\min\{\mu_A(x), \mu_R(x)\}$

$= \min\{\mu_A(x), \min(1,1- \mu_{A1}(x)+ \mu_B(x))\}$

According to Mamdani fuzzy inference

$= \min\{\mu_{A1}(x),\mu_A(x),\mu_B(x)\}$

If some relation R between A and B is not known According to The proposed fuzzy inference

$= \min\{\mu_{A1}(x), \mu_R(x)\}$

III. Wireless Sensor Technology

Natural calamities are unpredictable and happen within short periods. Therefore WSN technology [1] used to capture signals and transmitted by monitoring. Wireless sensor technology that can send the sensed data to a data analysis center.

Fuzzy Inference System may be used an alternative procedure. The capture data may be analyzed using fuzzy parameters, and these parameters are used in fuzzy inference system. Fuzzy inference system is applied to WSN to detect Coastal erosion.

WSN technology has the capability of capturing and transmission of critical data in real-time. The most common forms are minimum spanning trees for wireless networking sensors.

Shortest paths: Minimal spanning tree is the shortest path connecting all the nodes with minimum distance. The Prim's algorithm may be used to construct minimum spanning tree. The minimum spanning tree has the base node and destination node. The data is transmitted from destination node to the base server.

The Prim's algorithm is to find a minimum spanning tree with nodes and edges. The nodes (V) are Sensors, and edges (E) are distances in WSN.

Algorithm Prim(G)

G(V,E) is a weighted connected Graph

E_T is a set of edges of a minimum spanning tree

$V_T \leftarrow$ is the initial node with any vertex

$E_T \leftarrow \theta$

For i←1 to lVl -1 do

Find a minimum weight edges e*=(v*,u*) among all the edges (v,e)

$V_T \leftarrow V_T \cup \{v^*\}$

$E_T \leftarrow E_T \cup \{u^*\}$

Return E_T

The minimum spanning tree of Fig.3 may be given as

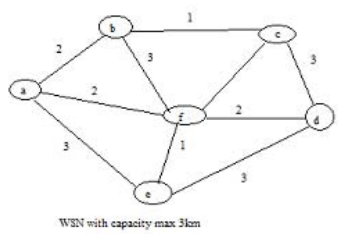

Fig. 3

The path may be given as

a→b, b→c,b→f,f→e, d→f

The node d is the base node.

The Prim's' algorithm constructs spanning tree for collection of Data from WSN. FIS is applied on WSN to detect Costal erosions

IV. New Method of Fuzzy Conditional Inference

Zadeh[10], Mamdani[2], and TSK[3,4] proposed fuzzy conditional inference for incomplete information. Zadeh and Mamdani's inferences need prior information for the consequent part in "if … then …"

if x_1 is A_1 and x_2 is A_2 and … and x_n is A_n then y is B

Zadeh fuzzy inference is given by $= \min(1, 1-\min(A_1, A_2, \ldots, A_n) + B)$

The proposed fuzzy conditional inference for Zadeh fuzzy inference as when consequent part is not known

$= \min(1, 1-\min(A_1, A_2, \ldots, A_n + 1))$, where B=1 because B is not known.

For instance $A_1 = 0.2/x_1 + 0.6/x_2 + 0.9/x_3 + 0.6/x_4 + 0.2/x_5$

$A_2 = 0.5/x_1 + 0.7/x_2 + 0.9/x_3 + 0.7/x_4 + 0.3/x_5$

if x is A1 and x is A2 then x is B=

$B = 1/x_1 + 1/x_2 + 1/x_3 + 1x_4 + 1/x_5$ and is not known

Zadeh conditional inference is not suitable

The fuzziness may be given for rule as

If Depression is High
and Temperature is High
and Wave velocity is High
Then Coastal Erosion is Savior

. = min(1, (1- min{.6,0.7,0.8) +0.9)

= 1 and is unknown

Zadeh fuzzy conditional inference is not suitable when consequent part is unknown

Mamdani inference is given by

if x_1 is A_1 and x_2 is A_2 and … and x_n is A_n then y is B

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

The proposed fuzzy conditional inference for Mamdani fuzzy inference is given as when the consequent part is unknown

$= \min(A_1, A_2, \ldots, A_n, 1)$, where B=1 because B is not known.

$= \min(A_1, A_2, \ldots, A_n, 1)$

$= \min(A_1, A_2, \ldots, A_n)$

if x is A1 and x is A2 then x is B=

$B = 0.2/x_1 + 10.6x_2 + 0.9/x_3 + 0.6x_4 + 0.2/x_5$

For Example

The fuzziness may be given for rule as

If Depression is High
and Temperature is High
and Wave velocity is High
Then Coastal Erosion is Savior

= min(.6,0.7,0,8,0.8)

=0.6

The TSK fuzzy conditional inferences are not known prior information for consequent part but it is difficult to compute applications like Control Systems and Medical diagnosis.

Consider TSK fuzzy conditional inference

If (A_1 and A_2 ….. An) then $y=f(x_1, x_2, \ldots, x_n)$ is B

A method is possible to define with memberships of $x_1, x_2, \ldots, x_n$ when consequent part is not known

The proposed method for TSK fuzzy conditional inference may be defined as using t-norm[5]

If x is A_1 and A_2 and ,…,and A_{n-1} or A_n then y is $B=f(A_1, A_2, \ldots, A_n)$

If x is A_1 and A_2 or A_3 then y is B = $A_1 \wedge A_2 \vee A_3$ $\min(\max(\mu_{A1}(x), \mu_{A2}(x)), \mu_{A3}(x))$

Where t-norm is

$t(a \vee b) = \max(a,b)$

$t(a \wedge b) = \min(a,b)$

if x is A1 and x is A2 then x is B=

$B = 0.2/x_1 + 10.6x_2 + 0.9/x_3 + 0.6x_4 + 0.2/x_5$

The fuzziness may be given for rule as

If Depression is High
and Temperature is High
and Wave velocity is High
Then Coastal Erosion is Savior

= min(.6,0.0.7, 0.8)

=0.6

It may be observed that the proposed methods of Mamdani and TK conditional inferences are equal.

V. Presentation of Fuzzy Set Type-2

The fuzzy set type-2 is a type of fuzzy set in which some additional degree of information is provided[6]

Definition: Given some universe of discourse X, a fuzzy set type-2 A of X is defined by its membership function

$\mu_A(x)$ taking values on the unit interval[0,1] i.e. $\mu_{\tilde{A}}(x)\rightarrow[0,1]$ [0.1]

Suppose X is a finite set. The fuzzy set A of X may be represented as

$$A = \mu_{\tilde{A}1}(x_1)/\tilde{A}1 + \mu_{\tilde{A}2}(x_2)/\tilde{A}2 + \ldots\ldots\ldots\ldots\ldots + \mu_{\tilde{A}n}(x_n)/\tilde{A}n$$

Headache= { 0.4/mild , 0.6/moderate, 0.9/severe}
John has “mild headache” with fuzziness 0.4
The fuzzy set type-2 may be defined as

Definition: The fuzzy set type-2 Ã is characterized by membership function $\mu_{\tilde{A}}$:XxY→ [0,1], x∈X and y∈A

Suppose X is a finite set. The fuzzy set A of X may be new represented by

$$\tilde{A} = \int\int \mu_{\tilde{A}}(x,y)/x/y = \sum\sum \mu_{\tilde{A}}(x,y) = (\mu_{\tilde{A}}(x_1,y_1)/x_1 + \mu_{\tilde{A}}(x_2,y_1)/x_2 +\ldots+ \mu_{\tilde{A}}(x_n,y_1)/x_n)/y_1$$

$$+ (\mu_{\tilde{A}}(x_1,y_2)/x_1 + \mu_{\tilde{A}}(x_2,y_2)/x_2 +\ldots+ \mu_{\tilde{A}}(x_n,y_2)/x_n)/y_2 + \ldots +$$

$$(\mu_{\tilde{A}}(x_1,y_m)/x_1 + \mu_{\tilde{A}}(x_2,y_m)/x_2 +\ldots+ \mu_{\tilde{A}}(x_n,y_1)/x_n)/y_m$$

$$\tilde{A}' = 1-\mu_{\tilde{A}}(x,y)$$

$$\tilde{A} = \{ (0.1/x_1+0.2/x_2+0.3/x_3+0.35/x_4+0.4/x_5)/high$$
$$+(0.4/x_1+0.45/x_2+0.5/x_3+0.55/x_4+0.6/x_5)/normal$$
$$+(0.7/x_1+0.75/x_2+0.8/x_3+0.85/x_4+0.9/x_5)/low \}$$

Let Ĉ and Ď be the fuzzy sets.
The operations on fuzzy sets type-2are given as

ĈVĎ=max{$\mu_{\hat{C}}(x,y)$, $\mu_{\check{D}}(x,y)$} Disjunction

ĈΛĎ=min{$\mu_{\hat{C}}(x,y)$, $\mu_{\check{D}}(x,y)$} Conjunction

Ĉ→Ď=min{1, 1-$\mu_{\hat{C}}(x,y)$ + $\mu_{\check{D}}(x,y)$} Implication

ĈXĎ=min{$\mu_{\hat{C}}(x,y)$, $\mu_{\check{D}}(x,y)$} Relation

VI. Fuzzy Inference System

Fuzzy Inference System is Fuzzy Control System, which contains fuzzification ad defuzzification. The Fuzzification will be defined using the fuzzy rule. The fuzzy algorithm is a set of statements with a single fuzzy value. The fuzzy conditional statement is defined as fuzzy algorithm

if x_i is $A1_i$ and x_i is $A2_i$ and … and x_i is An_i then y_i is B_i
The precedence part may contain and/or/not.

The Fuzzy Control System consists of a set of fuzzy rules

If (set of conditions are satisfied then (set of consequences inferred).

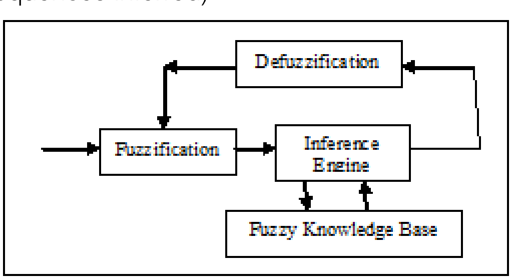

Fig. 4: Fuzzy Inference System

The Fuzzy control system contains fuzzy variable may be represent in a decision table

A1	A2	..	An		B
A11	A12	..	A1n		B1
A21	A22	..	A2n		B2
Am1	Am2	..	Amn		Bmn

Depression	Temperature	Wave Velocity	Erosion
High	High	High	Savior
Moderate	Normal	Moderate	moderate
Low	Low	Low	Normal
Moderate	Normal	Moderate	Moderate
High	High	Moderate	Moderate

The relational model of fuzzy inference system for Coastal Erosion is given as
If Depression is High
and Temperature is High
and Wave velocity is High
Then Coastal Erosion is Savior

For instance, consider the relational model of fuzzy control system

Depression	Temperature	Wave Velocity	Erosion
0.8	0.7	09	
0.6	0.5	0.8	
0.5	0.4	0.5	
0.6	0.7	0.6	
0.7	0.8	0.65	

The Proposed fuzzy conditional inference are given as for Coastal Eroson

$$0.7/x_1 + 0.5/x_2 + 0.4/x_3 + 0.6/x_4 + 0.65/x_5$$

Defuzzification

Usually Centroid technique is used for defuzzification. It finds value representing Centre of Gravity(COG) aggregated fuzzy generalized fuzzy set.

$$COG = \Sigma\, C_i\, \mu_{Ai}(x) / \Sigma\, \mu_{Ai}(x)$$

Erosion with Fuzziness and Transect Numbers are given as

{0.4/400 +0.5/800 + 0.6/12000+ 0.8/1600+0.9/2000}

COG = (0.4*400 +0.5*800 + 0.6*12000+ 0.8*1600+0.9*2000)/ (0.4+0.5+0.6+0.8+0.9)=1362.5

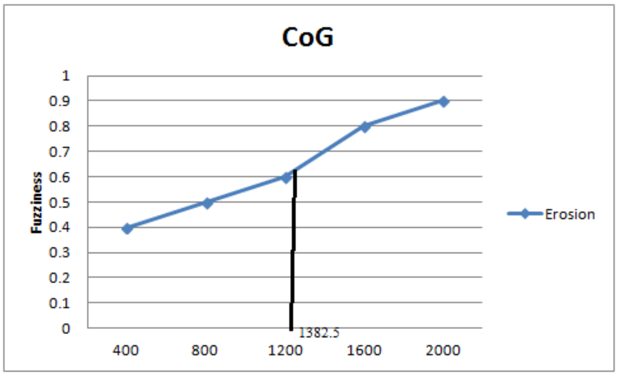

Fig. 5: CoG

VII. Conclusion

Some methods are studied for fuzzy conditional inference when prior information is unknown to consequent part. Zadeh and Mamdani methods are not suitable when prior information is unknown. A new method is proposed for "if … then …" when prior information is unknown to the consequent part with single fuzzy member function, and two fuzzy membership functions. Fuzzy Certainty Factor is defined with two membership functions to made a single fuzzy membership function. WSN are send data to the base station. The Fuzzy inference system (FIS) is Studied for WSN to detect Coastal erosions. The Prim's algorithm is used to construct a spanning tree for collection of Data from WSN to base station. Sensors are discussed an application for proposed fuzzy conditional inference. The Fuzzy Control System is given an example for FCF.

Acknowledgment

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