Fuzzy Wireless Sensor Network

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Abstract*— Zadeh, mamdani and TSK are proposed different fuzzy conditional inferences for "if … then … "to approximate with incomplete information. The Zadeh and mamdani fuzzy conditional inferences are require prior information for consequent part. The TSK fuzzy conditional inference need not know prior information for consequent part but it is difficult to compute. In this paper, new methods are proposed for "if … then …" when prior information is not known to consequent part with fuzzy membership function Sensors are discussed as application for proposed fuzzy conditional inference. *Fuzzy inference system (FIS) is discussed for WSN to detect Costal erosion and* Turbo Charger *Fuzzy Control System as an examples.

***Keywords*— *fuzzy logic;fuzzy conditional inference; fuzzy control systems;Wireless Sensor Networks;* Costal erosions**

I. Introduction

There are many theories to approximate incomplete information. Until recently probability theory was the only existing theory to approximate incomplete formation. Zadeh [11] proposed fuzzy logic to approximate incomplete information. The fuzzy theory allows us to represent set membership as a possibility distribution. Fuzzy theory is the most effective than the other theories because fuzzy theory depends on degree of belief rather than likelihood (Probability). The fuzzy conditional propositions are of the type if (precedent part) then (consequent part). Different methods of fuzzy conditional inference to approximate uncertain information [2,3,4,6,7]. The Zadeh and mamdani fuzzy conditional inferences are needed prior information for both precedent and consequent part. There are some applications like fuzzy control systems do not have prior information to consequent part. The TSK fuzzy conditional inferences are need not know prior information for 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 given as example for proposed fuzzy conditional inference.. It is necessary to give brief description of fuzzy logic and WSN.

II. FUZZY LOGIC

Zadeh [11] introduced the concept of a fuzzy set as a model of a vague fact. The use of the fuzzy set theory for control systems is now 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

$\mu_A: X \rightarrow [0,1]$

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 membership function

YOUNG = { $\mu_{YOUNG}(x)/x=1$ if xϵ[0,25]
=[1+((x-25)2)]-1 if xϵ[25,100]

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

$AVB=\max(\mu_A(x), \mu_B(y))$ Disjunction
$A\Lambda B=\min(\mu_A(x), \mu_B(y))$ Conjunction
$A'=1-\mu_A(x)$ Negation
$A\rightarrow B=\min\{1, (1-\mu_A(x)+\mu_B(y)\}$ Implication
$AXB=\min\{\mu_A(x), \mu_B(y)\}/(x,y)$ Relation
$AoR=\min_x\{\mu_A(x), \mu_R(x,y)\}/y$ 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
$= \min\{1, (1-\min(\mu_{A1}(x), \mu_{A2}(x), \ldots, \mu_{An}(x)) + \mu_B(y)\}$

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

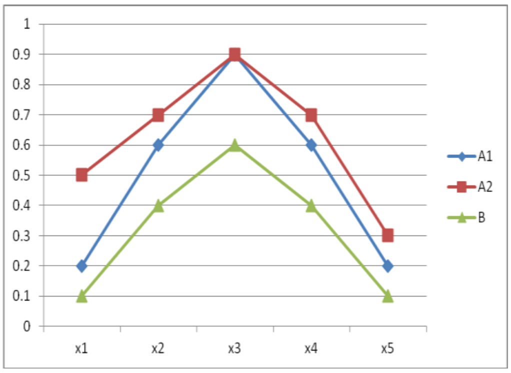

Fig.1 Implication

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.

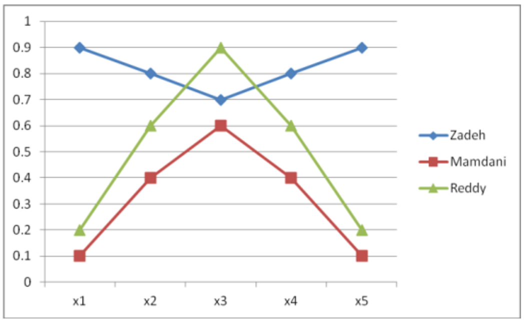

Fig.2 Composition

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 spans of time. Therefore WSN technology[1] has to be used to capture relevant signals and transmitted by monitoring. Wireless sensors are one of the technologies that can send the sensed data to a data analysis center.

The Fuzzy Inference System may be used as alternative procedure. The capture data may be analyzed using fuzzy parameters and these parameters are used in fuzzy inference system this fuzzy inference systems are applied to *WSN to detect Costal 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 shortest path connecting minimal distance in edge weights of the path from each node to the destination node. The Prim's algorithm or by Prim's algorithm may be used to construct minimum spanning tree. The minimum spanning tree and one of the nodes may take as destination node.

The Prim's algorithm is to find minimum spanning tree to easy to select edges with distances. The nodes (V) are Sensors and edges (E) are distances in the Graph (G) of WSN.

Algorithm Prim(G)

G(V,E) is weighted connected Graph

E_T is set of edges of minimum spanning tree

$V_T \leftarrow$ is initial node with any vertex

$E_T \leftarrow \theta$

For $i \leftarrow 1$ to IVI -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.3may be given as

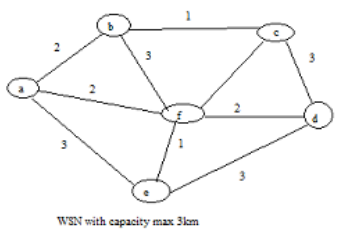

Fig.3

The path may be given as

a →b, b →c,b →f,f →e, d →f

The node d may be taken as base node.

The Prim's' algorithm is used to construct spanning tree for collection of Data from WSN and the FIS is discussed for WSN to detect Costal erosions

IV. NEW METHOD OF FUZZY CONDITIONAL INFERENCE

.

Zadeh[10], Mamdani[2] and TSK[3,4] are proposed fuzzy conditional inference for incomplete information. Zadeh and Mamdani fuzzy inferences need prior information for 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 ,… ,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 ,… ,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 Costal 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 not known

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 ,… ,A_n , B)

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

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

=min(A_1, A_2 ,… ,A_n ,1)

= min(A_1, A_2 ,… ,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 Costal 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 ,…, x_n) is B

A method is possible to define with memberships of x_1 , x_2 ,…, 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 ,…, $A_{n)}$

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

Where t-norm is

t(aVb)=max(a,b)

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

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 fuzzy rule. Zadeh introduced fuzzy algorithms . The fuzzy algorithm is set of fuzzy statements. 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 consist of set of fuzzy rules

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

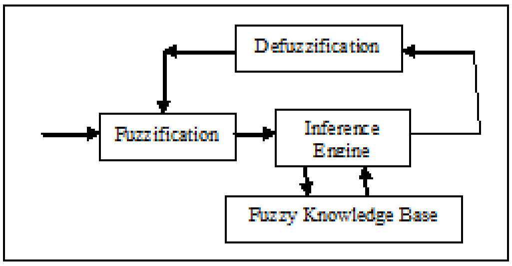

Fig.4 Fuzzy Inference System

The Fuzzy control system contains fuzzy variable may be represented in 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 Costal Erosion is given as

If Depression is High

and Temperature is High

and Wave velocity is High

Then Costal 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 CostalEroson

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

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

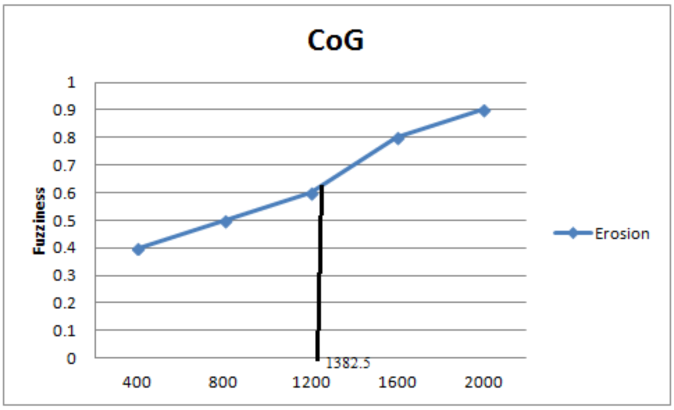

Fig.5. CoG

VII. Conclusion

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

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