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Fire Detection System Using Fuzzy Logic

Aiswarya Muralidharan[*1], Fiji Joseph[2]
[*1,2] Department of Electronics and Communication, Communication systems, Sri Shakthi
Institute Of Engineering And Technology , Coimbatore, India
aiswaryapilangu@gmail.com

Abstract

Fire detection system and the errors put up by the system is a major concern in the field of safe and secure infrastructure in the modern world. Rather than depending on a single sensor output for detecting fire, multi-systems are recommended to obtain more accurate and error free results. Complex mathematical or control systems, even though efficient, had their own problems in providing accurate results. The latest trend available in decision making systems is to employ artificial intelligence. In simple words it is better to utilize human way of thinking to provide accurate results. Here, keeping the above said factor as a major concern, Fuzzy Logic is employed in fire detection system, which is also multi sensor based. The driving force behind this was to develop an efficient but a simple and error free system for critical applications. The entire idea behind the system and obtained results are explained in the following sections.

Keywords: Fuzzy rule editor, Surface viewer, Membership Function.

Introduction

Earlier fire detection systems were mainly based upon single sensor outputs. It is evident that such systems provide lesser flexibility. Also the chance of providing faulty outputs were much greater. To overcome this, multi sensor based systems were introduced. Together with the application of Fuzzy Logic these systems could provide better results for cases which involve fire detection. The term "fuzzy logic" was introduced with the 1965 proposal of fuzzy set theory by Lotfi A. Zadeh[2]. Fuzzy logic has been applied to many fields. Its application field varies from control theory to artificial intelligence.Fuzzy Logic (FL) is a multi valued logic that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Fuzzy actually provides an output based on a set of rules applied on basis of input variables provided. The outputs to these rules are not basically depended on any mathematical calculations rather they depend on common way of human thinking and so it is easier to model real world conditions through the concept of fuzzy logic[1].

In classical mathematics we are familiar with wh at we call crisp sets. For example the possible interfer ometric [2] coherence g values are the set X of all real numbers between 0 and 1.A crisp set is a normal set and in normal approach assigns a 1 or 0 to a function. Fuzzy set value varies from 0 to 1 rather than two values 0 & 1.

Fuzzy Logic

In fuzzy logic there are three basic operations on fuzzy sets: union, intersection and complement.

Union

Let μA and μB be membership functions that define the fuzzy sets A and B, respectively, on the universe X. The union of fuzzy sets A and B is a fuzzy set defined by the membership function,[3] .

$$\mu_{A \cup B}(x) = \text{Max}(\mu_A(x), \mu_B(x)) \qquad (1)$$

Intersection

Let μA and μB be membership functions that define the fuzzy sets A and B, respectively, on the universe X. The intersection of fuzzy sets A and B is a fuzzy set defined by the membership function,

$$\mu_{A \cap B}(x) = \text{Min}(\mu_A(x), \mu_B(x)) \qquad (2)$$

Complement

Let μA be a membership function that defines the fuzzy set A, on the universe X. The complement of A is a fuzzy set defined by the membership function,

$$\mu_A c(x) = 1 - \mu_B(x) \qquad (3)$$

A membership function for a fuzzy set A on the universe of discourse X is defined as μA: X → [0, 1], where each element of X is mapped to a value between 0 and 1[3].

Fuzzy Inference System

A fuzzy inference system works in three basic steps. It includes fuzzzification, decision making (inference) and defuzzification and the inference system is as shown below.
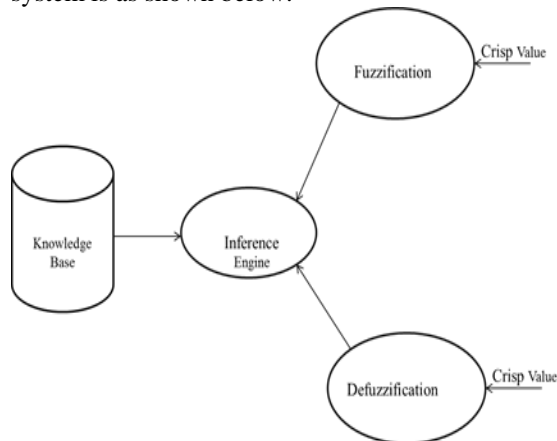

Fig 1: Fuzzy Inference system

Fuzzification

Fuzzification is a process by which a crisp quantity is converted to fuzzy quantity. For this the input variables that correspond to real world parameters are expressed in terms of fuzzy membership functions. Mamdani method of fuzzification is followed in this system. It is a most widely used method. This method was among the first control systems built using Fuzzy set theory. It was proposed in 1975 by Ebrahim Mamdani as an attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators. Mamdani's effort was based on Lotfi Zadeh's 1973 paper on fuzzy algorithms for complex systems and decision processes. A fuzzy system with two non interactive inputs x_1 and x_2 (antecedents) and a single output y (consequent) are described by a collection of r linguistic IF-THEN propositions in Mamdani form [2]

IF x_1 is A_1^k and x_2 is A_2^k THEN y^k is B^k for k=1,2,….r, where A_1^k and A_2^k are the fuzzy sets representing the kth antecedent pairs and B^k is the fuzzy set representing the kth consequent. In Mamdani method of inference we can use either min-max inference or max product inference. Former truncates the membership function for the consequent of each rule whereas the latter will scale the membership functions depending on the consequent of each rule.

Decision Making (Inference)

Decision making corresponds to the process of reaching conclusions based on input values provided.

For this base rule is used. It could be said that rules control the total fuzzy system. Normally fuzzy rules is of the form "IF premise$_1$ and premise$_2$ THEN consequence". The premises are defined by the input membership functions. Logic functions are used to connect premises. Consequent corresponds to the expected output condition. Based on our requirements we could form the rules to govern the fuzzy system.

Defuzzification

Defuzzification is the conversion of a fuzzy quantity to a precise quantity. The output of a fuzzy process can be the logical union of two or more fuzzy membership functions defined in the universe of discourse of the output variable .Mainly four defuzzification methods are there.

Maximum Membership Function

This method is also called height method. It is limited to peaked output functions. The defuzzified output will correspond to the maximum peak of the output membership function.

Weighted Average Method

The weighted average method is the most frequently used method in fuzzy applications since it is one of the most computationally efficient method. Unfortunately it is usually restricted to symmetrical output membership functions.

Centroid Method

It is also called center of area or center of gravity. It is the most prevalent and physically appealing of all the defuzzification methods.

Mean Max Membership Method

This method is also known as middle of maxima method. It is closely related to maximum method. The difference is that the locations of maximum membership can be non unique (ie, the maximum membership can be a plateau rather than a single point).

The Fire Detection System

Multi sensor based fire detection systems (MSbFD) are one of the important current development in automatic fire detection technology. The two main objectives of this progress are still unacceptable false alarm behavior and improvements in fire detection capabilities of the systems. This system basically takes inputs from three different sensors (smoke, light and temperature) and evaluation and processing of the sensor signals is carried out by using fuzzy logic. The output obtained from different sensors are applied to signal processing unit. The processed values are provided to the basic fuzzy inference system. The crisp value will undergo fuzzification. They are used to produce fuzzified

output based on the rules and the defuzzified output will be produced as a result. Here Mamdani method of fuzzification and centroid method of defuzzification is used. The rule basis is formed by employing five input variables where input parameters are added and its output parameters are specified by means of an FIS editor. It is splitted into five different input variables.

- Absolute Temperature (Ta)
- Differential Temperature (Td)
- Absolute Smoke Density (Sa)
- Fluctuation in Smoke Density (Sf)
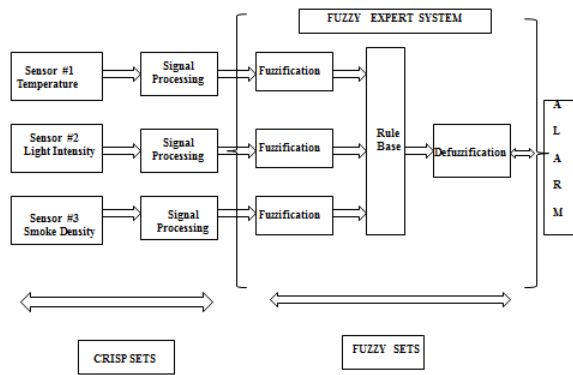- Light Intensity Variation (Lv)

Fig 2: Block Diagram of MSbFD

The output parameter is specified by an alarm. Input and output variables are individually provided with a membership function plot [3].

Membership Functions

All the input and output parameters for which all specifications are mentioned in membership plot. Absolute temperature and smoke density are specified by means if a Guassian plot with three regions of operations, low, medium and high having range 24-100 and 0-255 respectively. Differential temperature fluctuation and smoke density and luminous intensity are specified by means of triangular plot with two regions of operations low and high having ranges 0-76, 25-100 and 0-255 respectively. The output parameter represented by an alarm is specified by triangular plot with range 0-300.

Variable Name	Input/ Output	Membership Function	Range
Absolute Smoke Density(Sa)	Input	Gaussian	0-255
Differential Temperature(Td)	Input	Triangular	0-76
Fluctuation in Smoke Density(Sf)	Input	Triangular	25-100
Luminous Intensity Variation(Lv)	Input	Triangular	0-255
Alarm	Output	Triangular	0-300

Table 1:Input-Output Specification

Rule Basis

It is used to edit and add the rules which are used to carry out the inference of the system. Rules are defined by considering the different conditions of the input parameter and their effect in the output variable. Input and output relations helps in producing a suitable decision. In case of rule editor it will specify the input conditions and is connected by means of OR and AND operators. All the conditions of input and output variables are specified by individual rules and it is provided with a weight taken as one.

- IF Ta is low and Td is low and Sf is low and Sa is medium then alarm is no.
- IF Ta is low and Td is low and Sa is low then alarm is no.
- IF Ta is high then alarm is yes.
- IF Td is high then alarm is yes.
- IF Sa is medium and Sf is high then alarm is yes. IF Sa is high then alarm is yes.
- IF Td is high and Sf is high and Lv is high then alarm is yes.
- IF Td is low and Sf is low and Lv is low then alarm is no.

These rules were applied to the fuzzy system and the outputs formed were a 3D representation showing the relationship between input and output variables.

Analysis and Results

The results of the fuzzy logic based fire system is obtained in two different modes. One shows the different rules and inputs of the system in a column and row format and the other shows a three dimensional depiction of the inputs and outputs. Both the outputs show the variation of the alarm based on almost all the conditions of the input variables.

Rule Output

It's a read only tool which portrait the rule editor. It can show each input and its conditions to

their rules and it specifies its output variations as a fuzzified one. It produces a fuzzified out corresponding to each rule. All these output is defuzzified and a crisp output is obtained. This defuzzification is done with centroid method in mamdani method of fuzzification.

Surface Viewer

It is a 3 dimensional view of rules. It is a read only tool which represents the graphical relation of each parameter. Two of the inputs were plotted with respect to output variable and is shown in 3 dimensional plot. Fire detection is specified by means of different colours. Blue colour denotes high density and yellow denotes low density.it represents the three dimensional method of rules provided in the system.
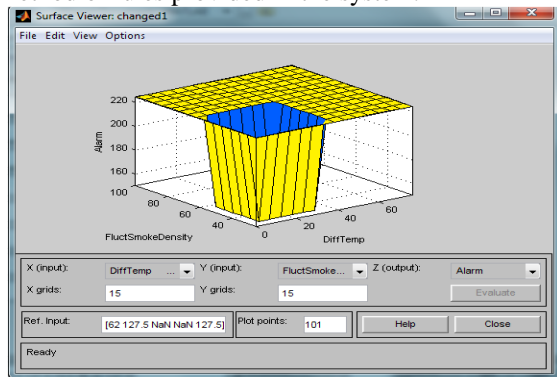

Fig 3: The Surface Viewer of the fuzzy system

Simulink Implementation

Simulink is a tool in MATLAB to create working models of circuit .Different blocks are available in the Simulink library. FIS editor is generated based on the rules and it is linked to the Simulink environment[3]. The fuzzy logic controller box in Simulink library is linked with FIS file. Input is provided to the block by a multiplexer. Output could be obtained on a simple display and it will be the defuzzified value. Five input variables are taken as constant sources and it is provided to the fuzzy logic controller box by means of a multiplexer. It is provided with FIS implementation and is connected to sink devices such as display device.
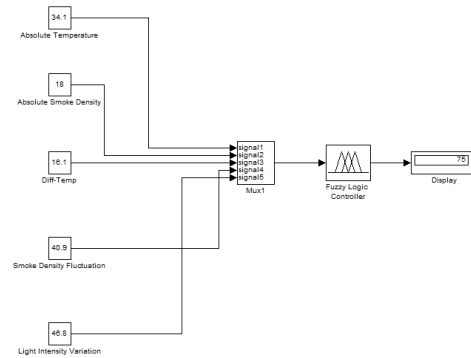

Fig 4: Simulation Results

Conclusion

Multi sensor based fire detection algorithm was implemented using fuzzy logic in matlab. FIS prepared was found to provide accurate values during different conditions of the input parameters. Simulink model generated was also found to provide precise results for different inputs. The implementation of fuzzy logic to a fire detection made the system much simpler and was closely related to real model concepts and human way of thinking.

Acknowledgements

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