Fire Detection Mechanism using Fuzzy Logic

Vikshant Khanna
Department of CSE & IT
Lovely Professional University, India

Rupinder Kaur Cheema
Department of CSE & IT
Lovely Professional University, India

ABSTRACT
Research in wireless sensor networks (WSNs) has experienced a significant growth in recent years. One topic of special interest is the use of WSNs in the detection of forest fire as it is a common disastrous phenomenon that constitutes a serious threat. Numerous detection mechanisms are available for forest fire in the literature using wireless sensor networks and other methods. The work presented in this paper expresses the idea of implementing Fuzzy Logic on the information collected by sensors. This collected information will be passed on to the cluster head using Event Detection mechanism. Thus multiple sensors are used for detecting probability of fire as well as direction of fire. Each sensor node consists of multiple sensors that will sense temperature, humidity, light and CO density for calculating probability of fire and azimuth angle for calculating the direction of fire. It will improve accuracy of the detection system, as well as reduce the false alarm rate.

Keywords
Forest fire detection system, Fuzzy Logic, Wireless Sensor Networks

1. INTRODUCTION
Wireless Sensor Networks (WSNs) have been widely considered as one of the most important technologies for the twenty - first century. Enabled by recent advances in microelectromechanical systems (MEMS) and wireless communication technologies, cheap, tiny, and smart sensors have been deployed in a physical area and networked through wireless links. The Internet provides unprecedented opportunities for a variety of civilian and military applications, for example, industry process control, battle field surveillance and environmental monitoring [1]. In some respects, a sensor network is more feasible as an early warning system for forest fires [2]. As resources are limited so it should be used wisely and efficiently so that lifetime of battery can be increased. In most of the applications, the sensors in the network are deployed randomly and are expected to perform their mission properly and efficiently. The harsh environments and energy constraint makes many sensors inoperable. Failure of one or few nodes does not affect the operation of the network due to its fault tolerant nature. The network topology is continuously and dynamically changing. The communication topology affects the lifetime of a sensor node and thereby affects the reliability of a system. Wireless communication channel is unpredictable and error-prone due to the noise present in the channel. Enhancement of noisy message data is a very challenging issue in many research and application areas. For real time application, reliable data delivery is a real challenging issue in WSNs. A critical event detected by the sensor network should be delivered to the user as soon as possible. Thus, for sensor networks, reliability and latency are important design parameters in addition to energy efficiency. The lifetime of a sensor node mainly depends upon the battery source. According to sensor node data sheets, the node will consume less power for processing than the communication activity. Therefore data fusion process in the cluster head using fuzzy logic is proposed to minimize the communication activity. Data Fusion technique has been producing single data by aggregating information from a set of different sources of data. The fused data contains greater information content for the event than single event sources alone. Features are extracted from different sensors and are merged to provide more accurate information. The reliability and overall detail of the information is increased because of the addition of analogous and complementary information. The atmospheric events are complex, ambiguous and vague in nature. Fuzzy set theory provides an appropriate tool in modeling the imprecise data [3]. Therefore, in this paper an event detection mechanism is proposed using fuzzy rule based system. Fuzzy techniques for treating uncertain qualitative information include fuzzy arithmetic and mathematics, fuzzy set theory, fuzzy logic, fuzzy decision making and fuzzy control. Rule based fuzzy operators are a novel class of operators specifically designed in order to apply the principles of approximate reasoning as shown in Figure 1.

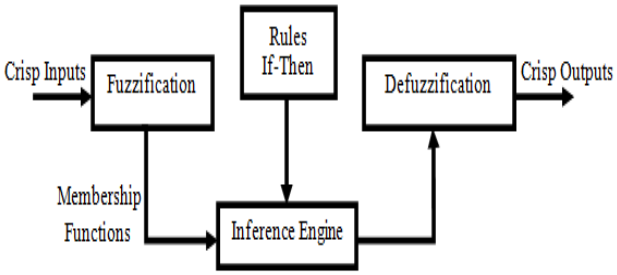

Figure 1: Block Diagram of Fuzzy Logic

2. REVIEW OF LITERATURE
Researchers have applied many technologies to forest surveillance, and early forest fire detection, which has acquired significant relevance in the domain, is becoming an important research and development topic. In previous papers various techniques were proposed for forest fire detection such as Artificial Neural Networks, Satellites, Image Processing, Video based techniques, Fuzzy Logic etc which are discussed below

In [4], authors have analyzed the potential of combining wireless sensor networks with artificial neural networks (ANNs) to build a "smart forest-fire early detection sensory system"(SFFEDSS). In this system, temperature, light and smoke data from low-cost sensor nodes spread out on the forest bed is aggregated into information. This information is temporally and spatially labeled into knowledge which will be encoded as input to ANN models that convert it into

intelligence. The automated SFFEDSS system can be used to monitor the forests without constant human supervision.

In [5], Giovanni Laneve carried out an analysis of the application of Spinning Enhanced Visible and Infrared Imager SEVIRI images to the early detection of fires in the Mediterranean regions. In fact, in principle, the high temporal frequency (15 min) of the images allows the detection of events characterized by fast dynamics such as fires.

In [6], Jerome Vicente presented an automatic system for early smoke source detection through the real time processing of landscape images. First part describes the segmentation technique used to extract persistent dynamical envelopes of pixels into the images, while second part deals with the method to discriminate the various natural phenomena that may cause such envelopes.

In [7], B. Ugur Toreyin developed an automatic video based algorithm for wildfire detection using an LMS active learning capability. Decision fusion is realized by the LMS based Weighted Majority Algorithm. Experimental results show that the learning duration is decreased with the proposed active learning scheme and false alarm rate is decreased compared to WMA based and fixed weights schemes.

In [8], A.K. Singh proposed a fuzzy type-2 approach for fire detection using wireless sensor networks. Fuzzy type-2 logic approach handles the uncertainty present in the data effectively and gives the best results with very low false alarm rate. The decision based on this approach is more accurate.

Since energy efficiency is always being an important point to be considered by the researchers, so [9] describes the comparison between the proposed type reduction algorithms till date and introduced a better algorithm for the same.

3. IMPLEMENTATION

3.1 Clustering and Event Detection Mechanism

In proposed system, enhancement is done in the system proposed by A.K. Singh which will have high accuracy with low alarm rate. The proposed system will not only find probability of the fire but the direction of fire also. The Simulation is done in MATLAB.

Nodes are divided into clusters and each cluster will have their own cluster head. Whenever fire is detected the nodes will send information to their respective cluster head. This will reduce processing cost at each node which can be used for further computations. This can be simulated in MATLAB using event detection mechanism as shown in Figure 2. Event detection is one of the main components in numerous wireless sensor network (WSN) applications. WSNs are deployed for military application to detect the invasion of enemy forces, health monitoring sensor networks are deployed to detect abnormal patient behavior, fire detection sensor networks are deployed to set an alarm if a fire starts somewhere in the monitored area. The data collected using multiple sensors is sent at base station where rule based Fuzzy Logic is implemented. Fuzzy Logic Toolbox in MATLAB is used for simulation which provides more accuracy, flexibility and scalability than other systems.

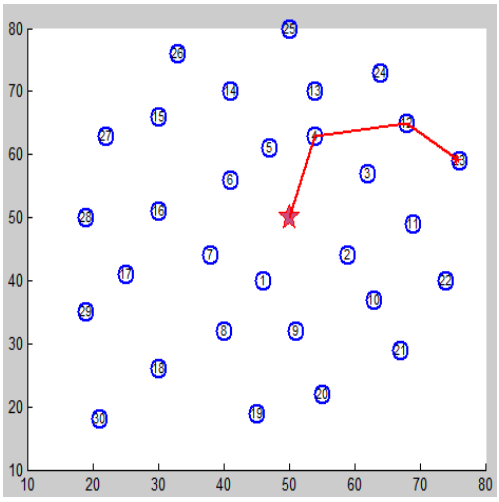

Figure 2: Fire detection using event detection mechanism

The concept of fuzzy set and fuzzy logic was introduced by Zadeh in 1965. His intention in introducing the fuzzy set theory was to deal with problems involving knowledge expressed in vague, linguistic terms. A crisp set is a collection of elements with some properties and each element is either belonging to set or not. In crisp set, there is no ambiguity or vagueness as for the belongingness of each element to the set concerned. A fuzzy set is a set with each element in a set having graded membership in the real interval [0, 1]. That is, elements can belong to a fuzzy set to a certain degree. Fuzzy set theory may be defined as a collection of elements in a universe of information where the boundary of the set contained in the universe is vague, ambiguous, and otherwise fuzzy.

Fuzziness describes event uncertainty and impreciseness of linguistic terms. Fuzzy logic fits best in applications where the variables are continuous and/or mathematical models do not exist or traditional system models become overly complex. WSN is typically used to monitor some parameters of an environment process. The atmospheric events are complex, ambiguous and vagueness embedded in their nature. Consequently, a fuzzy based approach is a viable option. The model of fuzzy logic system as shown in Figure 3 consists of fuzzification, fuzzy rules, fuzzy inference system and defuzzification process [10].

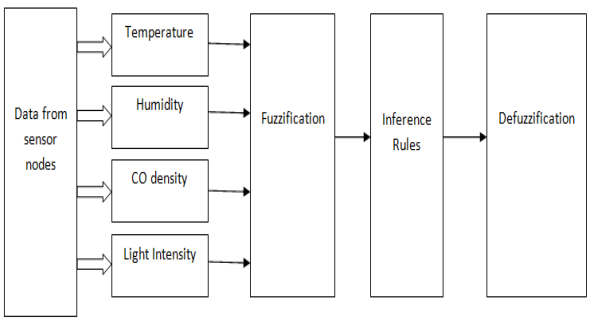

Figure 3: Forest Fire Detection System Mechanism

3.2 Fuzzification

The fuzzification is the process of transforming crisp values into fuzzy linguistic variables. The membership function is used to associate a grade to each linguistic variable. Selection of the number of membership functions and their initial values is based on process knowledge and intuition. A membership function has values between 0 and 1 over an interval of crisp variable. The number of membership functions can vary to

provide the resolution needed. Number of rules can grow exponentially as the number of input membership functions increases [10]. In proposed fire detection algorithm temperature, humidity, CO density, light intensity, azimuth angle are the input fuzzy variables. The fire probability and Direction of fire are the output variables. The membership functions LOW, MEDIUM and HIGH are defined on temperature, light intensity, humidity and CO density whereas 1,2,3,4 for Azimuth Angle as shown in Figure 4 to Figure 8. VLOW, LOW, MEDIUM, HIGH and VHIGH are defined on Probability of fire whereas NORTH, EAST, WEST, SOUTH on Direction of Fire as shown in Figure 9 and Figure 10.

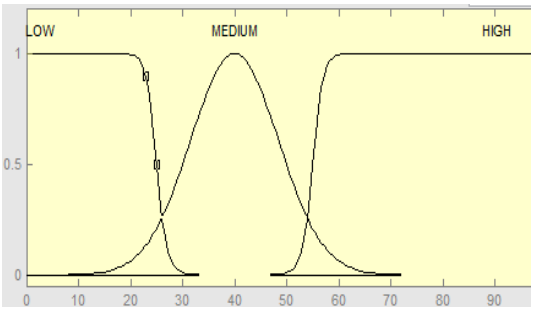

Figure 4: Membership Functions for Temperature

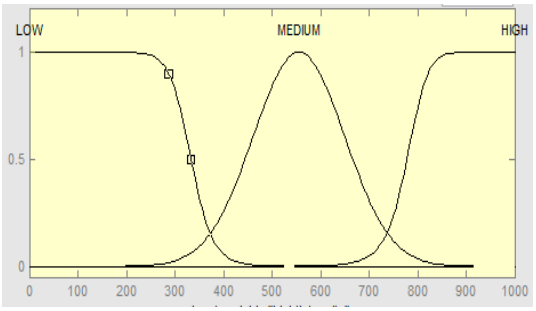

Figure 5: Membership Functions for Light Intensity

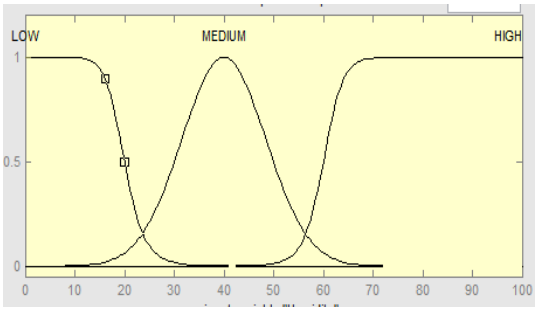

Figure 6: Membership Functions for Humidity

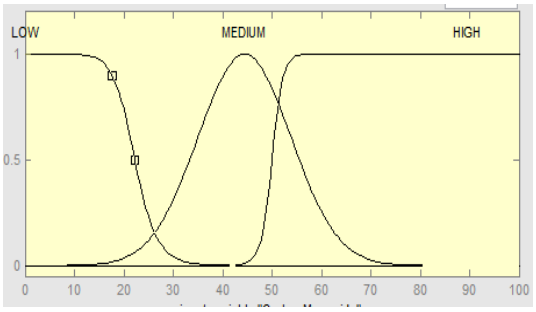

Figure 7: Membership Functions for CO density

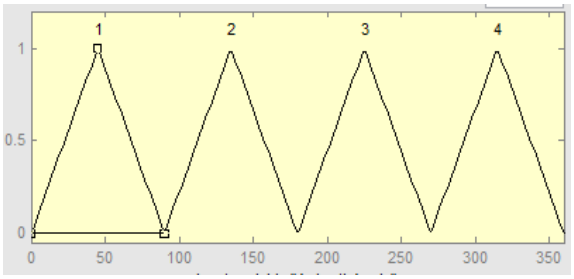

Figure 8: Membership Functions for Azimuth Angle

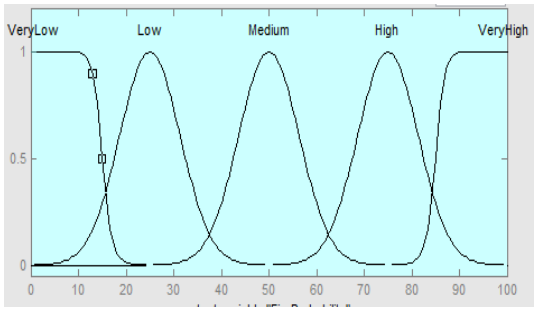

Figure 9: Membership Functions for Probability of Fire

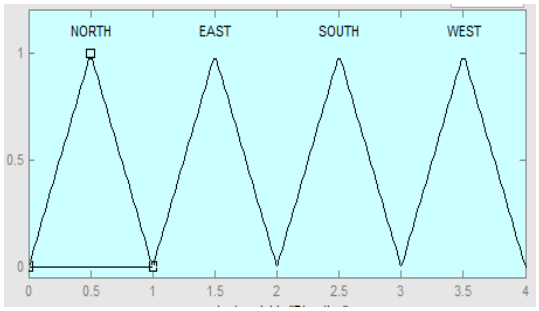

Figure 10: Membership Functions for Direction of Fire

3.3 Inference Rules

The fuzzy inference system consists of fuzzy rules (IF antecedent THEN consequent) that are devised by an expert knowledge base or through system input-output learning. Gaussian, triangle, and trapezoid functions are the most commonly used membership functions. In the fuzzy rules, triangular and trapezoidal-shaped membership functions are used for the variables to simplify the computations. The core of fuzzy system is this rule base system which mimics human reasoning. The most commonly used fuzzy inference technique is Mamdani method. Fuzzy rule base drives the inference system to produce fuzzy outputs, which are defuzzified to get system outputs. The Fuzzy if-then rules in expert system are usually is following:

IF x1 is A11 and x2 is A21 . . . THEN y is B1
else
IF x1 is A12 and x2 is A22 . . . THEN y is B2
.
.
IF x1 is A1k and x2 is A2k . . . THEN y is Bk

where *x1, x2* . . . are the fuzzy input(antecedent) variables *y* is a single output(consequent) variable and *A11* . . . *A1k* are the fuzzy sets [10]. There are 5 input variables, 4 variables consisting of 3 fuzzy linguistic variables and one consisting of 4 fuzzy linguistic variables. Therefore, the total 3*3*3*3*4=324 rules are used, which are all possible combinations of the input variables. Thus some of the example rules in this rule based system are as follows:

IF Temperature is LOW and Light Intensity is LOW and Humidity is HIGH and CO is LOW and Azimuth Angle is 1 THEN Fire probability is VERY LOW and Direction is north.

IF Temperature is MEDIUM and Light Intensity is LOW and Humidity is LOW and CO is MEDIUM and Azimuth Angle is 3 THEN Fire probability is VERY LOW and Direction is south.

3.4 Defuzzification

The transformation from a fuzzy set to a crisp number is called defuzzification. There are many kinds of defuzzification methods, usually maximum membership and centroid techniques are used. In practice, defuzzification is done using centroid method [10].

4. RESULTS

The results are crisp number from the set [0, 100] which is the scale of fire probability. Decision making could be done on the basis of output obtained by making few conditions.

1. If the output is between 0 and 15, then the probability of fire is very low.
2. If the output is between 16 and 35, then the probability of fire is low.
3. If the output is between 36 and 60, then the probability of fire is medium.
4. If the output is between 61 and 85, then the probability of fire is high.
5. If the output is between 86 and 100, then the probability of fire is very high.

For example if the input is [83 752 91 31 285], where first, second, third, fourth and fifth element of input matrix represents temperature, light intensity, humidity, carbon mono-oxide density and azimuth angle respectively, the output is 73 and 3.5 as shown in Figure 11. Thus probability of fire is high and direction of fire is west. Figure 12 to 15 shows a control surface of fire probability based on different input parameters.

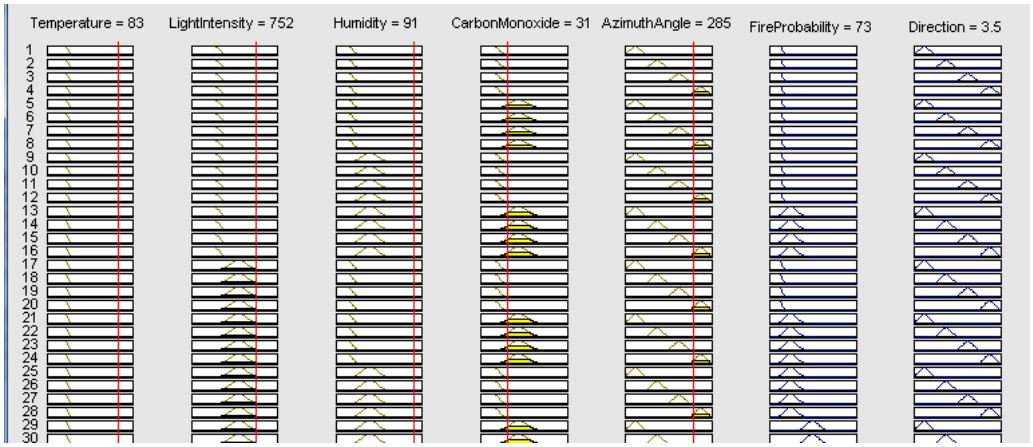

Figure 11: Rule Based Fuzzy Inference System For Forest Fire Detection

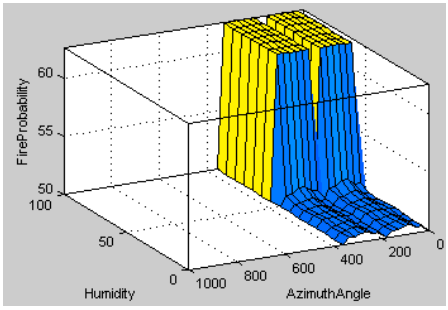

Figure 12: Surface view of fire probability with respect to Humidity and Azimuth Angle

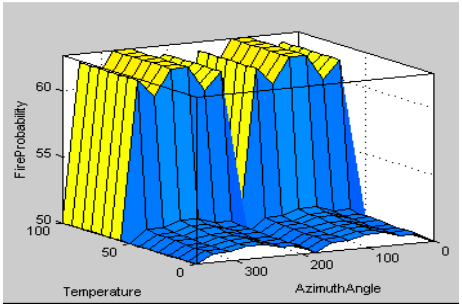

Figure 13: Surface view of fire probability with respect to Temperature and Azimuth Angle

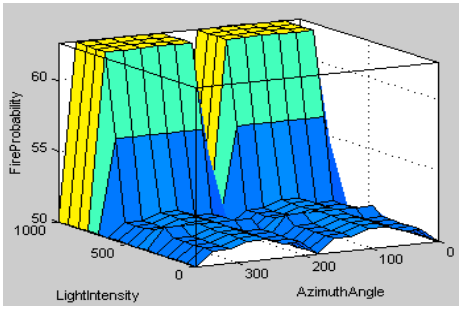

Figure 14: Surface view of fire probability with respect to Humidity and Azimuth Angle

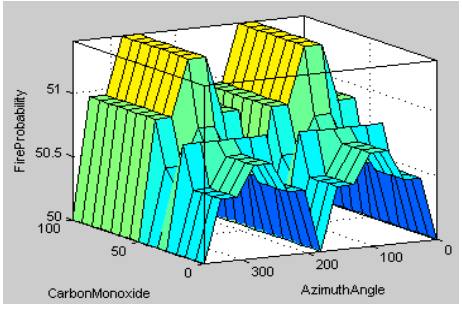

Figure 15: Surface view of fire probability with respect to Humidity and Azimuth Angle

5. CONCLUSION AND FUTURE SCOPE

In this paper, an event detection mechanism for detection of fire and fuzzy type-2 approach for calculating probability as well as direction of fire is proposed. Thus, the proposed forest fire detection handles the uncertainty present in the data effectively and gives the best results with very low false alarm rate. The decision based on this approach is more accurate. Furthermore, the results obtained are more accurate than the results obtained from type-1 fuzzy system. The membership functions and the parameters can be changed and modified as required. Rules also could be altered and adjusted according to parameters for further extending the work on this model.

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