Multi-Sensor Based Forest Fire Detection System

Parul Mohindru, Rajdeep Singh

Abstract*— Wireless Sensor Networks (WSNs) have become hot topic in field of research in recent days. In day to day life we come across many problems which left unresolved by humans, so at that time we think of collaborating human knowledge with technology to eradicate the problems. The efficient approaches of forest fire detection using multi-sensors describes one of the wireless sensor network applications for detecting a parameter that is fire and reporting it to the base station to save the humans and wildlife from destruction which is caused by the fire. The effort offered in this paper conveys the idea of implementing Fuzzy Logic on the information collected by multiple sensors. Thus multiple sensors are used for detecting probability of fire with variations during different time in a day. Each sensor node senses Temperature, Humidity, Light Intensity, CO Density and Time for calculating probability of fire. It will improve precision of the detection system, as well as false alarm rate will be reduced.

Keywords*— Forest Fire Detection, Fuzzy Logic, Sensor Networks.

I. INTRODUCTION

Wireless sensor network consist of large number of sensor nodes deployed densely in the environment. It consists of large number of sensor nodes which collect data and disseminate the collected data towards sink. This concept can be used for many crucial applications where manual involvement of humans is difficult. The summer 2007 showed to the world how big is the devastation caused by forest fires [1]. So, immediate notification of the fire is the most critical issue in forest fire detection systems in which WSN can provide real time fire detection with high accuracy. As forest fires may occur in wild areas due to human carelessness or change in environmental conditions. They cause threats to ecosystem, creating economical damage as well as endangering people's and animal's lives. Spread features of forest fires show that the fire fighter center should be aware of the threat in at most 6 min after the start of the fire in order to put out a fire without making any permanent damage in the forest [2]. For efficient use of Wireless Sensor Networks, all nodes are divided into small groups called clusters. Each cluster has its own cluster head which communicates with base station. In this way there will be no need of sending data from each sensor node to the base station. Sensor nodes will send their data to respective cluster head which will save lot of energy that is pointed as one of the main drawbacks in sensor networks is battery power. Therefore, in this paper an event detection mechanism is projected using fuzzy rule based system.]

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Fuzzy techniques for treating tentative qualitative information including fuzzy arithmetic and mathematics, fuzzy set theory, fuzzy logic, fuzzy decision making and fuzzy control. Rule based fuzzy operators are a new class of operators exclusively considered in order to relate the principles of estimated interpretation as shown in Fig 1.

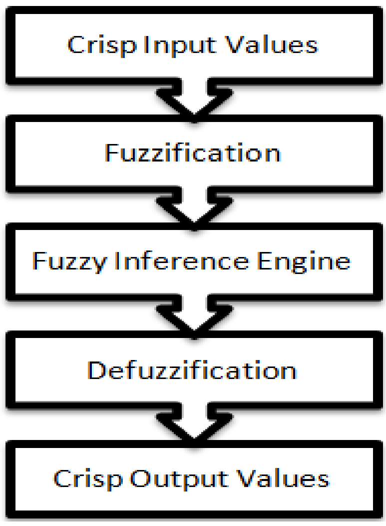

Fig 1: Fuzzy Logic

II. REVIEW OF LITERATURE

Al-Abbass Y. Al-Habashneh et al. proposed three MAC protocols for forest fire detection [3]. Two were based on carrier sense multiple access and one was based on time division multiple access. Results showed that there is no superior protocol which outperforms others in terms of power consumption, delay and complexity, however trade-off does exist.

Çağdaş Döner et al. have given a design in which nodes are randomly deployed with each node having temperature sensor attached to it, simple localization technique is used to get coordinates of the nodes and a distributed spanning tree for the messaging infrastructure [4].

ArnoldoDíaz-Ramírez et al. proposed two algorithms for forest fire detection [5]. The proposed algorithms are based on information fusion techniques. The first algorithm uses a threshold method and the other uses Dempster- Shafer theory. Both algorithms reported false positives when the motes were exposed to direct sunlight. However, if the motes are covered to avoid direct sunlight exposure, the number of false positives may be reduced.

YunusEmreAslan et al. proposed a comprehensive framework for the use of wireless sensor networks for forest fire detection and monitoring [2]. The framework considers all parts of the life cycle of a wireless sensor network system that is specialized for forest fire detection.

While considering the early detection of forest fires as the major goal, the system is constructed that regards the low energy capacity of sensor nodes and the difficult environmental conditions that may adversely affect the network operation and performance.

A.K. Singh and Harshit Singh proposed system for fire detection using wireless sensor networks and fuzzy type-2 logic [6]. Fuzzy gives the best result in such cases as the gathered data acts as input for the system on which Fuzzy logic was implemented to calculate the probability of the forest fire.

III. IMPLEMENTATION

A. Clustering

Nodes are divided into clusters and each cluster will have their own cluster head. The simulation for clustering of nodes is done in MATLAB. Fig 1 shows random deployment of nodes is area of interest whereas Fig 2 shows each cluster having its own cluster head.

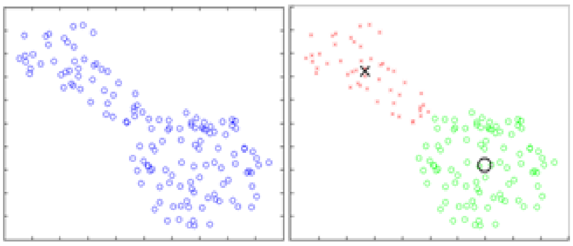

Fig 2: Clustering of nodes

B. Event Detection Mechanism

Event detection is a popular service in environmental monitoring and object tracking applications. Ambulatory medical monitoring, vehicle tracking, military surveillance, forest fire detection are some sample applications that event detection plays a key role. The popularity of this service is not limited to the application layer. Several wireless senor network middlewares provide the required primitives, such as event notification to facilitate event detection tasks in various applications. Fire detection sensor networks are deployed to set an alarm if a fire starts somewhere in the monitored area. So, 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 Fig 3.

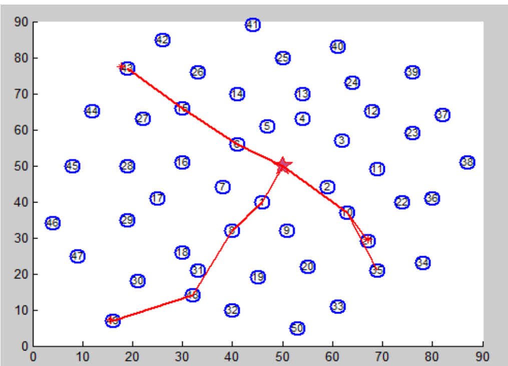

Fig 3: Event Detection Mechanism

C. Fuzzificaion

Fuzzy Logic was inroduced in 1965 by Lotfi A. Zadeh, who was professor in computer science at the University of California in Berkeley. Fuzzy Logic is a multivalued logic that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Fuzzy Logic has emerged as a profitable tool for the controlling and steering of systems, complex industrial processes, household, entertainment electronics, as well as for other expert systems and applications. The aim is to use fuzzy sets in order to make computers more 'intelligent', therefore. Fuzziness describes event ambiguity 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 difficult. WSN is typically used to supervise some parameters of an environment process. The atmospheric events are multifaceted, confusing and imprecision embedded in their nature. Consequently, a fuzzy based approach is a feasible option. The model of fuzzy logic system consists of fuzzification, fuzzy rules, fuzzy inference system and defuzzification process [7].

The Fuzzification is the first step in the fuzzy inferencing process. This involves a domain transformation where crisp inputs are transformed into fuzzy inputs. Crisp inputs are the exact inputs measured by sensors and passed into the control system for processing, such as temperature, position, pressure, rpm's, etc. Each crisp input that is to be processed by the Fuzzy Inferencing Unit has its own group of membership functions or sets to which they are transformed. The group of membership functions exists within a universe of discourse that holds all relevant values that the crisp input can possess [7]. In our fire detection algorithm temperature, humidity, CO density, light intensity, time acts as input fuzzy variables. The Probability of Fire is the output variable. The membership functions LOW, MEDIUM and HIGH are defined on temperature, light intensity, humidity and CO density whereas BEFORE NOON, NOON, AFTER NOON for Time as shown in Fig 4 to Fig 8. VERY LOW, LOW, MEDIUM, HIGH and VERY HIGH are defined on Probability of fire as shown in Fig 9.

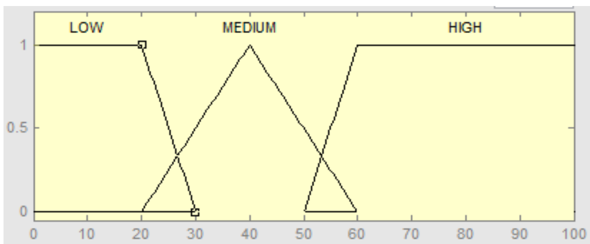

Fig 4: Membership Function for Temperature

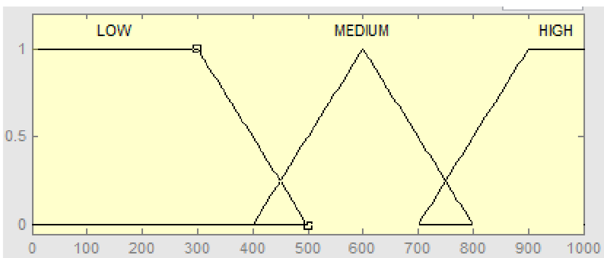

Fig 5: Membership Function for Light Intensity

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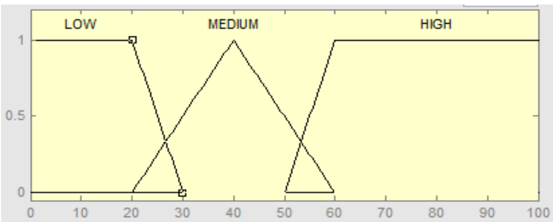

Fig 6: Membership Function for Humidity

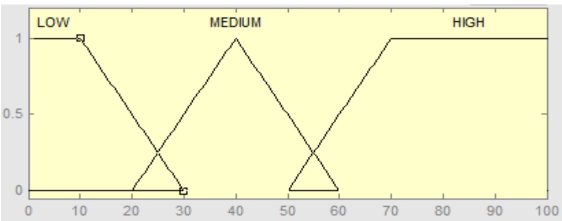

Fig 7: Membership Function for CO Density

Fig 8: Membership Function for Time

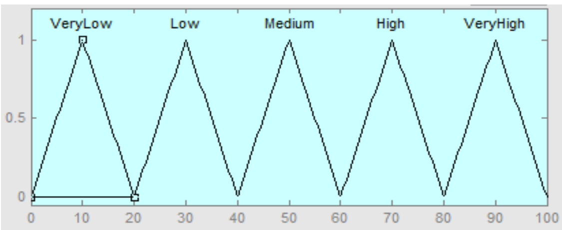

Fig 9: Membership Function for Fire Probability

D. Fuzzy Inference Engine

Fuzzy rules are IF-THEN rules introduced by Zadeh. They may be understood as partial imprecise knowledge on some crisp function. Gaussian, triangular, and trapezoidal 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. Rule evaluation consists of a series of IF- Operator-THEN rules. A decision structure to determine the rules require familiarity with the system and its desired operation. This knowledge often requires the assistance of interviewing operators and experts. 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. There is a strict syntax to these rules which is:

IF antecedent1 OPERATOR antecedent2, THEN consequent1 OPERATOR consequent2.

The antecedent consists of input variable IS label, and is equal to its associated fuzzy input or truth value μ(x). The consequent consists of output variable IS label, its value depends on the Operator which determines the type of inferencing used. AND, OR and NOT are three Zadeh Operators. The label of the consequent is associated with its output membership function [7]. There are 5 input variables that consist of 3 fuzzy linguistic variables. Therefore, the total 3*3*3*3*3 = 243 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 Time is Before Noon THEN Fire probability is VeryLow.

IF Temperature is HIGH and Light Intensity is LOW and Humidity is HIGH and CO is HIGH and Time is Noon THEN Fire probability is VeryHigh.

E. Defuzzificaion

Defuzzification involves the process of transposing the fuzzy outputs to crisp outputs. There are a variety of methods to achieve this such as method of averaging which is also known as the Center of Gravity method or COG. It is a method of calculating centroids of sets. In practice, defuzzification is done using centroid method [7].

IV. 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 20, then the probability of fire is very low.
2. If the output is between 21 and 40, then the probability of fire is low.
3. If the output is between 41 and 60, then the probability of fire is medium.
4. If the output is between 61 and 80, then the probability of fire is high.
5. If the output is between 81 and 100, then the probability of fire is very high.

For example if the input is [89 868 92 76 14], where first, second, third, fourth and fifth element of input matrix represents Temperature, Light Intensity, Humidity, Carbon Monooxide Density and Time respectively, the output is 90. Thus, the probability of fire is VERY HIGH at Time 2 PM as shown in Fig 10. Control surface of fire probability based on different input parameters are shown in Fig 11 to Fig 14.

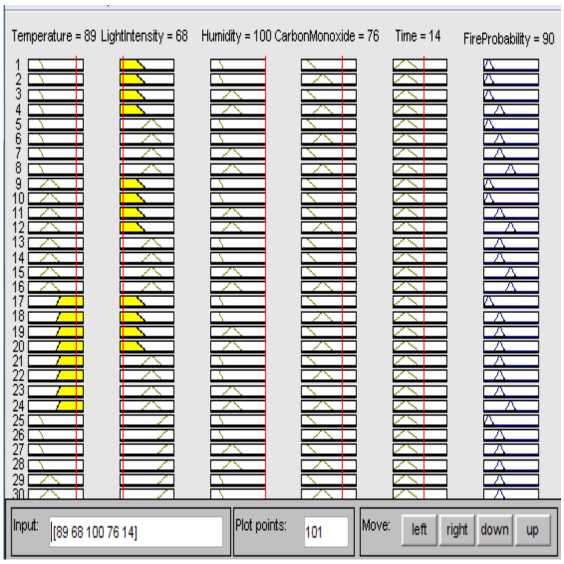

Fig 10: Fuzzy Inference Rule Based Fire Detection System

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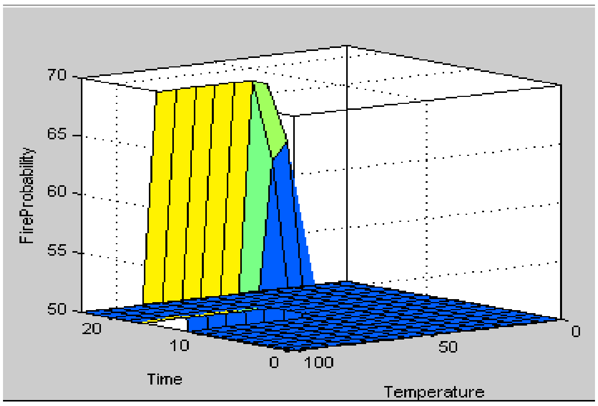

Fig 11: Surface view of fire probability with respect to Temperature and Time

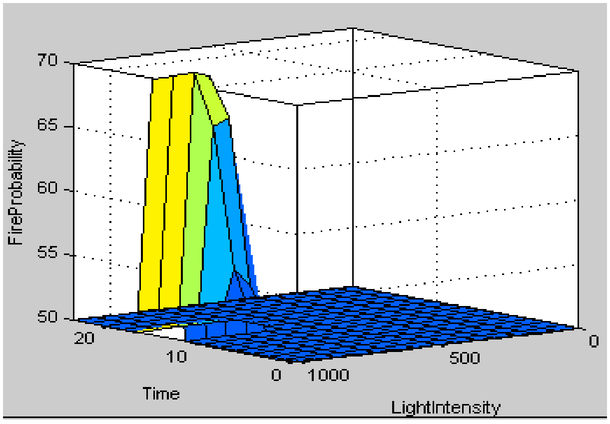

Fig 12: Surface view of fire probability with respect to Light Intensity and Time

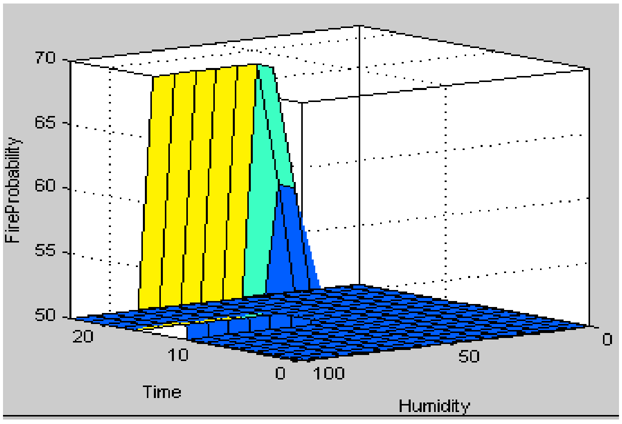

Fig 13: Surface view of fire probability with respect to Humidity and Time

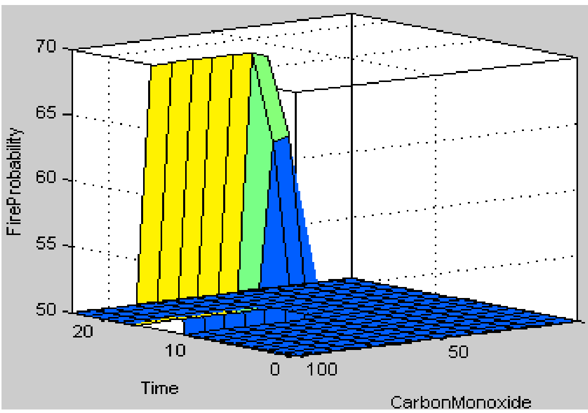

Fig 13: Surface view of fire probability with respect to CO Density and Time

V. CONCLUSION

In this paper, we projected an event detection mechanism for detection of fire and fuzzy approach for fire calculating probability of fire using multi-sensors. Our proposed forest fire detection handles the vagueness present in the statistics successfully and gives the finest results with very low false alarm rate. The decision based on this approach is more precise as it gives accurate results with variation of time and other physical parameters. 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 work on this model.

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