Comparitive Analysis of Fuzzy based Wildfire Detection Techniques

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Abstract— Wireless sensor network make use of sensing units deployed in an effective manner so that they can communicate in efficient manner. In this paper we have compared various Fuzzy based wildfire detection techniques with our proposed technique. The proposed technique make use of cluster gateway switch gateway routing protocol in which there are cluster heads which acts as master and this cluster heads have many sensors connected to it which acts as slaves. The sensors on detecting the fire sends the information to the cluster head and then cluster heads communicate with each other and the information is passed to the controlling authority. The proposed technique make use of Gaussian member functions and make use of more fuzzy rules so as to detect fire more effectively along with its intensity and the direction as well. In this paper the result of the proposed technique is compared with the previous techniques and later on the comparison shows how the proposed technique performs better than the other techniques.

Index Terms— Wireless Sensor Networks, Clustering, Inference Engine, Fuzzy, Wildfire Detection

1 INTRODUCTION

A wireless sensor network (WSN) is spatially distributed autonomous sensors to monitor physical or environmental conditions such as temperature, pressure, light, etc. and to cooperatively pass their data through the network to a main location. More modern networks are bi-directional in nature, also enabling control of sensor activities. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance system; today such networks are used in many industrial and consumer applications such as industrial process monitoring and control, health monitoring, and so on. WSN is built of "nodes" that vary from a few to several hundreds or even thousands, where each node is connected to other sensors. Such sensor network nodes have typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, microcontroller, electronic circuit for interfacing with the sensors and battery . A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, while functioning "motes" of genuine microscopic dimensions have yet to be created. Sensor node's cost is variable that ranges from a few to hundreds of dollars, which depend upon the complexity of the individual sensor nodes. The size and cost constraints on sensor nodes result in corresponding constraints on resources such as memory, computational speed and energy. The propagation technique between the hops of the network can be routing or flooding. The topology of WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network [1].

2 APPLICATIONS OF WSN

2.1 Process Management

Area monitoring is a common application of wireless sensor networks. In area monitoring, WSN is deployed over a region where some phenomenon is to be monitored. The application of sensors is to detect enemy intrusion, whereas a civilian example is the geo-fencing of gas or oil pipelines. Thus, Area monitoring is most important part

2.2Health care monitoring

The medical applications can be of two types: wearable and implanted. The wearable devices are used on the body surface of a human whereas implantable medical devices are those that are inserted inside human body. There are many other applications such as body position measurement and location of the person, monitoring of ill patients in hospitals and at homes. Body area networks can collect information about an individual's energy, health and fitness expenditure.

2.3Air pollution monitoring

Wireless sensor networks have been deployed in several cities to monitor the concentration of dangerous gases for citizens which can take advantage of the ad hoc wireless links rather than wired installations. It also makes them more mobile for testing readings in different areas.

2.4Forest fire detection

A network of Sensor Nodes can be installed in a forest to detect when a fire has started. These nodes can be equipped with sensors to measure gases, humidity and temperature which are produced by fire in the trees or vegetation. As the early detection is crucial for a successful action of the firefighters; so thanks to Wireless Sensor Networks because the fire brigade will be able to know when a fire is started and how it is spreading.

2.5Landslide detection

A landslide detection system makes use of a wireless sensor network to detect the slight movements of soil and changes in various parameters that may occur before or during a landslide. It may be possible to know the occurrence of landslides long before it actually happens through the gathered data.

2.5Water quality monitoring

Water quality monitoring involves analyzing water properties in oceans, dams, lakes, rivers, as well as underground water reserves. Many wireless distributed sensors enables the creation of a more accurate map of the water status and allows the permanent deployment of monitoring stations in locations of difficult access without the need of manual data retrieval.

2.6Natural disaster prevention

Wireless sensor networks can effectively act to prevent the consequences of natural disasters like floods etc. Wireless nodes have successfully been deployed in rivers where changes of the water levels have to be monitored in real time.

2.7Industrial monitoring

Wireless sensor networks have been developed for machinery condition based maintenance (CBM) as they offer significant cost savings and enable new functionality. The installation of enough sensors in wired systems is often limited by the cost of wiring.

2.8Data logging

Wireless sensor networks are also used for the collection of data for monitoring of environmental information which can be as simple as the monitoring of the temperature in a fridge to the level of water in overflow tanks in nuclear power plants. This information can then be used to show how systems have been working. Thus, the advantage of WSNs over conventional loggers is the "live" data feed that is possible [1].

3 Forest Fire Detection And Fuzzy Sets

Because of the rapid development of sensors, microprocessors, and network technology, reliable technological condition has been provided for our automatic real-time monitoring of forest fires control [2]. This approach presents a new type of early warning systems which use a wireless sensor network to collect the information of forest fire-prone sections for forest fire, wireless sensor nodes constitute a "smart" monitoring and control network through the self-organization and transmits the messages to the control center through the network which we can achieve the remote control of the forest fire.

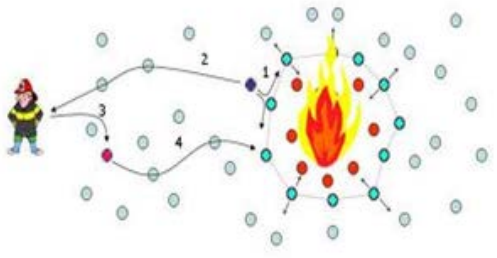

Fig. 1. Fire Detection

The happenings of Forest Fire troubled every country all along, which caused great losses every year. There was a message from China News Agency Beijing which was reported on February 16, 2009. It said that the constant high temperature and drought ,as well as the precipitation decreased ,resulted in the high forest fire weather rating in some provinces and regions of southern China. In addition, the growth of the moor bums which was brought about by farmers lead to the number of forest fire increased rapidly. Forest fire causes the timber to reduce the quantity and quality, so that a large number of animal and plant deaths, destruction of nature and ecological balance, even small climate change of the forest. Above all, the prevention of the occurrence of forest fires is significant. Traditionally, fire prediction can only analyzed and calculated the predicted weather conditions to get a rough and rigid fire index value. What's more, it used the traditional manual inspection methods which can't realize on-site and real-time monitoring and control. In recent years, because of the rapid development of sensors, microprocessors, and network technology, a reliable technological condition has been provided for our automatic real-time monitoring of forest fires control. This paper presents a new type of early

Wireless sensor networks have a wide application prospect and great value in the military, agriculture, environmental monitoring, medical and health, building monitoring, industrial production control, as well as commercial and other fields. It's not only one of the four new technology industries of the global future, but the world's three major high-tech industry's future which was proposed by the Massachusetts Institute of Technology (MIT) technical review.

It is at the peak period of the construction of infrastructure for China. The safety of the construction and monitoring of all kinds of large-scale projects are long-term concerned by building design units. The using of wireless sensor networks allow the building, bridges and other buildings to be able to feel self-conscious of their condition, and make the smart architecture which has a sensor network installation to tell the status of management their information automatically, then allow management to carry out regular maintenance work in accordance with the priority.

In this paper we have used fuzzy logic for detecting fire. Fuzzy gives best results in such systems which do not have exact mathematical model. Fuzzy takes less memory, less processing and less energy. The reasoning in fuzzy logic is very similar to human reasoning. Modeling of fuzzy system is done in natural language, which makes fuzzy logic easy to understand and better to implement.

Type-1 fuzzy logic controllers have been applied to many different applications successfully till date. However there is a need to cope with large amount of uncertainties. Type-2 fuzzy system can handle such uncertainties and gives a better and accurate result. Fuzzy system comprises of mainly three parts namely fuzzification, inference rules and defuzzification. Converting a crisp value to a fuzzy value is called Fuzzification. In this process the crisp numbers is given as input and fuzzified accordingly by using given membership function. Membership functions can be triangular, trapezoidal or Gaussian as required. Inference rules are the heart of every fuzzy system, after the input gets fuzzified mapping of fuzzified input to an output according to IF-THEN rules is done according to rule base table. IF part is known as antecedent and THEN part is known as consequent. After applying rules defuzzifier gives a crisp output from the fuzzy set that is the output of inference engine.

4 TOOLS USED

4.1 Platform

MATLAB (Matrix Laboratory) is a fourth generation high level programming language and interactive environment for numerical computation developed by MathWorks. MATLAB allows data analysis and visualization, function plotting, matrix manipulations, developing algorithms, interfacing programs written in other languages such as C, C++, creating models and applications. Applications of MATLAB include Communication Systems, Computational Biology, Test and Measurement, Embedded Systems, Digital Signal Processing, Control Systems, Mechatronics, Image and Video Processing, Computational Finance, FPGA Design and Co-design, and Technical Computing.

4.2 Fuzzy Logic Toolbox

The past few years have witnessed a rapid growth in the number and variety of applications of fuzzy logic. These applications range from consumer products to decision-support systems and industrial process control. In a narrow sense, fuzzy logic is a logical system which is an extension of multivalued logic whereas in a wider sense fuzzy logic is almost synonymous with the theory of fuzzy sets. In this perspective, fuzzy logic in its narrow sense is a branch of FL. Even in its narrow sense, the agenda of fuzzy logic is very different both in spirit and substance from the agendas of traditional multivalued logical systems. The basic ideas underlying Fuzzy Logic are explained very clearly and insightfully in the Introduction. Linguistic variable is a variable whose values are words rather than numbers. Most of Fuzzy Logic may be viewed as a methodology for computing with words rather than numbers. Words are inherently less precise than numbers; so their use is closer to human intuition. Computing with words exploits the tolerance for imprecision and thereby lowers the cost of solution. One more basic concept in Fuzzy Logic which plays a central role in most of its applications is that of a fuzzy if-then rule. The rule-based systems have a long history of use in Artificial Intelligence. In fuzzy logic, this machinery is provided by calculus of fuzzy rules. Calculus of fuzzy rules serves as a basis for the Fuzzy Dependency and Command Language. Although FDCL is not used explicitly in Fuzzy Logic Toolbox but it is effectively one of its principal constituents. In this connection, it is important to recognize is that in most of the applications of fuzzy logic, fuzzy logic solution is in reality a translation of a human solution into FDCL.

Fuzzy Logic Toolbox is so powerful that most of human reasoning and concept formation is linked to the use of fuzzy rules. Therefore, by providing a systematic framework for computing with fuzzy rules, the Fuzzy Logic Toolbox greatly amplifies the power of human reasoning. A trend which is growing in visibility relates to the use of fuzzy logic in combination with neurocomputing and genetic algorithms. Fuzzy logic and genetic algorithms may be viewed as the principal constituents of soft computing. Soft computing is aimed at an accommodation with the pervasive imprecision of the real world. The guiding principle of soft computing is to exploit the tolerance for imprecision, low solution cost and robustness. In coming years, the soft computing is likely to play an increasingly important role in the conception and design of systems whose Machine IQ is much higher than that of systems designed by conventional methods. From Various combinations of methodologies in soft computing, one which has highest visibility at this juncture is that of fuzzy logic and neurocomputing which is leading to so-called neuro-fuzzy systems. Inside fuzzy logic such systems play a particularly important role in the induction of rules from observations. This method is an important component of the Fuzzy Logic Toolbox. Fuzzy Logic Toolbox is highly impressive in all respects which make fuzzy logic an effective tool for the conception and design of intelligent systems. Fuzzy Logic Toolbox is easy to master and convenient to use. It also provides a reader-friendly and up-to-date introduction to the methodology of fuzzy logic and its wide-ranging applications [4].

5 COMPARITIVE ANALYSIS OF PREVIOUS APPROACH AND PROPOSED APPROACH

5.1 Clustering Technique

In Clustering architecture of previous approach, the sensors are grouping themselves to form a cluster with one node as a cluster head (CH). The clustering algorithm partitions the network into smaller area called cluster. There are number of clustering algorithms proposed for WSN in different contexts. All the sensor nodes send their data to the CH which aggregate and forward only the meaningful data to the sink i.e., base station (BS). The sink collects the data from all the CH which transmits the data to the user via Internet or satellite.

In Proposed approach, fuzzy c means clustering architecture is implemented. FCM algorithm is a distinctive clustering algorithm, has been exploited in extensive range of engineering and scientific disciplines. Initially developed FCM makes use of the squared-norm to determine the similarity between prototypes and data points, and it performs well only in the case of clustering spherical clusters. It gives best result for overlapped data set and comparatively better than k-means algorithm. Unlike k-means where data point must exclusively belong to one cluster center here data point is assigned membership to each cluster center as a result of which data point may belong to more than one cluster center [5].

5.2 Data Fusion Framework for Event Detection

In Previous Approach, all the sensor nodes send their data to the Cluster Head (CH) which aggregate and forward only the meaningful data to the sink i.e., base station (BS). Sink node collects the data from all the Cluster Head which transmits the data to the user via Internet or satellite.

In Proposed Approach, Cluster Switched Gateway Protocol is used. Mobile nodes are aggregated into clusters and a clusterhead is elected and all nodes that are in the communication range of the cluster head belong to its cluster. The gateway

node is a node that is in the communication range of two or more cluster-heads. The source of the packet transmits the packet to its cluster-head which sends the packet to the gateway node that connects this cluster-head and the next cluster-head along the route to the destination. Gateway node sends it to that cluster head and so on till the destination cluster head is reached in this way. An extra advantage of hierarchical protocols is that in case of a route failure the entire route doesn't need to be recalculated but only the part of the route in the sector where the route has been broken needs to be recalculated. In case of flat networks if a route fails then the entire route has to be recalculated from the source to the destination [6].

5.3 Fuzzy Logic

Fuzzy logic starts with and builds on a set of user-supplied human language rules. Fuzzy systems convert these rules to their mathematical equivalents. It simplifies the job of the system designer and the computer which results in much more accurate representations of the way systems behave in the real world. An additional benefit of fuzzy logic includes its simplicity and its flexibility. It can handle problems with imprecise and incomplete data and it can model nonlinear functions of arbitrary complexity.

5.3.1 Membership Functions

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1.

In Previous approach, triangular membership functions are used as they are simple to implement [6].

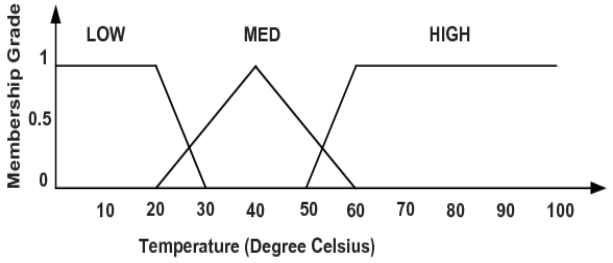

Fig 2: Triangular membership function for temperature

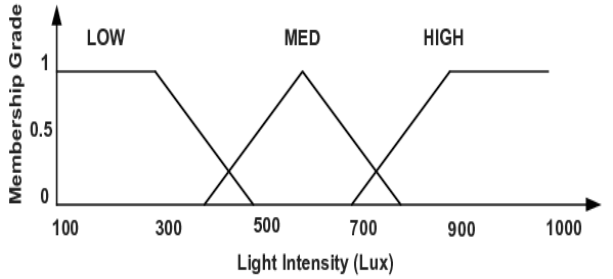

Fig 3: Triangular membership function for light intensity

In Proposed approach, Gaussian membership functions are used. Gaussian functions facilitate obtaining smooth, continuously differentiable hyper surfaces of a fuzzy model. It facilitates theoretical analysis of fuzzy systems as they are continuously differentiable and infinitely differentiable.

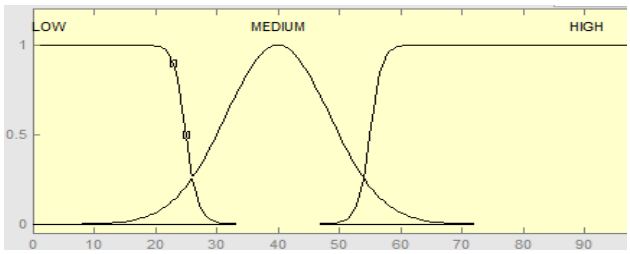

Fig 4: Gaussian membership function for temperature

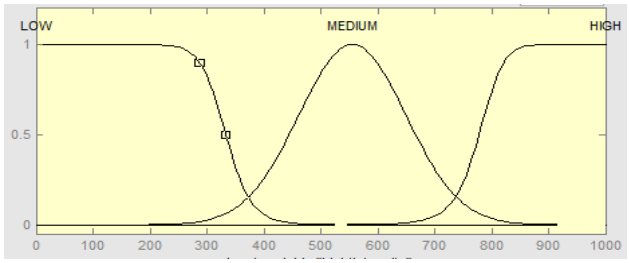

Fig 5: Gaussian membership function for light intensity

5.3.2 Structure of Fuzzy Based Forest Fire Detection System

In Previous approach, there are 4 input parameters i.e. temperature, humidity, light intensity, carbon monoxide and 1 output parameter fire probability. Each parameter has 3 membership functions i.e. low, medium and high. Hence no. of rules for inference engine will be 3*3*3*3=81 rules [6].

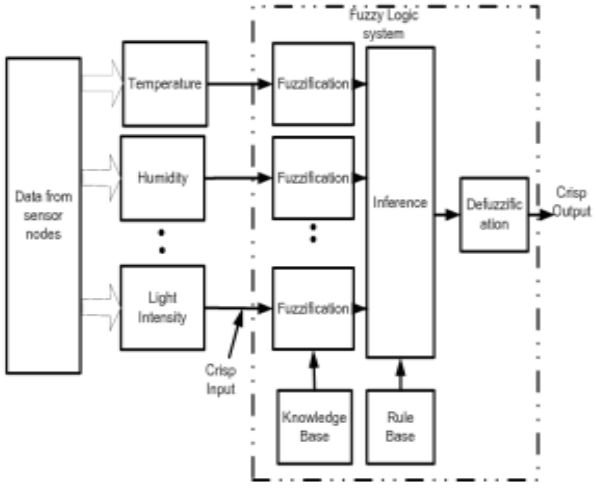

Fig 5: Previous Approach

Whereas in our proposed approach there are 5 input parameters i.e. temperature, humidity, light intensity, carbon monox-

ide, azimuth angle and 2 output parameters fire probability and direction of fire. Hence no. rules 3*3*3*3*4=324 rules.

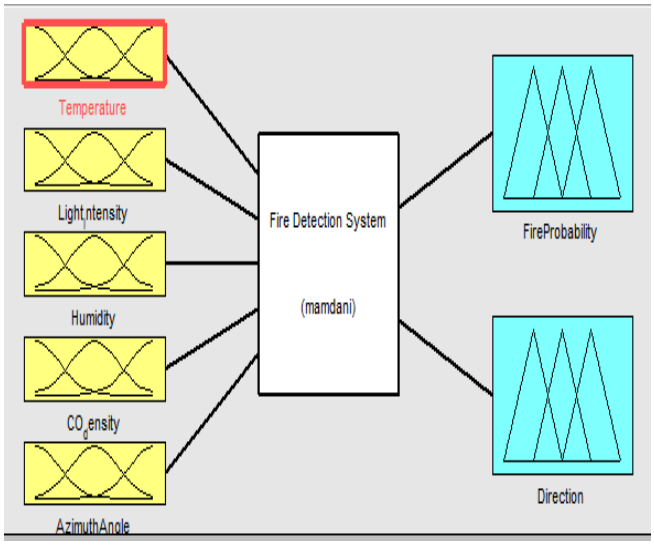

Fig 6: Proposed Approach

5.3.3 Surface View

The Surface Viewer is a GUI tool that examines the output surface of a FIS stored in a file for any one or two inputs. It does not alter the fuzzy system or its associated FIS structure in any way as Surface Viewer is a read-only editor. Using the drop-down menus, we can select the two input variables that we want assigned to the two input axes (X and Y), as well the output variable you want assigned to the output (or Z) axis

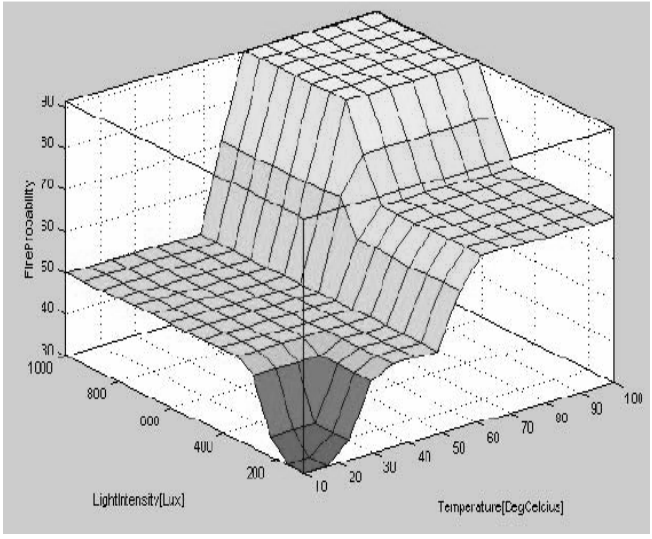

Fig 7: Surface View of Previous Approach

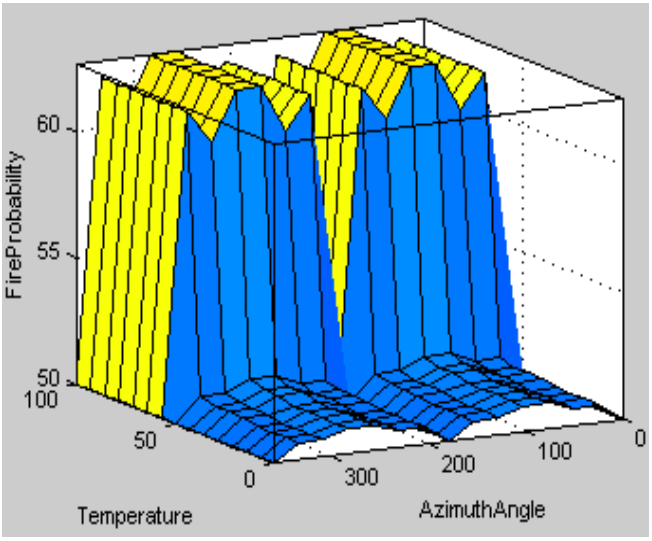

Fig 7: Surface View of Proposed Approach

6 Conclusion

The wireless sensor network is a collection of nodes organized in an effective manner so as the sensors can communicate with each other so as to perform the specific functions. The use of fuzzy logic in order to detect fire in forests has made the wireless sensors networks a broad category. We can conclude from the research that the Gaussian member functions used in this approach yields better results than the triangular member functions. The use of more fuzzy rules makes this approach more accurate and can detect the location of the fire more efficiently. The results shows the clustering techniques used in the research perform very well in communication of the data from the sensors. Fuzzy c means clustering gives best result for overlapped data set and comparatively better than k-means algorithm. Unlike k-means where data point must exclusively belong to one cluster center here data point is assigned membership to each cluster center as a result of which data point may belong to more than one cluster center. In Our Approach the use of Gaussian functions facilitate obtaining smooth, continuously differentiable hyper surfaces of a fuzzy model. The Gaussian functions facilitate the oriental analysis of fuzzy systems as they are continuously differentiable and infinitely differentiable. Moreover use of Azimuth angle helps to analyze the surface views more efficiently. So based on the results we can see that the proposed approach is working better than the previous approaches and helps to detect fire and its location more effectively along with its intensity.

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