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Wireless sensor node threshold algorithm for Fire detection

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Abstract: *The environmental events measured by sensor nodes are detected by the Wireless Sensor Networks (WSNs). In this proposed work WSN is used to detect the fires and threshold algorithm for fire detection are analyzed. In this the sensor nodes are equipped with SHT75 temperature humidity sensor and OPT101 light sensors. The idea in this detection method is detecting fire using only these two sensors even it cannot afford other sensor units such as photo electric sensors, cameras and smoke detectors. The result shows that this algorithm along with the sensor node detects fire at their initial stage. This is efficient method to detect the environment conditions. In addition the use of light is to differentiate the sunbeam and fire is also discussed.*

Keywords: Security Systems – wireless sensor networks – fire detection – threshold algorithm to detect fire.

I. INTRODUCTION

Wireless sensor network is a network consists of sensor nodes to perceive the environment condition and to act on the environment through actuators. These networks are specially designed to monitor the environmental parameters, detecting or tracking them for different field such as industry, medical, military environmental and automotive. These nodes consists of low power devices equipped with one or more sensors, a processor, memory, power supply, wireless transceivers XBeePro and actuators. In this project SHT75 and OPT101 are used to detect environmental parameters such as temperature humidity and light respectively.
The satellite images are also used to detect fire in some cases with limitations as follows:

a) Low frequency image capture leads to large response time.
b) Depends on image resolution, they detect fire when the area is large.
c) Cost of launching and maintaining satellites are huge.

Due to these limitations, some areas use video cameras to monitor environment, but the coverage of these systems are very limited. Hence the efficiency of wireless sensor network depends on the sensors and suitable algorithms used for detecting the task. In some case, the sensors may not available to detect. They are available with high cost and consume high power. In these cases, a suitable algorithm leads to get acceptable and best results. This threshold algorithm processes different input data to provide an output. But this output is better than the input data individually. WSN is equipped with XBeePro wireless IC transfers the important and processed data to PC central monitoring station. This PC receives information from the sensor nodes, process them and take appropriate actions. For example, inform user about the event, communicate it worldwide and display the information. Fire detection will be very helpful in avoiding human and material loss.

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In this paper, threshold algorithm for fire detection is proposed and evaluated. This node is equipped with temperature, humidity SHT75 sensor and OPT101 light sensors. The performance of the threshold algorithm is evaluated with the comparison algorithm with the metrics such as delay time in detecting fire, precision in finding, un-detecting fire and detecting un-fire. The final results show that the threshold algorithm method is able to detect fires at their initial stages efficiently.
The rest of this document is organized as follows. The related work is presented in Section 2. In Section 3, the proposed threshold algorithm for fire detection is discussed. In section 4, the experiment results are analyzed. Finally, in Section 5 the conclusions are presented.

II. RELATED WORK

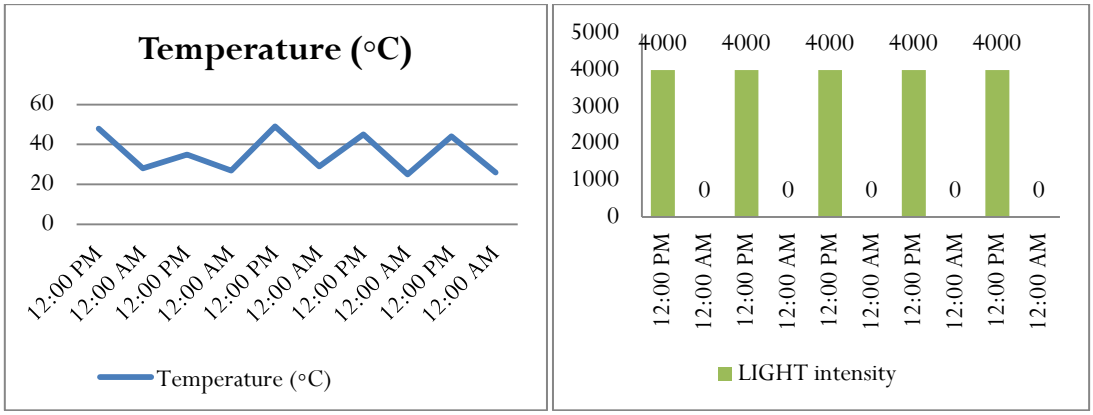
The Cetin Elmas and Yusuf Sonmez [1] are analyzed the data fusion framework with novel hybrid algorithm for multi-agent decision support system for forest fire. The Andrey Somov et al. [2] are discussed about the deployment and evaluation of a wireless sensor network for methane leak detection. The Gui Yang et al. [3] are analyzed about the study on remote monitoring system for landslide hazard based on Wireless Sensor Network and its application. The Daniela Ballari et al. [4] were discussed a mobility constraint model to infer sensor behaviour in forest fire risk monitoring. Wei Tan et al. [5] is discussed the Mine Fire Detection System Based on Wireless Sensor Network. Yeon-sup Lim et al. are analyzed [6] Fire Detection and Rescue Support Framework with Wireless Sensor Networks.

III. THRESHOLD ALGORITHM TO DETECT FIRE

Environmental properties are identified to differentiate between fire event conditions and normal condition. To achieve this, temperature humidity and light are measured for few days without fire event occurrence. Based on this, the environmental physical properties behaviour under normal conditions could be understand. The data in the presence of fire is also collected. The behaviour difference is compared between normal and abnormal environmental conditions. The threshold algorithm is applied on collected data. The sensor node is designed with the sensors such as temperature/ humidity SHT75 and light sensor OPT101 to collect environmental data. Sensor nodes continuously collect temperature and light measurements that are used for fire detection. Initially, the data is collected in the period between April and May 2015 at campus and analyze them to identify properties that allow differentiate normal condition from fire condition. The following points are observed. Based on these observations, threshold algorithm is proposed for fire detection.

1. Environmental measurements are following a cyclic behaviour every day.
2. At night, light measurements remain in an extreme low level of intensity. So that fire presence can be detected by comparing the light with a simple threshold light level.
3. The fire and sunbeam are differentiated upon temperature measurements.
4. When the sensor node is exposed to the sun, light measurements by sensor assume greater values and remain constant, whereas light measurements affected by fire occurrence do not achieve the same level. So, light measurements are used to differentiate between the fire and sunbeam.
5. Since sunbeam is a cyclic event, the fire from sunbeam is also differentiated by comparing current measurements with past measurements.
6. The temperature and relative humidity values maintain an inversely proportional relationship among them. When the temperature increases, the relative humidity decreases.
7. The light intensity shows a stable and high level during the day and a stable and very low level during the night. The light values show a sudden change during transition period of day to night, and vice versa.

The temperature, relative humidity values (SHT75) and light (OPT101) show a cyclic behaviour as shown in Figure 1. When a fire occurs, the temperature shows a rapid increment, whereas the relative humidity decreases fast. The light intensity does not show a significant change in the presence of a fire.



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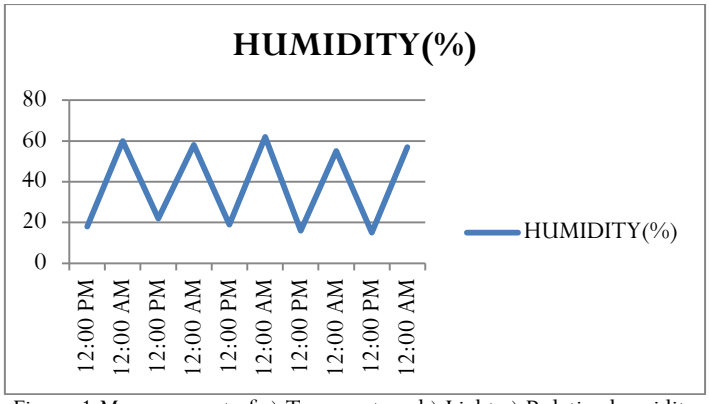

Figure 1 Measurement of a) Temperature b) Light c) Relative humidity

The threshold algorithm is based on the state machine shown in Figure 2. The transition from one state to another is generated when a relevant change in the values of temperature, light or relative humidity is detected, indicating the probable existence of a fire. To develop the application to collect the sensed data and send them to a central monitoring station, the embedded C programming language is used.

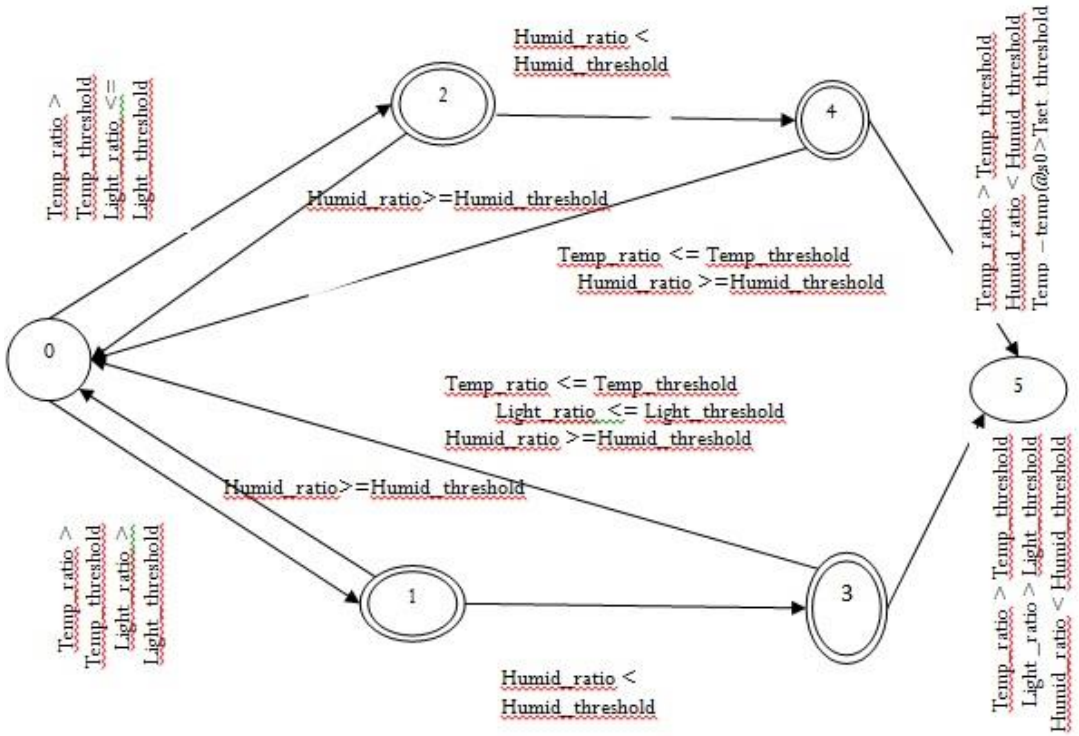

Figure 2 State change diagrams to detect day/night fire

State 0 represents initial, normal no fire environmental conditions. The State 1 and State 2 are transition state for night fire and day fire respectively. State 3 and state 4 represents sunrise and direct sunshine conditions respectively. State 5 represents the occurrence of fire. At state 0 temperature measured (Tm) by sensor SHT75 is evaluated. The memory window (M_T) contains average of most recent temperature value recorded by sensor. The ratio (Temp_ratio) between Tm (temp@s0) and M_T is calculated. If this is greater than Temp_threshold, means a large change in temperature value and a fire may be detected.

To determine if it is night or day fire, the rate of change of the light is evaluated. The memory window (M_L) contains average of most recent light value recorded by OPT101 sensor. The ratio between Lm (light measured) and M_L is found and called as Light_ratio. If this is greater than Light_threshold, the machine changes to the State1. Otherwise, it changes to the State2 day fire.

In state 1, the memory window M_H contains the average of recent relative humidity values. The ratio (Humid_ratio) is determined between humidity measured (Hm) and M_H. If this is less than Humid_threshold, the machine moves to State3; otherwise, it return back to State0.

While the machine is in State3, the ratios are still computed, and if they are greater (or smaller, in the case of humidity) than their respective thresholds the machine moves to State5 and an alarm is triggered and information is wirelessly communicated, indicating the probable occurrence of a night fire.

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To identify the day fire event at state 2 the following are done. If the ratio (Humid_ratio) is less than Humid_threshold, the machine moves to State 4 from state 2; otherwise, it return back to State 0. In State 4, if the temperature and humidity ratios maintain their relationships, the difference of the current temperature value and temp@s0 are calculated. If the difference is greater than Tset_threshold, the machine changes to State5, which means that perhaps a day fire has occurred.

IV. EXPERIMENTAL RESULTS

The following parameters are determined using the algorithm.

1) Memory window size between every 5 second and 5 different average values are calculated initially.
2) After experiments, Memory window size (M) and threshold (T) are varied to evaluate the metrics.
    - Undetected fire: it occurs when the methods do not detect a fire event (event is not detected).
    - Detect unfired: it occurs when the methods indicate a false fire presence (event is wrongly detected).
    - Delay time: The difference between the time of a fire event starts and the time it is actually detected.
    - Precision in finding: Precision indicates how the methods agreed to classify the condition of the environment as normal.

In this paper, undetected fire and detect unfired are the major metrics. Since in practice it has to be avoided both cases.

3) The results indicate that, for every memory window size and the threshold value increases, the algorithms converge to undetected fire, but detecting unfire increases accordingly.
4) To select the best threshold for a given memory window size, the threshold of minimum value is chosen for no detection with the smallest undetected fire.
5) It is noted that larger window size cause stable and less detected unfired condition in Threshold algorithm.
6) The delay of event detection in algorithms was less than 3 milliseconds, which is an acceptable value to make reactive actions depending on the location of application.
7) To save energy, the sensed data were sent to the PC center monitoring station every 5 seconds.
8) The performances of the algorithm using the following values are evaluated. The best performance was obtained using a memory window size greater than or equal to 25, and the following threshold values:
    temp_threshold = 1.15, light_threshold = 1.2, humid_threshold = 1.01, and tset_threshold=3.5◦C.

V. CONCLUSION

In this paper proposes the threshold algorithm for fire detection in wireless sensor network that use only light OPT101 and temperature/humidity sensors SHT75. The data is analyzed and shows few parameters allow automatic fire event detection based on measures collected. Finally, conclude that this threshold algorithm is more reliable because of the stability to represent the environmental conditions in the form of state diagrams. It is simpler to implement and showed a good performance. The use of more sensors will add reliability to the detection process, but will increase the energy consumption and the deployment costs. Thus, this node with this simple algorithm was to make a compromise between efficiency and cost. This work will be extended for best algorithm and more sensing parameters.

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