Classification and Detection of Fire on WSN Using IMB400 Multimedia Sensor Board

Varun Pande, Wafa Elmannai, Khaled Elleithy
Department of Computer Science and Engineering
University of Bridgeport
Bridgeport, CT 06604, USA
{vpande, welmanna, elleithy}@bridgeport.edu

Abstract

Over the years fire detection systems have been developed using multiple techniques. These systems monitor the damage done by forest fires and tend to reduce the environment degradation and save the natural as well as human resources. On the other hand, these techniques or methodologies still need a lot of effort because they are mostly a high cost maintenance process for early detection. Otherwise some systems have been considered as slow systems in detecting fires. It is a well documented fact that detecting a fire would not be enough for real time cases. An early detection and an early alarm system can rapidly improve the detection process and avoid loss of life as well as property or natural damage. In this paper we introduce a new detection system for fire detection using a multimedia board in order to detect and verify the fire in less time. The idea of the new algorithm is to add the capability of multimedia in an efficient way. Therefore, we used the IMB 400 Multimedia board in order to capture the images and run our filtering algorithm over the images to detect the fire. Hence, with the IMB 400 board's sleep/wake up ability, we can save on the critical issue of energy consumption. With this system, we will be able to detect and verify the fire in an environment at the same time and save the fire images in a database for further training of the classifier. This would be a robust system itself. Lastly, in this paper we are showing the importance of color information and movement over the detection of fire systems by using the Multimedia board (IMB400) in our implementation.

1. Introduction

In many places over the world fire hazards threaten the natural environment. Even the modern cities today face this issue. It is not new to hear about the forest fire accidents especially in California, USA, and how there is loss of life and damage to property as well as wild life. In addition, the aftermath of forest fires leave a lot of environmental damage that takes up years and a lot of money to clean up [1].

Early fire detection systems are based on either using human for monitoring or motorized devices to protect a critical area. Lately, the smoke detecting devices are used to protect small building or houses but these systems detect the fire and raise an alarm after the fire has reached a certain temperature or a smoke particle was detected by the smoke detector. Although such systems work fine they are not efficient as in most cases the loss of property is already done. Furthermore, false alarms are high in such cases as a room temperature can increase due to multitude of factors though this is a very rare coincidence.

Hence, even the ordinary detectors can cost a lot in terms of energy, money and manpower. To deploy a current system, it needs a large number of people in order to setup the smoke alarms to have a monitoring station with human monitoring the video relay. Thus, such systems result in human error as communication errors [2].

Apart from the fact that our system can work in indoor environments, in this paper we are mostly focusing and discussing about the fire dete4ction issues in outdoor environments such as forests. The techniques discussed earlier cannot satisfy dectection as well as providing sufficeint information on fires like smoke properties, the size of the fire and the movement of the fire. with In addition, the current systems are difficult to deploy. It is quite difficult to set up a network of sensors in an outdoor environment and its only possible to cover a certain perimeter and not an entire forest. [1]

Satellite communications have been used for most recent fire detection systems [3-6]. In 1999, the Moderate resolution Imaging Spector radiometer (MODIS) was introduced as the first image detection technique [3]. It helps in providing information about the forest fire around large areas of forests all over the world. The satellite has the ability to scan the earth's surface daily. It receives the information over three dimensional determinations. They are: 5 bands in 500 m, 29 bands in 1,000 m and 2 bands in 250 m. This systems provide fire detection information in real time cases. The flaw in this system is the fire can be studied rather that detected at the start. Our goal in this paper is to detect fire at its source from the start. Thus, the suggested system prevents severe damage that can be caused by the fire.

Many researchers have tried to improve the forest fire detection systems and they have used many different techniques. Examples of such are AVHRR and MODI. Both these methods have been used in getting the data in order to detect the fires over two countries which are Canada and China [4],[5]. However, most of the above methods have several limitations related to the sensitivity of the satellite, depth of the forest and the scale of the fire. Therefore, we are introducing an efficient implementation with the help of the IMB400 multimedia board in detecting the fire. The system works by capturing the images of the fire and stores them in a database. Our algorithm starts collecting the color information from the images. This approach helps in determining the temperature and the size of the fire.

The paper is structured as follows: The IMB 400 multimedia board overview is explained in section 2. The related work is stated in section 3. System architecture is presented in section 4. The simulation setup is given in section 5. Simulation results and analysis are presented in section 6. Finally, conclusions are provided in section7.

2. IMB 400 multimedia board overview

IMB400 is the development board for Imote2 platform. It has the ability of processing multimedia information. Figure 1 shows the IMB400 board. This board can be used to take images, videos (no video drivers developed yet), play audios and recording. Based on the multimedia information provided by the board, we can develop third-party software to perform any kind of processing on that data. For example, we can store the images in a database for use by a classification program. The largest contribution of this board to the wireless sensor network is its ability to save energy. The development of the board enables the user to allow certain individual functions like the camera, speaker and microphone to stay in a sleep state while the PIR sensor is active in monitoring the movement. This enables the nodes to have a longer battery life. [7].

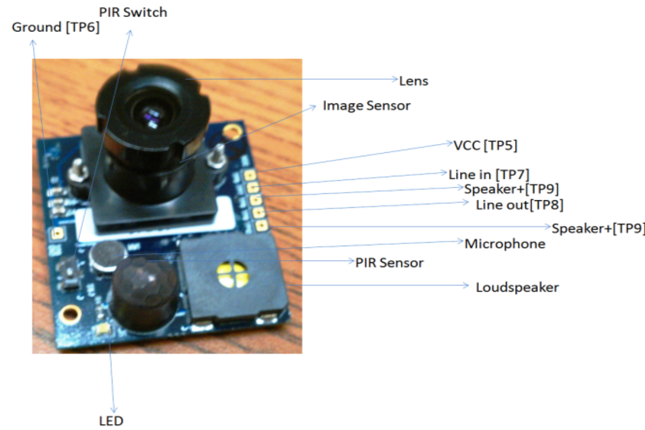


Figure1: IMB 400 multimedia board

The IMB 400 board suports the following main feature:

1. Camera: This device was developed to improve Imot2. It has 640x480 pixels, 30 fps max image resolution and its format is RGB, YCbCr or YUV. This camera has the capability to control sharpness, saturation, gamma, and hue.
2. PIR Sensor: its range is up to 5m and the angles of determining is 80-100.
3. Audio Codec: 48 kHz, mono is its rate. It has the ability to filter defeat of noise.

The environments of IMB400 board are TinyOS on the Ubuntu operating system and Cygwin is used for windows operating system, and Linux.

The IMB 400 multimedia board has a huge subsystem. It can run Audio Codec and Playback Codec (e.g: Wolfson WM8940), the Camera allows for taking Color Image (OmniVision OV7670), also on the board Miniature Speaker and Microphone allow for working with sound frequencies, and the PIR Sensor can be used for motion detection.

3. Related Work

Many researchers have studied the fire detection systems but there is a limited number of publications that discuss the details of the implementation. Many papers present their ideas in mathematical models. There are different kinds of systems that have been shown; some are single and other are multisystem or mixed systems of different techniques. In this section we review several techniques and studies that are presented in literature.

The authors of [9] present mostly the structure of the wireless sensor network. The team presents the data processing application, which is an artificial neural network to the in-network over WSNs in real time detection systems. Whereas, in [8] the artificial neural network was implemented in order to analyze the sensing of data at individual time periods. Hence, the authors consider this implementation as sensing dynamic data over the time.

The possible materials that may cause the forest fire were studied in [6]. The authors revised all the conditions for space-based view with different types of risks. Also, they created a map for the fuel, observing the fire and determining the way of recovering the burned places. The study was done on determining which condition can really cause the fire and how could the performance of the satellite be improved scanning more efficiently.

FireSensorSock system was introduced in [12]. The idea of this system is to make the sensor nodes safe over the WSNs. This system provides a special kind of protection during the nodes process and allows them to sense current data without having any damage. The result gives different values of temperature which show if there is a fire or not. The providence of protection of the nodes will allow sensing over larger and harsh environmental conditions.

4. System Architecture

Most common fire detection systems use smoke detectors to detect the cause of the fire. Such detection approach, though work, can be too late in the detection of fire as the smoke particle needs to be detected by the filter inside the module and while this happens a lot of damage is done. Our method of fire detection is a vision based system which allows the detection of fire based on a picture- based interface and thus further processing (in milliseconds) allows us to determine whether the images are actually of a fire or not. This way an early alarm can be raised to prevent extensive damage. Also the fact that our systems is based on WSN and have their own ad-hoc network, it allows the deployment of these nodes from anywhere into any environment i.e. from an indoor environment to and outdoor environment such as forest or isolated places. The systems shown in Figure 2 works as follows:

1. The images are retrieved from the Cygwin platform that is the Tiny-OS platform which supports the IMB 400 camera board interface.
2. Once the images are stored in our base station, they will be used as input images for our second application which is a program written in C# programming language.
3. This application gathers the information from each image by doing the following:

a) The initial color image is retrieved by our application.
b) The color image has information that needs to be converted from the RGB color scale to the Ycbcr color scale
c) As we are dealing with fire, we need to get the information of luminance which is known as Segmentation.

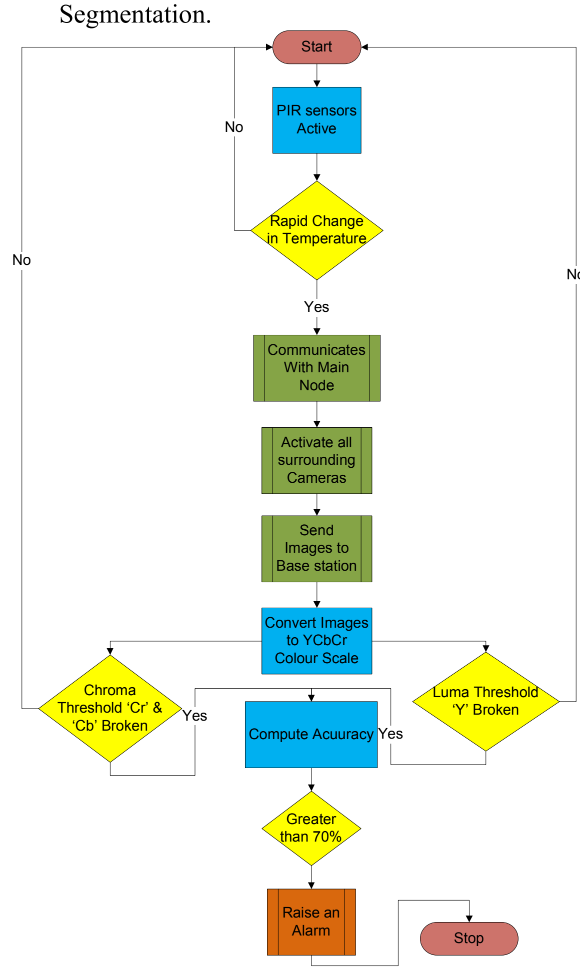


Figure2: The flow chart of our system

There are several steps we have to do to convert from the RGB to the Ycbcr color scale:

1. The segmentation is the image's documentation and isolation into areas that correspond to physical units. Overall approaches to segmentation can be gathered into three classes: Continuity-based methods, Pixelbased Methods, and Edge-based methods.
2. Pixel based methods: the most common and efficient method is thresholding where all pixels

having strength above or below a threshold value will be ordered as part of the segment. The Input image should be in RGB format. RGB color model contains of three colors: blue ,red, and green. Because the RGB color space is delicate to the light environments, thus the detection may be non-decisive if the lighting conditions fluctuate. Thus we use YCbCr color space in our proposed method. The actual color showed depends on the real RGB primaries which are used to show the signal. YCbCr color space stores the Luminance information (Y) individually from the chrominance information (Cb and Cr). Luminance (Y) can be demarcated as the illumination (Luma), However chrominance is denoted as the difference of two color modules, Cb and Cr. The Module Cb is blue detriment the luma (B-Y), whereas the module Cr is red detriment the luma (R-Y). The change of RGB color space into YCbCr color space is done by the following formula:

$$Y = 0.299R + 0.587G + 0.114B$$

$$Cb = -0.1687R - 0.3313G + 0.5B + 128$$

$$Cr = 0.500R - 0.4187G - 0.0813B + 128$$

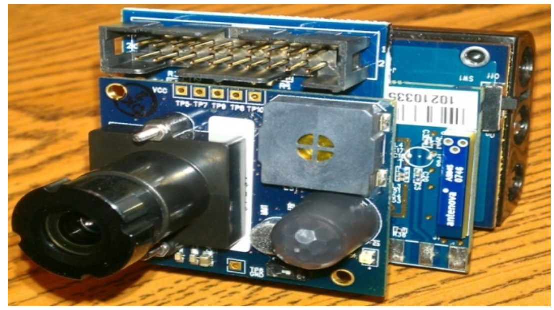
Where $R, G, B \in [0,255], and\ Y, Cb, Cr \in [0,255]$

However, our proposed method calculates the RGB color for each pixel in the taken input. After that, the RGB color space is changed to YCbCr color space. The resultant YCbCr color frame is split into 3 different layers of Y, Cb and Cr color spaces individually. Finally, if any of the threshold values set by our algorithm is broken, then an automated system initializes the alarm.

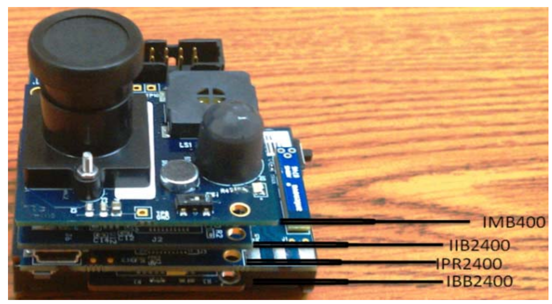
5. Simulation Setup

We have implement out new algorithm over Cygwin on windows. We have also installed TinyOs 2.x under UBUNTU. The IMOTE2 sensor boards are supported in Tinyos and we run the simulations for the sensor boards like MICAZ. However, the algorithm is implemented using NESC (Network Embedded C). The implementation includes three sections to run any sensor. The sections are: Configuration File, Component File, and Make File.

The drivers for the images, video and sound have been developed for the IMB400 Camera Board. The IPR2410 is the communication board and is the most important board in our setup for the wireless communications environment. We have also used boards such as the IIB 2400 and IBB240 to make a robust system . The complete module is shown in Figure 3.1.



Module Frontal Views



Module View with Board Description

Figure 3.1: Module Implementation

Communication in this board is done using their own ad-hoc networks as each module is given an individual ID so that it is easier to know which module sensed the fire in our case. Even if the sensor is not close to a primary node or to a base station, the signal can be sent through the other nodes in the network till it reaches the destination. A network diagram is shown in the Figure 3.2 to diagrammatically explain the communication network between the nodes.

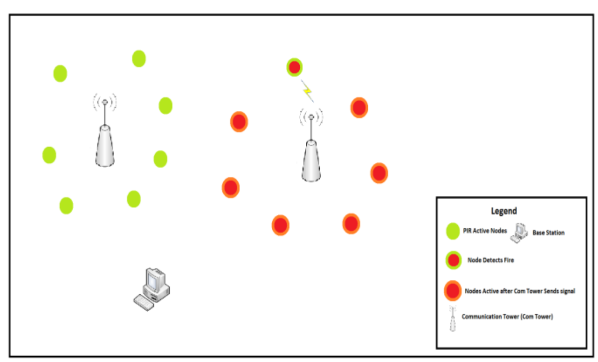


Figure 3.2: communication network between the nodes

6. Simulation Results

As we explained in section 5, we have used the IMB400 multimedia boards. The boards help in saving the energy over the network by providing the ability to allow the various sensors to wake up / sleep. Therefore, all the sensors do not transmit all the time to improve the battery life. In our implementation, only the camera sensor wakes up to capture images if there is movement detected by the PIR sensor. The images captured are sent to the base station.

Based on these inputs our implementation provides us with sufficient and necessary information if there is a fire. In this case it provides the temperature intensity of the fire as presented in [13]

The algorithm presented in this paper allows us to choose the type of detection we need. This feature is optional and can be activated if we need more variables to compute and get more information out of the image about the fire. Since the PIR sensors has the ability to pick any changes in the temperature which occur due to motion of objects or animals thus this allows for improving the false positive results. Figure 4 shows the interface and where the images are received by the base station.

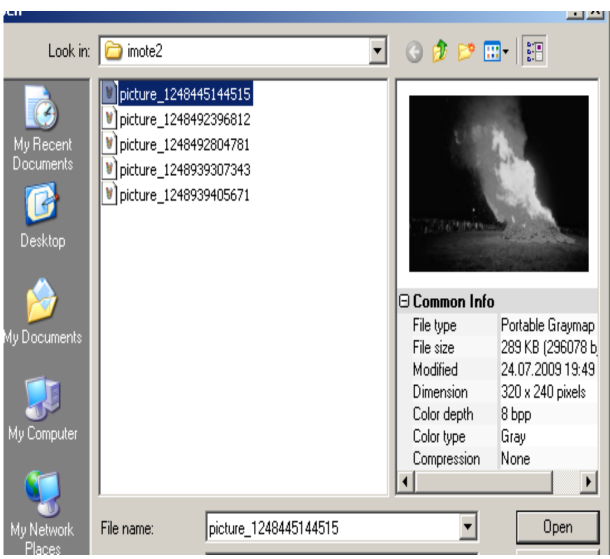


Figure 4: Samples of Stored images

Finally our implementation gathers all the information from each image by applying the color conversion from RGB to YCbCr color space. The individual histograms allow us to see and understand the individual intensities of the chrominance and the luminance as shown in Figure 5.

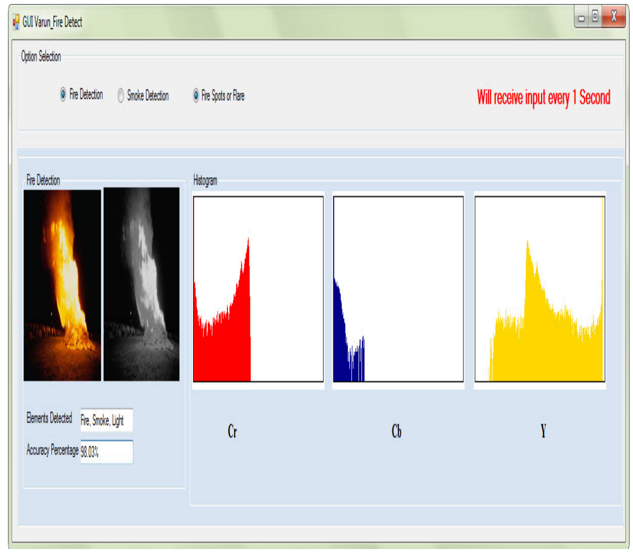


Figure 5: The fire detection system

The system analyzes this information based on above system architecture. Figure 5 shows how the system retrieves the image then covert the colors. Based on these colors we can get the temperature's level[13]. Then from the relation between the fire color and the fire temperature, we can get the size of the fire. Furthermore, by using camera board we can detect if there are human beings or animals that caused the incident to happen. Hence, such approach provides solutions to many issues in fire detection.

7. Conclusion

Different applications were used for implementing the forest fire detection systems. However, in this paper we have introduced a unique fire detection system by using multimedia board IMB400. use Using the system presented in this paper, we can reduce the percentage of error possibility since we can detect any movement and determine any object. Other issues such as deployment were also solved. The approach helps in conserving the battery life. Due to the use of camera boards and image monitoring, we have actually improved the system correctness of fire detection. Our proposed system could prove the successes in verifying the fire in less time.

This work will be extended by using the IMB400 multimedia boards and the MTS 300 boards together to improve communication between the nodes and have an alarm system deployed in the outside environment. Furtehrmore, we plan to improve the system by adding filtering mechanisms to improve the accuracy of detection as well as determine the location of the fire.

Because there is no automatic positioning system for the modules, we are yet to determine a method for locating the fire in an outdoor environment. In our previous work we were able to use the micaz motes to determine location of the fire using acoustic ranging technique. We will try implementing that method with the current work to develop and deploy a complete monitoring system for fire detection and prevention.

References

[1] Jaime Lloret, Miguel Garcia, Diana Bri and Sandra Sendra, "A Wireless Sensor Network Deployment for Rural and Forest Fire Detection and Verification", sensors, 2009.

[2] D. Schroeder, "Evaluation of three wildfire smoke detection systems," Advantage-Forest Engineering Research Institute of Canada (FERIC), vol. 5, pp. 1–8, 2004.

[3] http://modis.gsfc.nasa.gov/, MODIS Web.

[4] Z. Li, S. Nadon, J. Cihlar, "Satellite detection of Canadian boreal forest fires: development and application of the algorithm," International Journal of Remote Sensing, vol. 21, no. 16, pp. 3057-3069, 2000.

[5] G. Guo and M. Zhou, "Using MODIS Land Surface Temperature to Evaluate Forest Fire Risk of Northeast China," IEEE Geoscience and Remote Sensing Letters, vol. 1, no. 2, April 2004.

[6] T. J. Lynham, C. W. Dull, and A. Singh, "Requirements for space-based observations in fire management: a report by the Wildland Fire Hazard Team, Committee on Earth Observation Satellites (CEOS) Disaster Management Support Group (DMSG)," in IEEE International Geoscience and Remote Sensing Symposium, vol. 2, pp. 762-764, June 2002.

[7]http://www.openautomation.net/uploadsproductos/imote2_imb400_preliminary.pdf,"Imote2 Multimedia – IMB400", CrossBow Technology INC, Document Part Number: 6020-0390-01 Rev_A PRELIMINARY Subject to change without prior notice.

[8] H. Soliman, K. Sudan, and A. Mishra, "A smart forest-fire early detection sensory system: Another approach of utilizing wireless sensor and neural networks," in IEEE Sensors, 2010, pp. 1900–1904.

[9] L. Yu, N. Wang, and X. Meng, "Real-time forest fire detection with wireless sensor networks," in Proceedings of International Conference on Wireless Communications, Networking and Mobile Computing, vol. 2, 2005, pp. 1214–1217.

[10] P. Dutta, J. Hui, and J. Jeong, "Trio: enabling sustainable and scalable outdoor wireless sensor network deployments," in IPSN '06. ACM, 2006, pp. 407–415.

[11] M. Minami, T. Morito, and H. Morikawa, "Solar biscuit: A batteryless wireless sensor network system for environmental monitoring applications," in The 2nd international Workshop on Networked Sensing Systems, 2005.

[12] Antoine-Santoni, T.; Santucci, J.-F.; Gentili, E. De; Silvani, X.; Morandini, F. Performance of a protected wireless sensor network in a fire. Analysis of fire spread and data transmission. Sens. J. 2009, 9, 5878-5893.

[13] Varun Pande, Wafa Elmannai, Khaled Elleithy, "Optimized Algorithm for Fire Detection over WSN using Micaz Motes," 25th International Conference on Computers and Their Applications in Industry and Engineering (CAINE-2012), New Orleans, Louisiana, USA, November 14 – 16, 2012.