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Image Processing Based Fire Suppression System with Location Tracking and Wireless Sprinkler Operation

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ABSTRACT: The "Image Processing Based Fire Suppression System with Location Tracking and Wireless Sprinkler Operation" aims at developing a self-sufficient Fire-Suppression system that is Fully-Automated and modifies the current fire-suppression systems by making use of Image Processing and Wireless Communication. This system also eliminates the use of hardware smoke/fire detectors and uses hardware wireless communications to suppress the fire at its specific location. The system makes use of Image Processing algorithm to identify the origin of fire and also performs real-time location-tracking of the fire. The location of fire is then communicated to the advanced water sprinklers that suppress the fire at its specific location and do not spray water anywhere else. The image processing algorithm also monitors the fire while it is being extinguished. The water sprinklers are thus turned off automatically as-soon-as the fire is extinguished completely, hereby, eliminating human to fire interaction to the minimal. This project also address the problem of water wastage by spraying water at every location irrespective of presence of fire at that location or not as, water is sprayed by the sprinklers only at the location of fire and is shut off as soon as the fire is extinguished.

KEYWORDS: Self-Sufficient, Fully-Automated, Image Processing, Wireless Communications, Real-Time, Location-Tracking

I.INTRODUCTION

The sole motivation behind developing this project was to develop a fire-suppression system that is more advanced, robust and self-sufficient compared to the existing fire-suppression systems available presently. This project eliminates the use of conventional sensor-based techniques to detect fire and replaces it with a more advanced system that uses image processing algorithms to detect fire and track its exact location in real-time.

A camera is used to monitor the surroundings in real time. A processor attached to the camera is constantly running an image-processing algorithm that captures multiples frames and runs these frames through the image-processing algorithm. Once fire is detected, the image processing algorithm captures the location of fire in real-time and broadcasts this location to the multiple wireless water-sprinkler nodes. A controller present in each of these wireless water-sprinkler nodes turns the sprinkler on only when the location of the fire matches their exact location. . Also, the controller in each of the water sprinklers gets command from the co-ordinator node when the fire is extinguished, and the controller switches the sprinklers off. This helps to achieve more efficiency in attacking fire at its exact location and also water-saving as no extra water is wasted by the sprinklers.

The main purpose of shifting to image processing technology rather than the conventional sensor technology to detect fire, was to eliminate the various problem faced while using sensors, such as false detection due to dust layer accumulation; judging steam, cooking smoke, chemical sprays, etc. as fire-smoke ; time delay in detection if sensors are installed at high-heighted ceilings, etc. Also, this system being completely independent eliminates the need for human interaction with fire while trying to extinguish fire thus reducing the risk at fire-fighting.

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I.LITERATURE SURVEY

Vision based Fire Detection has been the interest of many papers published since the past few years. In [8], the authors used a mixture of Gaussian in the RGB colour space to classify pixels as being fire-coloured or not. No previous works have ever worked on a fully automated smart firefighting system. The authors in [1], have made use of the relationship between the individual colour components of YCbCr colour space by defining a relationship equation between them to identify the area in the image to be fire or not. Also, the authors here, made use of Fuzzy Logic to determine fire pixels more accurately.

The most advanced fire safety system today is developed by Stat-X Fire Suppression Systems based in the United States of America. This system incorporates the selective extinguishing action but uses Condensed Aerosol as an extinguishing element. The drawback being, it still makes use of hardware detectors for the detection of fire.
Incorporating selective sprinkler action will involve use of wireless communication for the sprinkler modules to interact with each other. For this purpose, the system of WSN (Wireless Sensor Networking) plays an important role as the architecture and the layout of the WSN system can be used for selective sprinkler action. In [7], the author has extensively explained the various WSN concepts and components. The architecture involving the nodes such as coordinator, router and end nodes was studied and used in this project for the sprinkler nodes architecture.

III.BACKGROUND AND PAST WORK

In the past, various image-processing methodologies and algorithms have been used for detection of fire pixels. Relationship between the intensity levels of the individual components of the YCbCrcolour space at every pixel's individual spatial location was used to determine the probability of a pixel being a fire pixel or not [1]. In a paper published by Walter Phillips III and rest, a very strong method of Temporal Variation and Computer Vision was used to mask the pixel that did not belong to the fire-pixel group to identify fire in images and video [2]. Also, fuzzy logic along with defining pixel intensities in the RGB and YCbCrcolour space has proven effective in identifying fire-pixels from the rest of the image/video. Whereas, I have adopted methodologies of Image Masking, Background Subtraction, Peak detection and Colour Segmentation to successfully identify fire in images and video in real time.

Wireless Sensor Networking (WSN) has been in use since a long time wherein originally, the system was used to develop a network of autonomous sensors that would monitor physical or environmental conditions and report back the data to a central or co-ordinator processor node via networked communication. In a project by Javier Solobera[3], multiple motes (sensor+wireless processor) that monitored 4 parameters, namely Temperature, Relative Humidity, Carbon Monoxide and Carbon Dioxide, were deployed in a large area. These sensors would use WSN networking to communicate the data analysed to determine if a fire has broken out in the forest or not. WSN concept originally was defined for sensors to capture data and communicate the data to a central processor with optional wireless or wired communication capability.

IV.IMAGE PROCESSING BASED FIRE DETECTION AND LOCATION EXTRACTION

The image processing algorithm used in this project was a result of multiple trial and errors. The final algorithm consists of image processing concepts such as:

- Peak Detection
- Background Subtraction
- Colour Masking
- Mean Intensity relationship between Colour Space Components
- Blob Detection

1. The colour space used in this project was the HSV (Hue-Saturation-Value) colour space as my model analyses the Saturation Intensity of each of the pixel values. Saturation in Image Processing is defined as how white the colour is. A pure red is fully saturated, with a saturation of 1; tints of red have saturations less than 1; and white has a saturation of 0 [4]. The figure below illustrates how exactly saturation can be helpful in differentiating fire-pixels from other pixels in a HSV colour scale image.

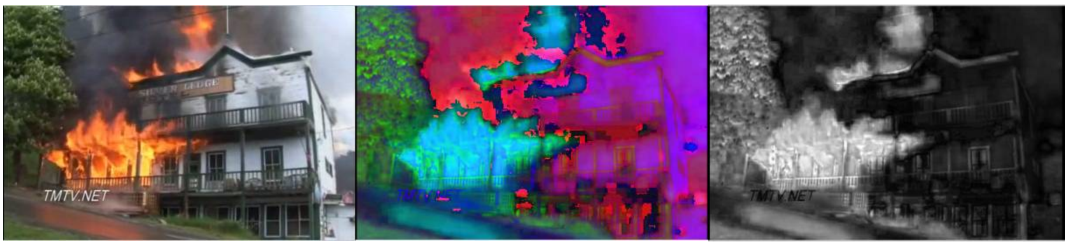

Fig1.a – Original Image; Fig1.b – Image converted to HSV; Fig1.c – Saturation component extracted

2. Pixel intensity is the amount of light or the numerical value of a pixel [5]. The next step is to differentiate the higher intensity pixels from the lower intensity pixels. By setting a threshold for the intensity value, and by using masking method, the pixels that are below the threshold defined, are masked with the pixel value 0 (black). Since fire-pixels are much brighter than the rest of the pixels in the image, an appropriate threshold will assist in capturing fire-pixels in the entire image. The figure below shows the process of thresholding the intensity and masking the pixels below the defined threshold.

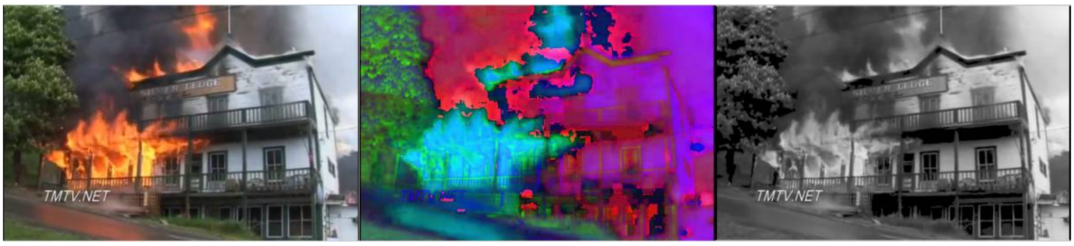

Fig2.a – Original Image; Fig2.b – Image converted to HSV; Fig2.c – Masking with Intensity threshold of 50%

3. Thus, the final outputs in the above mentioned two steps and the Fig1.c and Fig2.c; we have obtained two images that have been able to partially distinguish fire-pixels from the rest of the image. If observed carefully, in the two output images (Fig1.c and Fig2.c), every pixel in one image is a compliment of the same pixel in the second image, except all the fire-pixels.

4. A simple multiplication of these compliment images will eliminate the non-fire-pixel area completely and will output only the area that is occupied by the fire pixels. A simple conversion of the final output image to black-and-white colour space will display the exact area covered by fire-pixels

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Fig3. The multiplication of the first two compliment images results in fire-pixel detection. The last image is BW converted of the result image.

5. Location tracking of the detected fire is done in the 2-Dimentional plane. The algorithm of Blob Detection is used for this location tracking. A Blob in image processing means a group of connected pixels. Blob detection is performed only on binary images. As seen in the Fig3, the final output of fire detection algorithm is a Binary image. The algorithm of Region Properties is then applied to the output of Blob Detection to get the location of the fire in the 2-Dimentional plane. The figure below shows the output:

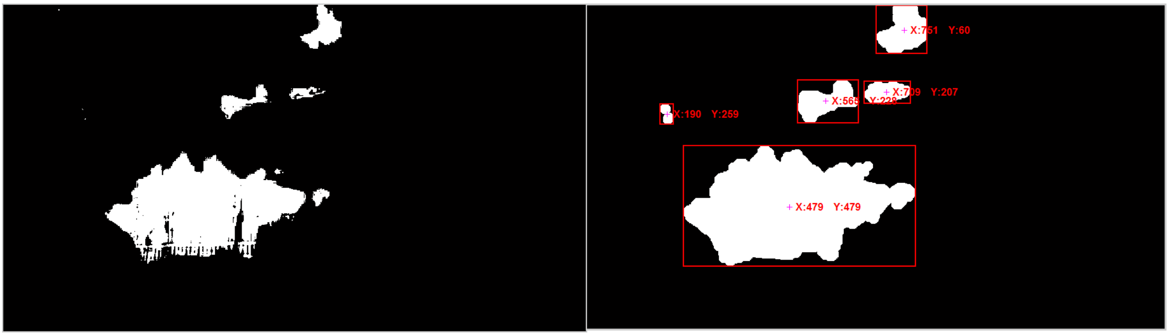

Fig4. The first image is the binary converted image and the second image shows the location of the fire in X-Y coordinates

V. WIRELESS SPRINKLER NODES AND COMMUNICATION WITH CO-ORDINATOR NODE

The platform used in this project for communication between the co-ordinator node and the wireless sprinkler nodes is majorly based on the Wireless Sensor Networking (WSN). A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions. A WSN system incorporates a gateway that provides wireless connectivity back to the wired world and distributed nodes [6]. The protocol I used in this project for communication was ZigBee protocol. A ZigBee protocol consists of a Co-ordinator Node, a Router Node and an End-device Node. I made use of the Star network topology. Refer to the diagram below:

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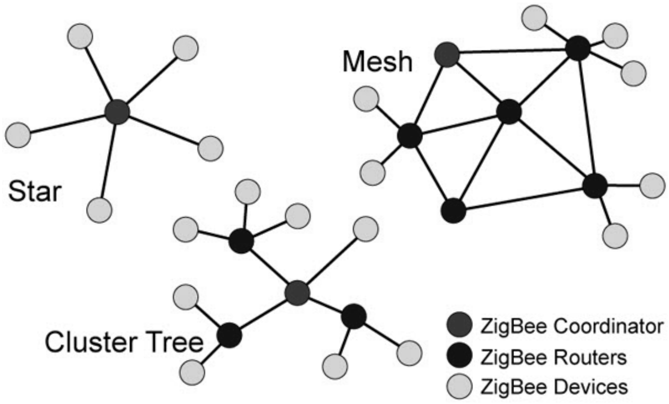

Fig5. The ZigBee Protocol Network Topologies [7]

The Star topology served perfect as I just required one-to-one communication between the Co-ordinator node and the end devices. The main processor fetching results from the image processing algorithm, along with a zigbee S2 module, served as the Co-ordinator node. Whereas, the Sprinklers along with a processor and a zigbee of their own; served as the End-device nodes. An electronically operated valve was used at every end-node to trigger the water sprinklers. The block diagrams of the Co-ordinator node and the End-Node are shown below:

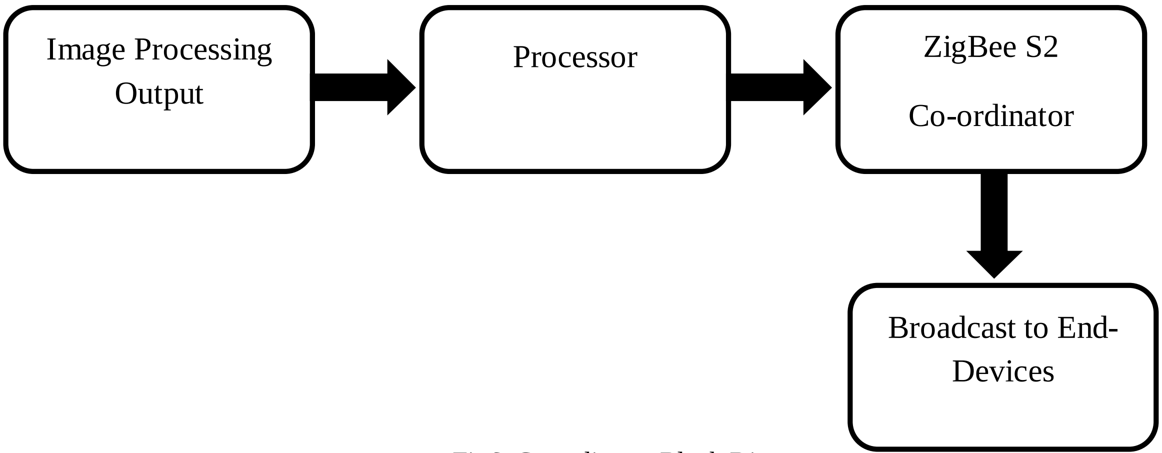

Fig6. Co-ordinator Block Diagram

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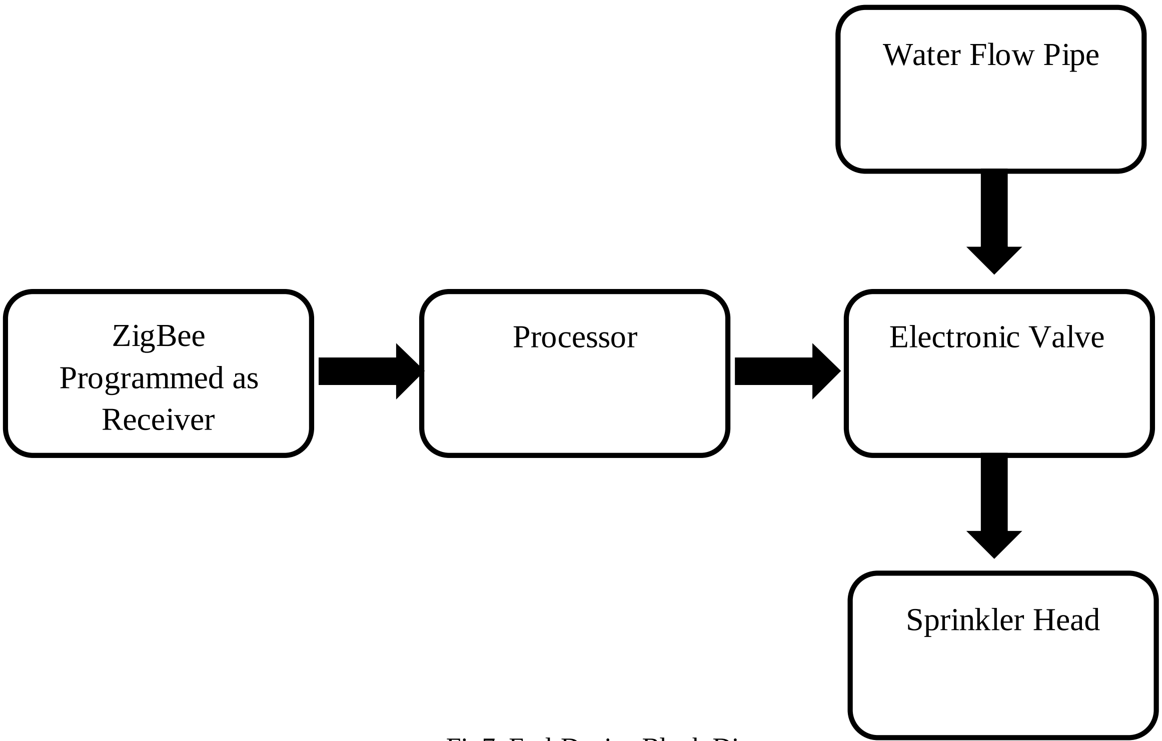

Fig7. End-Device Block Diagram

1. The Co-ordinator node:

The co-ordinator node consists of controller connected to the image processing algorithm and a zigbee module. The image processing algorithm obtains the location of the fire detected using Blob Detection algorithm; as shown in Fig4. The controller is connected to the image processing algorithm Serially. Using serial communication, the location co-ordinates of the fire, in X-Y domain are transmitted to the controller using the Com-Port serial communication. The baud-rate specified for this serial communication needs to match the baud-rate of the controller. The Zigbee S2 module used in this project communicates with the controller using serial communication as-well. The processed location co-ordinates are communicated to the zigbee, which then broadcasts these location co-ordinates to the End-Nodes.

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The flowchart for the Co-ordinator node processing is shown below:

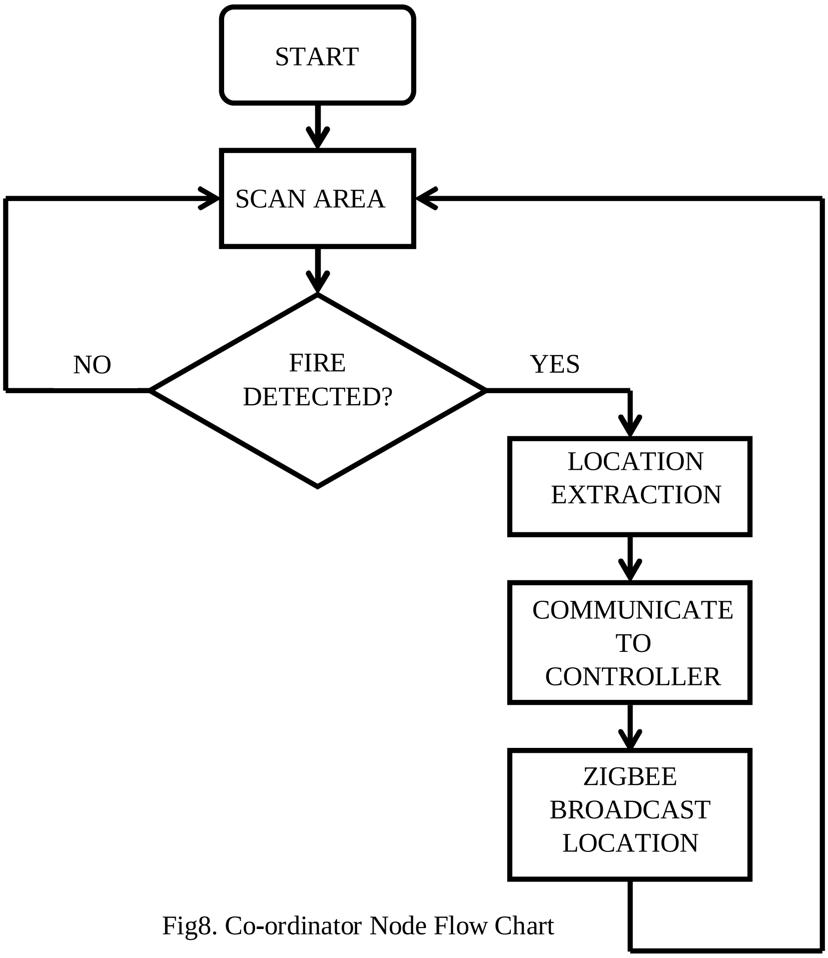

Fig8. Co-ordinator Node Flow Chart

2. **ZigBee Communication:**

The Zigbee communication protocol operates in the 2.4GHz unlicensed band. The maximum data-rate in the 2.4GHz band is250kbps. I have made use of the Zigbee S2 modules in this project. For these zigbees to be able to communicate with each other, these zigbees need to be configured to have the same exact PAN IDs. Also for the end-node zigbees to receive data from the co-ordinator node, all the zigbees in the network have to have the same baud rate. Using any zibgee configuration software, these zigbees need to be updated as Co-ordinator or Router or End-device. In my project, I have only made use of Co-ordinator Zigbee and End-Device Zigbee.

3. The End-Device Node:

The end-device node consists of a zigbee module configured as a receiver. This module is connected to a controller and communicates using serial communication. The data broadcasted by the co-ordinator node is received by this receiver zigbee as it is configured with the exact same PAN ID as that of the co-ordinator node. This data is then communicated to the controller via serial communication for further processing.

The controller present in the End-Device, processes the data received from the zigbee. This data is the location co-ordinates of the detected fire. Every controller is programmed with a specific range of location co-ordinates which are covered by the sprinkler connected to that controller. The controller processes the X-Y coordinates and compares it

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with the location co-ordinated programmed into it. If the location of the fire lies within the location specified within the controller, the controller turns on the electronic valve; which in-turn sprays water. If the location co-ordinates do not match, the controller neglects the data and awaits further data from the zigbee. The image processing algorithm also monitors when the fire has been extinguished. Thus, if the zigbee receives data of fire being extinguished, the electronic valve is turned off thus stopping the sprinklers from spraying water.

The Flowchart for the end-device node is as follows:

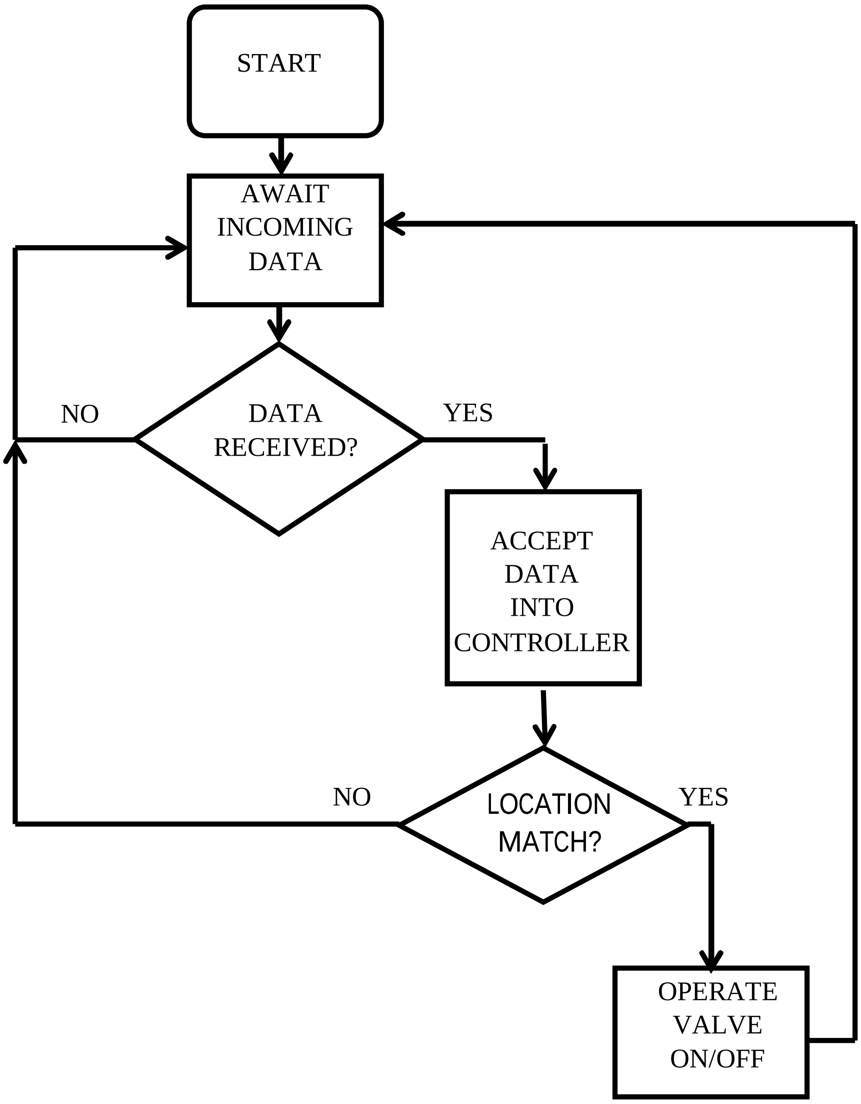

Fig9. End-Device Flow Chart

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VI. RESULTS

To carry out a demonstration of the concept of this project, a simple assembly involving the following apparatus was set up:

1. A computer running the Image Processing algorithm.
2. A 5MP camera attached to the computer to monitor the area under observation.
3. A 2-sector area was developed to imitate the different locations under observation.
4. A Co-ordinator node receiving Serial communication from the Image Processing algorithm
5. Two Wireless End-Device Sprinkler nodes to spray water over the two regions under observation.

The Demonstration:

The figure10.a below shows the full project apparatus setup. The apparatus includes a camera viewing over 2 sectors marked by numbers “1” and “2” respectively. These sectors represent two areas under observation to monitor for fire bursts..

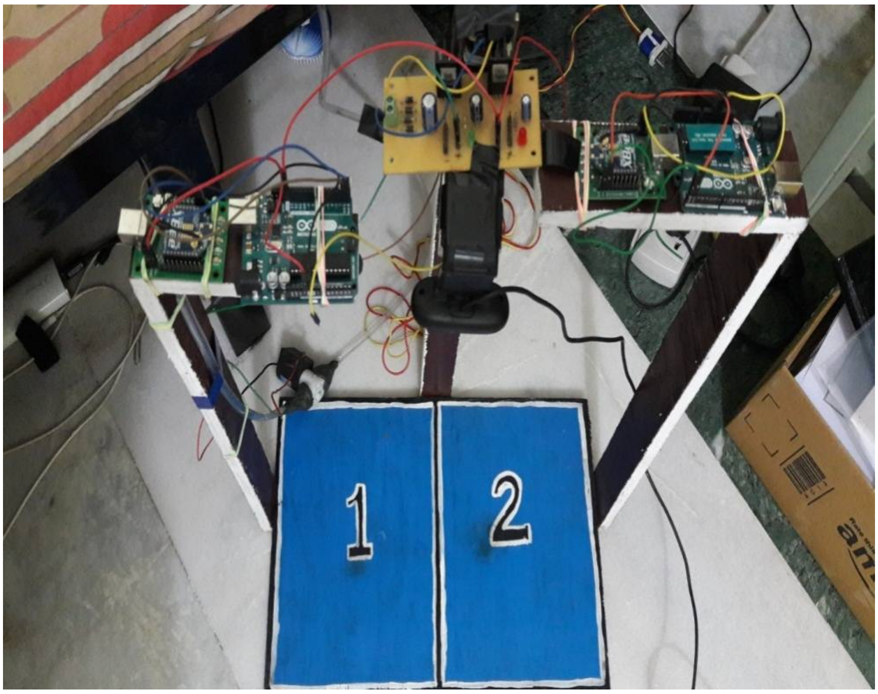

Fig10.a – The apparatus setup

The figure10.b shows starting of the demonstration by lighting a small fire in the Sector 1. The frame is as captured by the camera that is used to monitor these areas.

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Fig10.b – A Fire is lit in Sector 1.

The figure10.c shows the output of the image processing algorithm. The fire in that was lit in sector 1 is detected by the image processing algorithm and location in X-Y coordinates is also displayed.

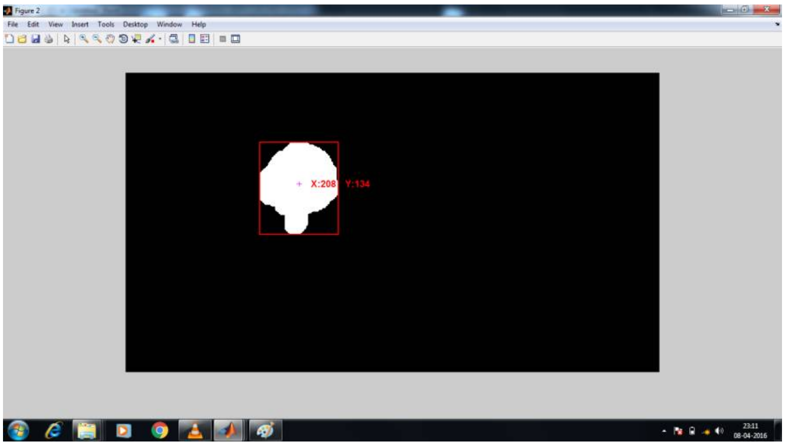

Fig10.c – The Fire is detected by the image processing algorithm and location co-ordinates are extracted.

The figure 10.d below shows notifications given my the image processing algorithm that notifies the user that a fire has been detected in Sector 1.

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Fig10.d – The algorithm also outputs a string notifying of fire in sector 1.

The figure 10.d shown below, shows the phase of the project where the sprinkler, operated by an electronic valve is activated and water is sprinkled on the fire. Thus extinguishing the fire.

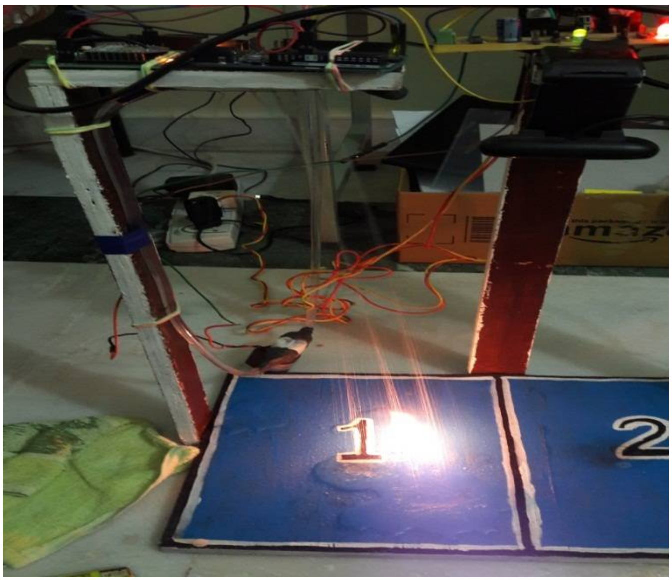

Fig10.e – The Wireless End-Device Sprinkler is automatically started via wireless communication from the co-ordinator node.

VII. CONCLUSION

The image algorithm is successful in detecting an occurrence of fire in real time. The image-processing algorithm is also successful in determining the exact location of the fire and has effectively obtained the location in X-Y plane by tracking the fire. The Wireless-communication has also been able to quickly analyse the results of the image processing algorithm and has effectively turned the sprinkler ON and OFF by observing the burst and extinguishing of fire, respectively.

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This project has positively given a firm alternative to the existing fire-extinguishing systems by being completely automated and has also been helpful towards water-saving. This concept can thus prove helpful in limiting the human interaction with fire while extinguishing fire to the minimum. Along with providing a strong alternative to the existing system, this project also leaps into the future of technology by making use of Image Processing over conventional fire detection sensors to detect and extinguish fire, self-sufficiently.

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