



## **Real Time Video Surveillance System for Fire and Smoke Detection Based on Wavelet Transform**

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### **Abstract**

Fire detection processing technique for Video Surveillance Systems (VSS) has attracted the interest of a lot of researchers because of its crucial value in various applications in our daily life. In this research work, a real time video surveillance system for fire detection based on wavelet transforms is proposed. It aims to design and implement fire detection in a spatial and wavelet domain domain. The input video is first extracted into frames and then the motion detection algorithm for the change detection is applied to separate moving objects from the static objects. Test results of the proposed fire and smoke detection methods at different distance from one to ten meters indicate that the accuracy of the system for frames with performing contour algorithm (average accuracy for (1-10) meter is equal to (99.46%). On the other hand, in a frequency domain the system has a better performance for detecting energy of fire than a smoke.

### **Introduction**

Video Surveillance Systems (VSS) and their applications are very important in our daily life; these applications exist in airports, banks, offices and even in the houses to keep home keepers secure. The VSS currently experience a modification where more and more traditional analog solutions are being replaced by the digital ones. The Digital Video Surveillance (DVS) offers much better flexibility in video content processing and transmission compared to the traditional analog. Moreover it can easily implement advanced features such as motion detection, fire and smoke detection [1]. Basically smoke and fire detectors typically detect the presence of certain particles generated by smoke and fire by ionization or photometry. A main weak point of detectors is that they are distance limited and fail to work in open or large spaces. The crucial point of using video in fire detection is the ability to monitor large and open spaces. At the present time fire and flame detection algorithms are based on the use of color and motion information in video. Wavelet transform is a time-frequency analysis tool and one can examine an entire frequency band in wavelet domain. It is ideally suited to determine an increase in high-frequency activity in some fire and flame colored objects. In addition, turbulent high-frequency behavior exists not only on the boundary, but also inside a fire region. Spatial wavelet analysis can easily detect high-frequency behavior inside a fire region [2].

In order to detect and eliminate fire at very early stage, during the past decades, different kinds of technologies are developed by researchers. However, traditional methods usually depend on heat sensors, optical sensors (ultraviolet, infrared), ion sensors, or thermocouples. These sensors suffer from the transport delay of the fire (heat or smoke particles) to the sensor, and cannot work

effectively if the fire is far away. Moreover, these sensors cannot provide the situation and development of the fire for validation and rescue. With the increasingly wide usage of video surveillance systems, in recent years, video based fire detection technologies received many attentions from researchers. Smoke is usually generated before flames and can be observed from a great distance, it is an important sign for early fire detection. Since the video camera can accomplish real-time monitoring in a large range, the smoke of uncontrolled fire can be easily observed by it. Therefore, video based technologies are much more competent in fire detection especially for large and open areas [3].

The problem statement behind this work is that there are approximately 278 million deaf of hearing impaired people worldwide. While they are sleeping, what are the chances that they wake up during a fire by a flashing strobe light? 23% [12]. Also, all fire alarm systems for the deaf are very elaborate and require a full reinstall of a system and become very expensive. In this case the person can use the mobile phone vibration mode while they are sleeping.

The main goal of this work is to propose an effective fire detection system and develop such system based on wavelet transformation. The digital camera will be used for detecting a large area with a large distance from the camera. The system can help people with hearing problem by alerting them through Android mobile devices when the mode vibration is activated. To evaluate the performance of the proposed scheme, the real time capture video and offline videos are tested to find out the accuracy for both smoke and fire detection.

The rest of the paper is described as follows: Section I gives some recent related works. In section II a fire detection system steps is presented. Sections III and IV describe test samples that are used throughout this work and obtained test results respectively. Finally in section V some conclusion is given.

## **II Related Works**

Fire detection systems are one of the most important parts in surveillance systems which are used to monitor buildings, environment, forest, factory as part of an early warning mechanism that reports ideally the start of fire and damages. Researchers in this area began to think about the implementation of the fire detection algorithm which can resist some kind accidents and damages that caused by fire events. The advantage of using video in fire detection is the possibility to monitor large and open spaces. Current fire and smoke detection algorithms are based on the use of color and motion information in video [4]

The fire and smoke detection in a large area using camera to capture a digital video frames is proposed based on a novel method to detect fire and/or flame by processing the video data generate by an ordinary camera monitoring a scene [2]. The fire is detected based on either the color range of the fire [5] or on the shape of the fire [6].

Automatic fire detection methods which are studied in color domain, spatial domain and temporal domain investigated fire and flame colors of pixels [7]. Performance of this system is given according to different thresholds and different features. A real-time detection system that uses information in color, spatial and temporal domains is proposed for videos [8]. High-frequency analysis of moving pixels (HL, LH and HH) is carried out in wavelet domain. Wavelet transform is a time-frequency analysis tool and one can examine an entire frequency band in wavelet domain [9, 10]. Hence, it is ideally suited to determine an increase in high-frequency activity in some fire and smoke colored objects. A hybrid method for fire detection in the forest based on extracting the contour of the fire or smoke is proposed in [11]. In this method of video based fire detection, wavelet was usually used to test whether a pixel belongs to fire region, while Fast Fourier Transform was used to describe the contour of fire area.

## **III Proposed Fire Detection Algorithm**

In this research an effective fire detection system is proposed and developed based on wavelet transformation. Fire detection algorithms for detecting fire in the real time or recorded video are used. The camera will be used for detecting a large area with a large distance from the camera. The system can help people who have hearing problems by alerting them through Android mobile devices when the vibration mode is activated. In this section the design and implementation steps are presented through the flowchart.

The video data could be either online or offline based on the test strategies. The input video is first extracted into frames and then converted from RGB color space to the HSV space then it is converted to binary images. The motion detection algorithm for the change detection is applied to separate objects in movement with the static objects. Then fire or smoke is separated in the motion objects based on the color range. And then, the wavelet transform is applied to the binary image to find out sub-bands image (LL, LH, HL, and HH) from the original frame. Finally the energy for each band is calculated. The general block structures of the proposed fire detection scheme are shown in Fig 1.

**A. Motion Detection**

After taking the extracted frames from the camera or input video files, a method based on finding the big contour is used to detect objects in movement in successive frames. Contour filter is one of the most important methods that are used to detect tumor region in digital image. This filter is used to remove smaller objects (noise) and extracting only the biggest objects. This leads to separate the frames with biggest contour from the frames that have small contours. The flowchart of the motion detection algorithm for fire detection with the biggest contour frames is shown in Fig 2. The system decides that whether frames are fire or smoke depending on the color range of it.

**B. Post Prospecting Algorithms**

During the processing of fire or smoke detection, frames normally contain some noise or undetected objects. Thus, some post processing methods can apply on these frames to remove the noise. Here cvSmooth and cvErode are used in this research; these methods are taken from Opencv version (2.4.8) library.

**C. Fire Detection in Wavelet Transform**

After a brief explanation of how the fire and smoke are detected in the video (real time or offline) in the spatial domain, the fire and smoke are also detected in a frequency domain. In this research the simplest type of wavelet transform algorithm (Haar wavelet) is used to calculate the energy of both fire and smoke.

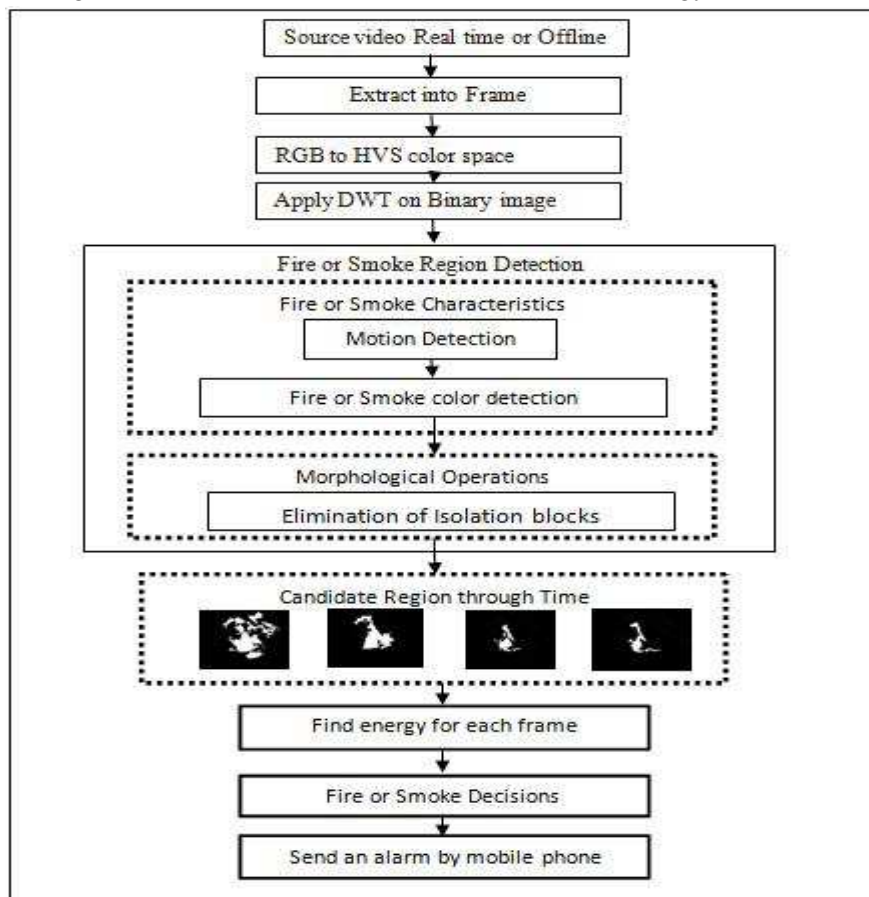


Figure-1: Proposed scheme general diagram

After converting the frame to square size, it is ready to apply discrete wavelet transform algorithm on them. This technique is applied on binary frames in two steps, in the first step the wavelet is applied on frames for dividing them to four sub-bands (LL,HL,LH,HH) and then determines the objects of frames in the band (LL) which represents the approximation of the object. The second step is to apply the wavelet to determine the energy of objects in the other bands (HL, LH, LL). The flowchart of the proposed method in a wavelet domain is illustrated in Fig 3.

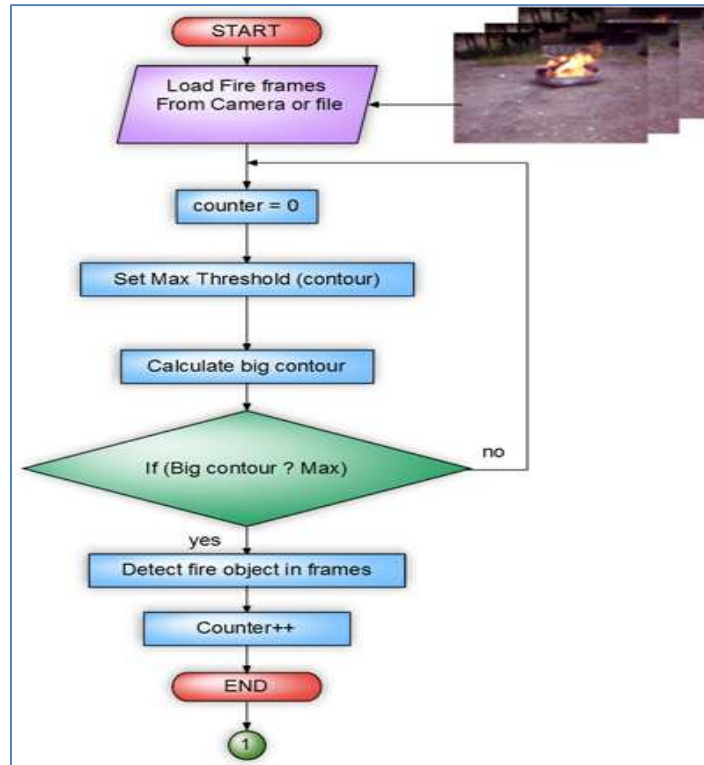


Figure-2: Flowchart of fire frames with biggest contour

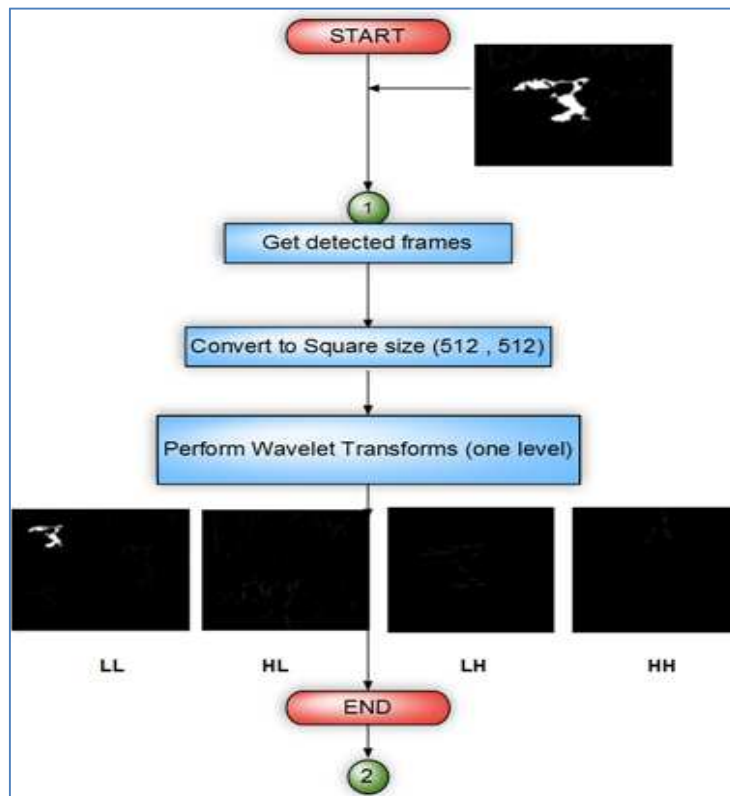


Figure-3: Flowchart of wavelet transforms on detected fire frames

**D. Energy Calculation**

After detecting objects in frames by applying wavelet transform technique the energy value for each sub-band is calculated by a specific mathematical equation. Then, the total energy of each frame is determined. This energy as given in eq. 1 is used to decide whether this frame contains fire, smoke or not. Fig 4 shows the flowchart of energy calculation:

$$wn(x,y) = /LHn(x,y) /^2 + /HLn(x,y) /^2 + /HHn(x,y) /^2 \tag{1}$$

Where, n is number of wavelet transforms levels (one or two level of decomposition).

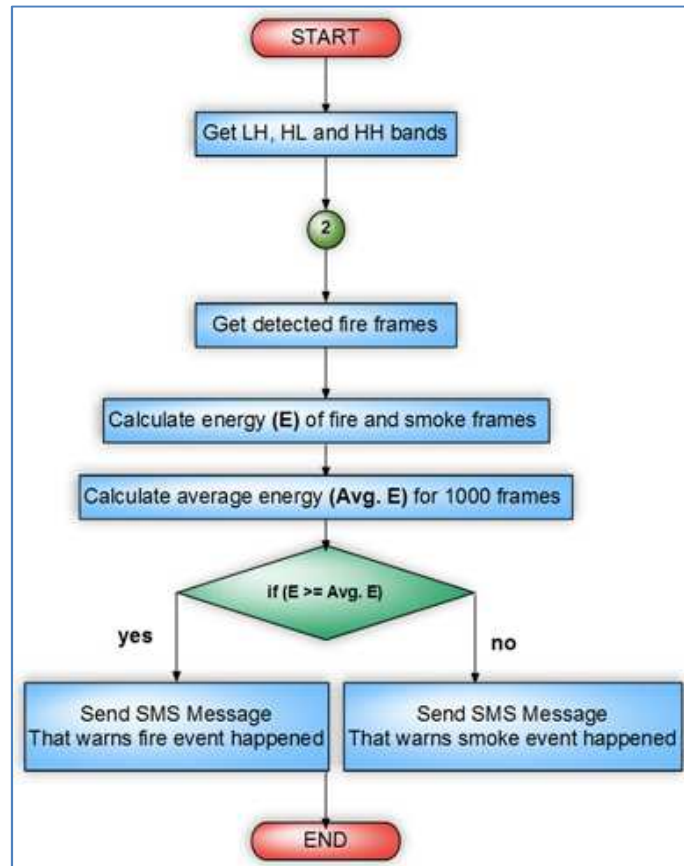


Figure-4: Flowchart of wavelet energy calculation

**IV Test Samples**

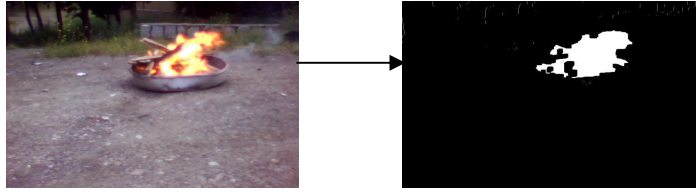
In this section some test samples are shown for both smoke and fire with and without using contour algorithm which are taken by us using a digital camera.

**1. Real time video sample (Fire with contour)**

Table 1 and Fig 5 present a sample of a fire frame properties and its image contour respectively.

Table-1: Fire Detection (Fire with contour)

Property	Value
Length	Online
Frame Width	640
Frame Height	480
Frame Size	86.4 KB
Distance from Camera	3 Meter
Frame Rate	30 frames/second



Figur-5: Real time Fire Detection (Fire with contour)

**2. Offline video sample (Fire with contour)**

Table 2 and Fig 6 present an offline sample of a fire frame properties and its image contour respectively.

Table -2: Offline Fire Detection (Fire with contour)

Property	Value
Length	Offline
Frame Width	1280
Frame Height	720
Frame Size	180 KB
Distance from Camera	10 Meter
Frame Rate	30 frames/second

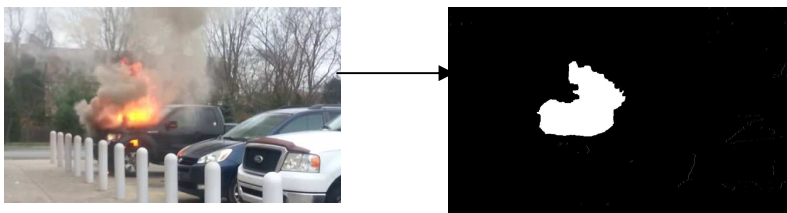


Figure-6: Offline Fire Detection (Fire with contour)

**V Test Results**

The result of Fire Detection Method is the combination of fire detection and wavelet process, which gives an improvement in detection rate. The performance test results of proposed FDM were evaluated by tuning some of the involved parameters such as color and distance of the fire from camera. These parameters affect the system accuracy in spatial and frequency domain as well. The efficiency of the proposed FDM was evaluated using detection rate. The programming language, Java and Microsoft Visual Studio 2012(VC#) with OpenCV 3.0.0 Library, were used as development tools to construct required program, tested on Windows 7 Enterprise, Lenovo-PC (Intel(R) CoreTmi5 CPU, 2.30 GHZ processor and 4.0 GB installed memory), Sony Ericsson mobile phone with GSM Android system and (comm.jar) file of Library was also used.

**1. Fire detection at different (10 meters) with contour**

1000 frames are taken for every meter to find the accuracy detection for these different distances. Table 3 shows the accuracy of the system with changing the distance of the fire, and Fig 7 shows the result of the accuracy of detection of the fire with the frames. The accuracy percentage (eq.2) is calculated from true positive (TP) object, which represents the fire in the frames, and false positive object (FP) which represents the fire as another object in the frames. TN and FN represent the correctly and incorrectly rejected the fire or smoke respectively.

$$\text{Accuracy} = (\text{TP} + \text{TN}) / (\text{TP} + \text{FP} + \text{FN} + \text{TN}) * 100\% \tag{2}$$

Table-3: Accuracy of Fire Detection System with contour according to distance

Distance(meter)	TP	FP	Accuracy
1	1000	0	100%
2	992	8	99.20%
3	990	10	99.00%
4	988	12	98.80%
5	995	5	99.50%
6	998	2	99.80%
7	1000	0	100.00%
8	988	12	98.80%
9	995	5	99.50%
10	1000	0	100.00%

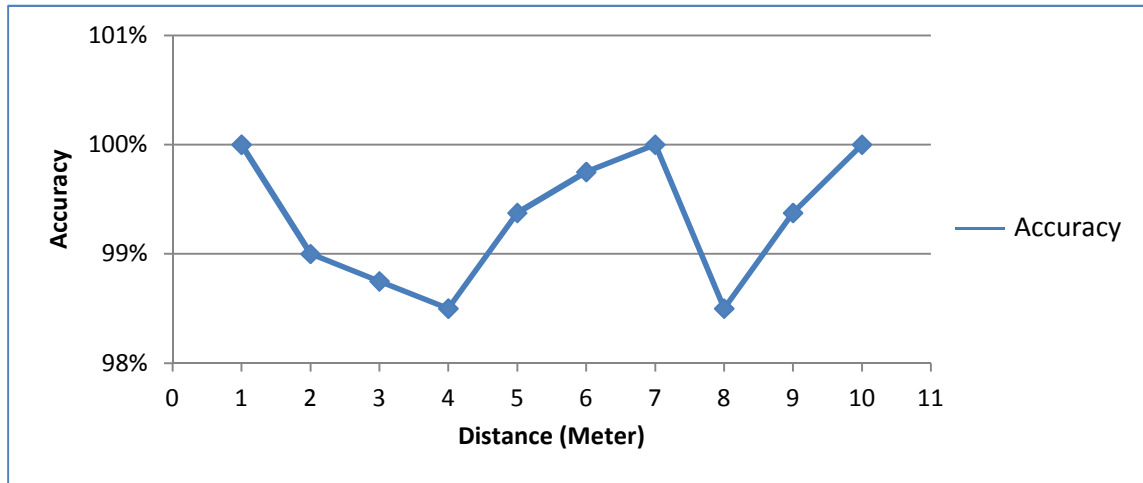


Figure-7: Accuracy of FDS according to the distance

**2. Fire detection at different distances without contour**

Table 4 shows the accuracy of the system with changing the distance of the fire, and Figure 8 shows the result of the accuracy of detection of the fire with the frames without applying contour filter.

Table-4: Accuracy of FDS without contour according to distance

Distance(meter)	Tp	FP	Accuracy
1	840	160	84.00%
2	890	110	89.00%
3	891	109	89.10%
4	783	117	78.30%
5	772	228	77.20%
6	689	311	68.90%
7	695	305	69.50%
8	672	328	67.20%
9	700	300	70.00%
10	702	298	70.20%

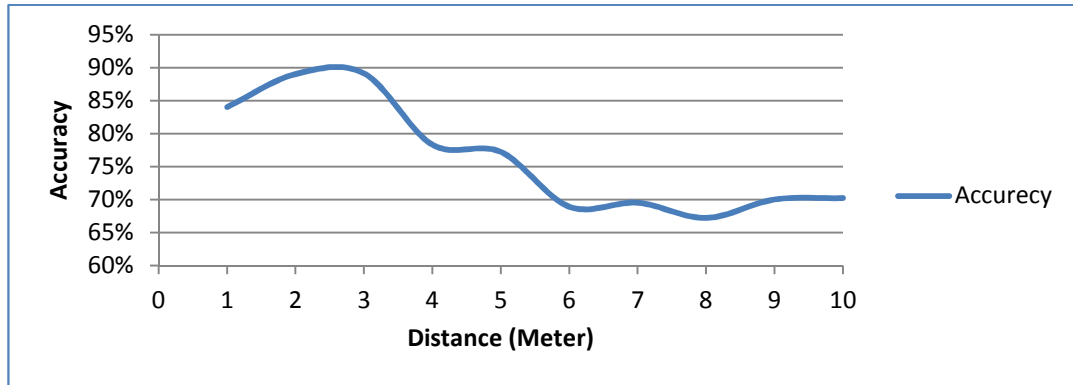


Figure-8: Accuracy of FDS without contour according to the distance

### 3. Energy Calculation for Fire and Smoke

The aim of this section is to separate the fire or smoke objects from other objects in the video frames. This process is done through the calculation of the energy of wavelet bands. According to the amount of energy, the system decides whether the object is smoke or fire. This leads the system to warn the company or any establishment by sending an alarm through a message using mobile phone devices.

#### a. Fire Energy with Contour

Table 5 shows the Average energy (as shown in eq.1) of the system with changing the distance of the fire from one to ten meters when the number of frames is equal to 1000 with contour.

Table-5: Average energy of fire frames with contour

Distance (m)	Average fire energy
1	1067957.36
2	831097.38
3	594727.045
4	328839.53
5	258218.583
6	335637.621
7	111782.903
8	69683.456
9	102569.434
10	268962.002

#### b. Smoke Energy with Contour

Table 6 shows the Average energy of the system with changing the distance of the smoke from one to ten meters when the numbers of frames are equal to 1000 with contour,

Table-6: Average energy of smoke frames with contour

Distance (m)	Average smoke energy
1	325522.634
2	417137.949
3	301905.181
4	290464.688
5	482194.429
6	190969.136
7	288087.857
8	296398.21
9	443373.944
10	127078.836

Figure 9 shows the result of the average energy of the extracted frames to fire and smoke.

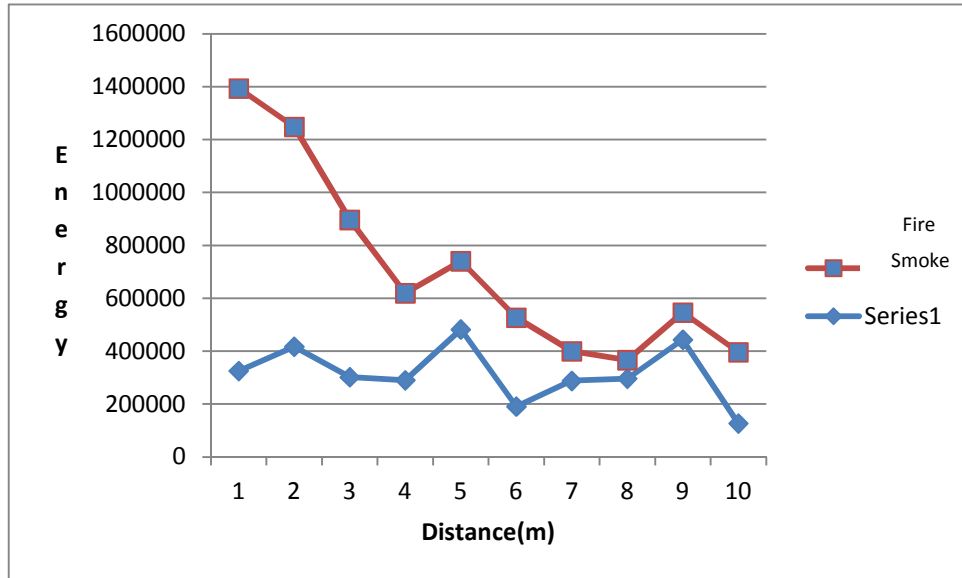


Figure-9: Fire and smoke energy with contour

## VI Conclusions

In this research, the fire and smoke detection processes for the real time video and recorded video file (offline) are studied. In addition to that some improvements are proposed to enhance its performance in terms of accuracy detection. The test results show that a better performance is achieved when the wavelet transform is applied for the fire and smoke detection with performing contour algorithm.

1. The proposed scheme concludes that by applying the FDS and SDS frames with or without contour parameters, the accuracy values vary as follows:
  - a. When there is fire with contour, the average accuracy=99.46% for the real time video.
  - b. When there is fire without contour, the average accuracy=76% for the real time video.
  - c. When there is smoke with contour, the average accuracy=99.39% for the real time video.
  - d. When there is smoke without contour, the average accuracy=93.43% for the real time video.
2. Experimental results show that the accuracy of smoke detection does not significantly change with and without applying contour selection algorithm.
3. Experimental results show that the system has better performance for calculating energy for fire than smoke.

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