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Real Time Fire Detection System with Image Processing

Min Thu Soe*, Thein Oak Kyaw Zaw, and Wong Wai Kit

***Abstract* - Fire detection system by image processing is a growing research field in this era. There are many methods used to detect fire out, but still need to develop an accurate method to detect fire without false alarms. This is due to the fact that many methods used RGB colour mode for detection. In this paper, mainly focus on detecting the fire effectively using thermal video from a thermal camera while in the same time the system will alert the people if fire was detected, and also observed the speed of the fire. This will enormously benefit to the fire fighters. With this system, the fire can be detected effectively while alerting the people and giving valuable information to the fire fighters for their job more effectively.**

Keywords— Fire Detection, Image Processing, Thermal Video, Fire Speed.

I. INTRODUCTION

Over the years, image processing has been used quite extensively in researches for fire detection. Yong et al. [1] stated that it is due to the fact that sensor-based detections are more expensive than a video-based fire detection technology. Fire detection system using video is less affected with the distance. It is because the camera will capture the live video from a distance and will process it. It doesn't matter the distance is near or far, because the changes are only the size and the intensity of the color. Furthermore video-based fire detection system is more appealing on the limited effectiveness and high false alarm rates of other conventional fire detection system. Most of the conventional fire detection systems use smoke sampling, particle sampling and temperature sampling. All of these methods have high false alarm rates [2]. These are the main reasons on why many researches are shifting to video-based fire detection system. The other reasons are due to video-based fire detection system offers lower cost, high effectiveness and less affected by distance.

There are many types of cameras in the market but for the fire detection, a specific camera needs to be chosen which will make the fire detection easier, faster and more accurate. Thermal camera was the best choice because it is resistive against the influence of airflow [3][4]. This is due to the fact that normal airflow will not show too many changes in the thermal video because of its low temperature. There will be changes in the video only once the temperature is quite big. Furthermore, thermal video removes another disadvantage of a normal conventional camera which is the influence of smoke [3][4]. When there are a lot of smokes, the vision becomes obscure and thus will create false alarms as the smoke hides away the fire. Normal conventional camera usually uses RGB colour

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model. Although the usage of RGB is famous in video-based fire detection, but it come with a price to be paid.

Çelik et al. [5] stated that video-based fire detection system that uses RGB color model in its detection creates a high false alarm rate. So YCbCr is more preferable and used more due to its ability to distinguish luminance and chrominance information.

Thermal video from a thermal camera is still the best because the fire can be seen clearly and influence of smoke can be eliminated. This makes the detection easier, faster with higher efficiencies.

A lot of video-based fire detection system uses color information in its processing step. Phillips III et al. [6] used information from the color and temporal variation of a small subset of images to recognise the fire in the video. A manual segmented fire was also used in training the system to recognise fire color pixels of the fire. A look-up table was used formed using the training set.

Chen et al. [7] used chromatic and dynamic features of the video to recognize the real smoke and fire. Moving object will be employed with an algorithm in the preprocessing phase. Then the components will be filtered with fire and smoke filter to raise an alarm if fire is detected throughout the process. In making of the filter, a generic fire and smoke model was used. A detection process can be more complicated when color and motion were involved.

Parkhi and Verma [8] proposed a real-time algorithm to detect fire in the video sequence. Motion and color information as well as the fire flicker analysis on the wavelet domain were combined. Parkhi and Verma [8] also proposed another algorithm that combines RGB color space, motion information and also Markov process with a training set. With it, analysis for fire flickering was enchanted and the system is more reliable and accurate in its detection.

There are many problems can come from video-based fire detection. Some of them are the lighting conditions, low video quality, complex scenery and also poor processor performance [9][10]. Marbach et al. [10] stated that flexibility need to be great and reliability need to be high, to reduce the false alarm rates. CCTV can be used as the camera, and temporal accumulation from time derivative images, to recognise and identify the fire region. The fire alarm will be turned on if the fire pattern persisted for a critical time.

An edge detector will be needed to identify the fire block. Although there are many edge detectors, canny edge detector is used for identification process. This is because the Canny algorithm will perform hysteresis thresholding [11] which makes it low error rate. Even though it will require high computing, it has remained a standard for many years. Moreover, canny edge detector has the best performance among all other the edge detectors [11][12].

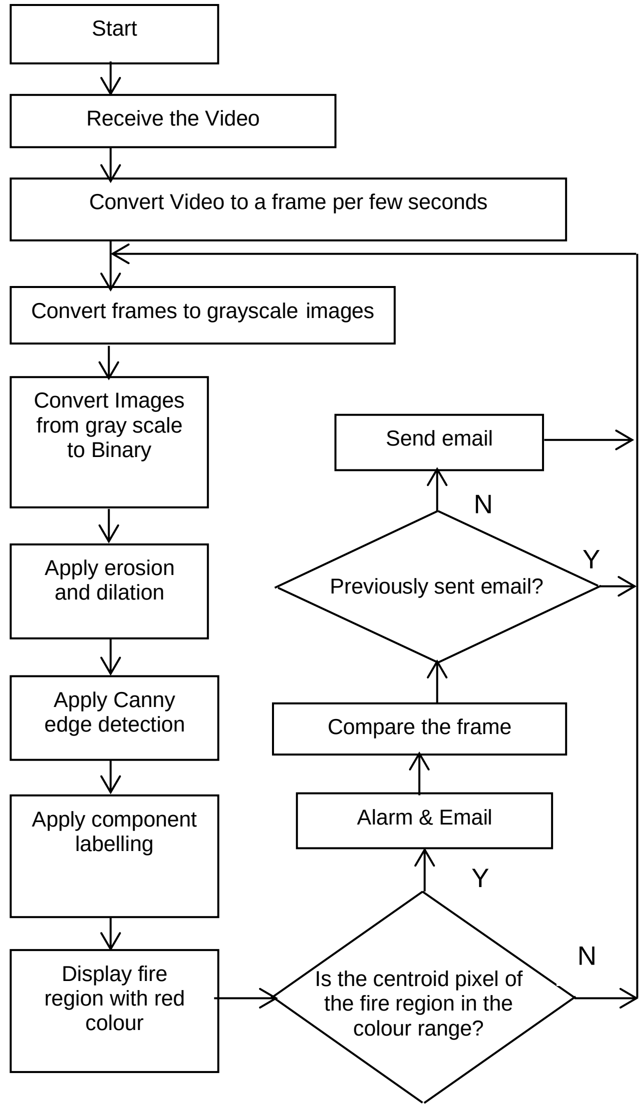


FIGURE 1. Program flowchart.

II. Research Method

The thermal camera will supply the thermal video which will send to the PC direct once the program will run. Afterwards, speaker will give the alarm sound if fire is detected.

The input is thermal videos. Alarm and email are the outputs to alert the fire. First, the speaker was used to alert the people nearby or the people inside the building. Second, an email will be sent to the fire department along with the size of the fire as from detection. This will make the fire fighters to react faster and know the size of the fire that they will be dealing with.

Figure.1 shows the flowchart of the program in detail. The program will convert the video into a frame per few seconds once received the thermal video file. The number of frames can be set later according to suitability of the environment. All those frames will be converted to grayscales images and afterwards it will be converted to binary. This process is to make certain the fire region will be apparent while the background will be eliminated. Only after that, erosion followed by dilation will be applied to the frames. Erosion and dilation are to remove the unwanted noises in the frames. After the unwanted noises have been filtered out, canny edge detection will be applied. This edge detection will ensure that the fire component can be labelled as an object.

Afterwards, component labelling is applied to label the fire region as an object of interest. In this component labelling, the biggest block will be selected as the possible fire region and will be shown in red colour in the GUI. With this possible fire region selected, a secondary check will be applied on it. This is to ensure that the region is really the fire region and not the false region. To do this, the program will check the centroid pixel of the region and see if it is in the fire colour range. If it is in the colour range, without any further delay, the alarm will be turned on.

During the alarm is on, frames will be analysed to figure out the speed of the fire whether it is small, medium or growing big. After the size has been confirmed, an alert email will be sent to the authority. The content of the email will include the location of the place and the size of the fire. The email will be sent only once to avoid spamming of emails at the receiver's side. Afterwards, the program will keep on looping so that alerting and monitoring the size of the fire will keep ongoing. No extra emails will be sent afterwards.

A. Speed and Size of Fire

Speed and size of fire is crucial information for the fire fighters. From that information, they can prepare the materials and the resources needed to face the fire. Speed of the fire can be translated or have the same meaning for the size of the fire. If a person says a fire is spreading fast, it means the size of the fire is getting bigger in a fast pace. That is why speed and size in term of fire means the same thing.

In this project, the size of the fire is calculated using ratios. Equation (1) shows the general equation used in ratio calculations. The ratio is achieved by dividing the current fire size with the previous one. All the ratios will be saved in the second table up to maximum of 10 values.

$$\boldsymbol{ratio_n} = \frac{Current\ Fire\ Size_i}{i-1} \tag{1}$$

Each time a fire is detected, the size of the block will be recorded. There will be two lists of data for calculations. The first one will be the list for area of the fire while the second one will be the ratio of the areas for previous and current. At first, when the fire is detected, the size will be saved in the first list and also in the second list as a ratio. The first case will have a ratio of 1 as it divides by itself. As more data comes in, the list becomes longer. Only after 4 data has been received, then only the size of the fire will be determined. A limit was set to have maximum of 10 ratios to reduce the processing and memory needed for the calculations.

$$\boldsymbol{Fire\ Size} = \frac{\sum \boldsymbol{ratio}}{\boldsymbol{n}} \tag{2}$$

Equation (2) is used to determine the size of the fire. Total sum of ratio value will be divided by the total number of ratios. If the fire size is less than 1.5, a message will be shown stating that the fire is enlarging slowly. If the result is less than 1.8 but bigger than 1.5, a message will be stated as the fire is enlarging in medium speed. While for the range that is bigger than 1.8, a message will be stated as fire is enlarging rapidly. When the total ratio is divided by the number of ratios, the number will be higher than 1 because the fire gets bigger, the fire size value will increase. Fire size value 1.8 means that the size of the fire is getting bigger almost twice of the earlier size.

B. Test Methods

There are a lot of factors affecting the test. One of these is the video quality. Most of the videos were taken from the internet so each video has different quality. The noise for each video and the environment is also different. This can affect the efficiency of the detection itself. Equation (3) is used to test the efficiency.

$$\boldsymbol{E} = \frac{\boldsymbol{NCF}}{\boldsymbol{TNFT}} \tag{3}$$

Number of corrected frames (NCF) will be divided by the total number of frames tested (TNFT).

NCF means the frames that detected the fire correctly. The program will capture a frame every X millisecond. The number X will be set in the program itself. When X decreases, the program will capture more frames due to the short interval. That is why number of frames tested will increase as X decreases.

For the testing, each video will be tested few times by varying the threshold, noise filter strength and the frame rate to reach maximum efficiency for each environment. The environment and noise level for each video are different. Thus, it requires adjustments in the settings to reach maximum effectiveness. Whether the program is successful or not, a benchmark was selected at 90% for overall efficiencies.

III. Result And Analysis

A. Fire Status

Fire status is the most important thing in showing the size of the fire and also the whether the detection is correct or not. This section was intended to show the statuses and the speed of the fire so ignoring other settings.

When there is no fire detected, the status will be stated as "fire not detected" in the fire status section as shown in Figure.2 (a). The data needs at least 4 data of the fire size ratios for it to determine the speed or the fire size. Without the four fire size data, the fire status will show that data is insufficient as shown in Figure.2 (b). Increase the frame rate, the fire status will reduce the time and take for the fire speed data to be completed.

When the fire is enlarging slowly, as shown in Figure.2 (c), the average of fire area ratios will be lesser than 1.5.

When the fire is enlarging in medium rate, as shown in Figure.2 (d), the average of fire area ratios will be lesser than 1.8 but bigger than 1.5. When the fire is enlarging rapidly, as shown in Figure.2 (e), the average of fire area ratios will be bigger than 1.8.

Figure.2 (f) shows the main menu GUI when the fire size is too big. In this case, the average of fire area ratios is bigger than 0.4. This is important because, it means that the fire region is reaching almost half of the image frame.

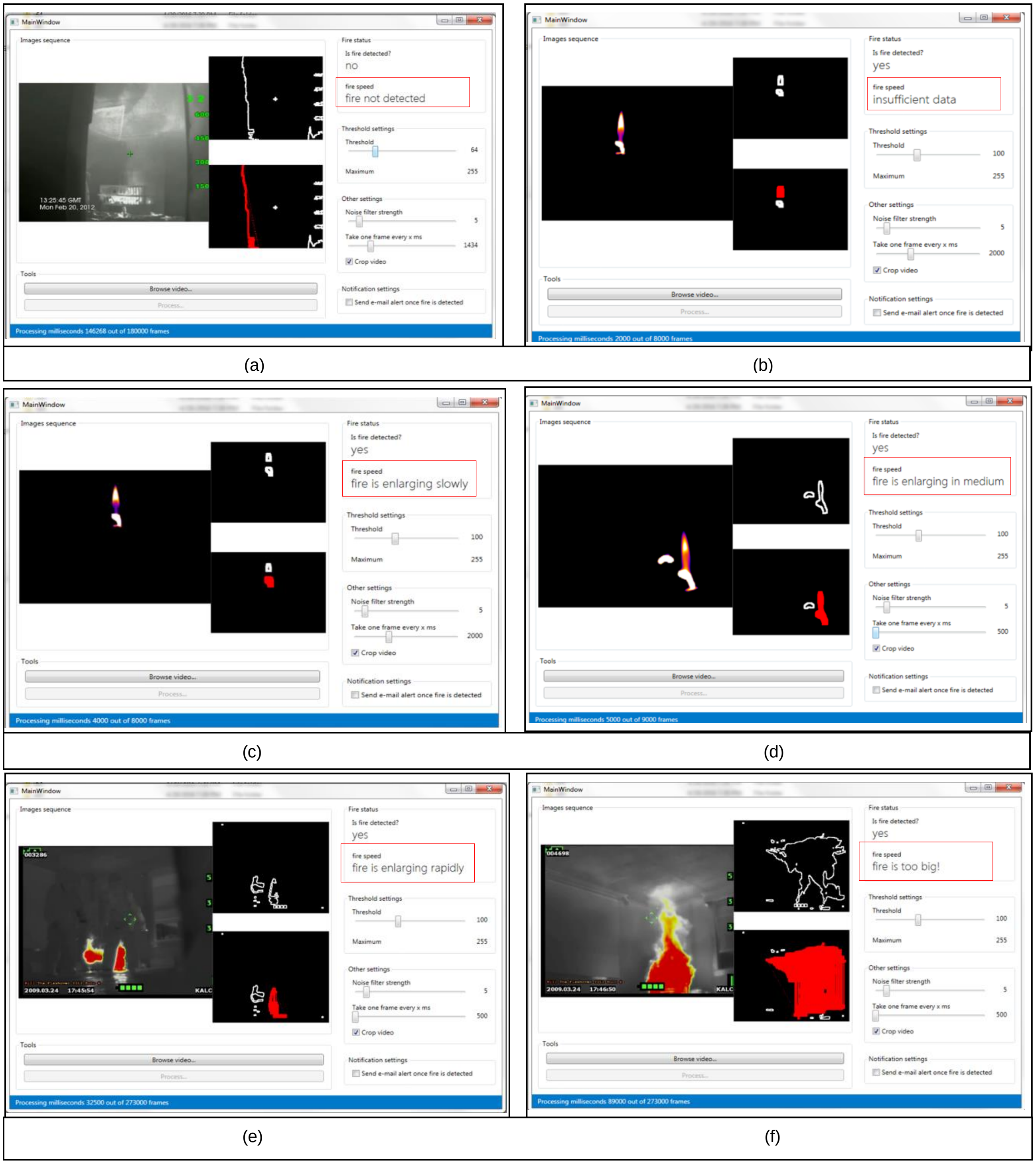
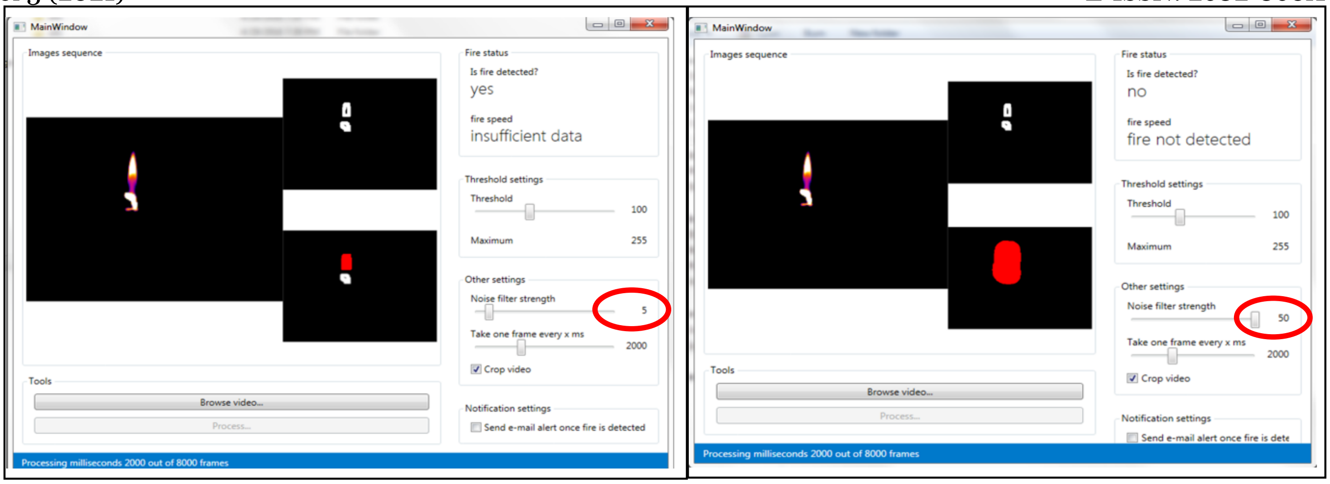


FIGURE 2. **Main menu GUI of fire status.**



(a) (b)

FIGURE 3. Noise filter result.

B. Noise Filter

Noise filter is also important because it is a main factor in determining the size of the possible fire region. The noise filtering sequence used in this project was erode for the first, dilate as the second, canny and finally comes again dilate.

The slider used for the noise filter strength in 'Other settings' section. It will only affect the final dilation.

After canny edge detection has been used, it is only left to label the components. But sometimes it is not enough because the component can be small in size and needs to be enlarge. This was done by dilation process.

When noise filter was set to 5, as shown in Figure.3 (a), fire region detected was only for the top part, not include the bottom part as seen in the 'Image sequence' section. Although no errors in detection for this case, but it may bring errors in other videos. It can affect the detection because the possible fire region may be too small that no detection will occur and may be too big that the centre pixel is not fire pixel. Noise filter setting requires to adjust for different places as the dissimilar conditions of each place.

When the noise filter was at its maximum which is 50, as shown in Figure.3 (b), the fire region has become bigger and encompasses the top and bottom part of the fire as seen in the 'Image sequence' section. This helps in the detection and can reduce errors for some cases.

C. Test Result

A total of 7 thermal videos were tested. The first two the videos are taken using a thermal video camera while another 5 are from the internet. Two of the videos from the thermal camera give 100% accuracy which means it is very efficient.

A benchmark for accuracy was set at 90% correct detection to determine whether the project has failed or not. Average best accuracy is at 90.32% from the testing as shown in Table 1.

TABLE 1. Test Result.

No	Threshold	Noise filter strength	One frame every X ms	Accuracy %
1	100	5	2000	100
	100	**5**	**500**	**100**
2	100	5	2000	100
	100	**5**	**500**	**94.44**
3	100	5	2000	61.11
	72	**10**	**2000**	**77.67**
4	100	5	2000	91.04
	126	**5**	**500**	**93.54**
5	100	5	2000	90
	114	**5**	**500**	**94.25**
6	100	5	2000	81.68
	124	**7**	**500**	**84.67**
7	152	0	2000	77.78
	187	**7**	**500**	**82.11**
	Average Best Accuracy			**90.32**

IV. CONCLUSION

In this paper, we propose a method for fire detection system using image processing. Image-based fire detection approaches offer several advantages, including relatively inexpensive equipment and fast confirmation over traditional methods. Current testing methods has average accuracy of 90.32% because detection error for each frame was relied on human's sight and hearing. However, it appeared that the performance of this paper has been promising and the method used has been quite effective. This is suitable to use in real time fire detection system.

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AUTHOR CONTRIBUTIONS

Thein Oak Kyaw Zaw: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;

Wong Wai Kit: Project Administration, Writing – Review & Editing;

Min Thu Soe: Project Administration, Supervision, Writing – Review & Editing.

CONFLICT OF INTERESTS

No conflict of interests were disclosed.

ETHICS STATEMENTS

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org/

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