Fire Detection Based on Image Using MATLAB GUI Programme

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***Abstract*—Computer vision-based fire detection systems overcome this limitation in that they do not identify flammability on a product-by-product basis. In this study, fire detection was carried out using the YCbCr, RGB, and HSV map approach. The offered system uses color segmentation as a component of fire detection analysis. These three colors space segments will then be extracted to determine the presence of fire in the image used. A rule which consists of five rules based on color space condition had been constructed for classification of a pixel classified as fire. If a pixel satisfies these five rules, the pixels belong to fire class.This paper consists of 6 steps, including image acquisition, image pre-processing, image segmentation, feature extraction, image classification, and GUI creation. GUI provides a visual interface that is intuitive and easy for the user to understand the proposed system. By using button and another visual elements, users can interact with the system efficiently. Based on the tests carried out, the proposed system can detect images of fire in dark and light conditions. Performance testing is done by collecting a set of fire images on the internet. Performance is judged based on how many errors are generated when detecting fire. Performance is categorized into five types, including very good, good, fair, poor, and very poor.**

Keywords—Fire detection, YCbCr, RGB, HSV, segmentation, extraction, GUI

I. INTRODUCTION

Environmental and community safety is an important issue that is always discussed. One of the things that can threaten the safety of the environment and society is fire. Fire can happen anytime and anywhere. Fires can be caused by various things, such as electrical short circuits, cooking utensils, to cigarettes that are thrown carelessly. To minimize and neutralize the occurrence of fires, we need a technology that can detect the presence of fire. Fire detection can be done in several ways. In conventional fire alarm systems, smoke and heat sensors are commonly used. Smoke detectors have a working principle by utilizing reflected light. The reflection of light which is disturbed due to the incoming smoke dust is taken into consideration in deciding a fire to occur at that location. The system currently being developed is the use of computer vision to detect fire. Visual fire detection can be useful when conditional detectors are not working properly. Where particles, temperature, and air transparency are usually the methods used. This method requires a measuring distance that is close to the fire source. In addition, this detector makes it possible to produce false alarms that are generated from cigarette smoke.

It is difficult to detect fires effectively and prevent or extinguish fires and safely evacuate occupants, especially indoors. Today's indoor fire detectors are mainly conventional smoke detectors whose detection is based on particle scanning, temperature scanning, relative humidity scanning, air permeability testing and smoke analysis in addition to conventional ultraviolet and infrared scanning. Therefore, the detection technique relies on the by-product of the spark. In the event of a fire, the smallest detection delay is required to minimize property damage and save lives. The reliability of conventional fire alarm systems mainly depends on the location of the sensors.

Due to rapid developments in digital camera technology and video processing techniques, conventional fire detection methods are going to be replaced by computer vision-based systems [4]. Computer vision-based fire detection systems overcome this limitation in that they do not identify flammability on a product-by-product basis. It also recognizes through the camera, which is the volume sensor, and includes everything from people captured by the camera. In the development of video fire detection systems, flame image segmentation, recognition, tracking and predication are important areas of investigation. This paper focuses on analysis techniques for the presence of fire based on existing image samples. This paper consists of five sections, including an introduction to image-based fire detection, an explanation of previous work, system design, experimental results, and conclusions.

The research paper describes many videos image-based fire detection systems, some of which are detected by video sequencing. Fire detection research based on video sequences can be divided into two categories, namely fire detection and fire detection from smoke [1]. Since our proposed system deals with flame detection, it is discussed in this section.

Celik [2] proposed a real-time fire detector that combines foreground object information with pixel statistics of flame color. A simple adaptive background model of the scene is generated using three Gaussian distributions, where each distribution corresponds to a statistical pixel in its respective color channel. Foreground information is extracted using adaptive background subtraction algorithm, and then verified by the statistical flame color model to determine whether the detected foreground object is a flame candidate or not.

Kim proposed [3] an image-based fire detection method using CNN (Convolutional Neural Network). In this method, firstly we extract fire candidate region using color information from video frame input and then detect fire using trained CNN. Also, we show that the performance is significantly improved compared to the detection rate and missing rate found in previous studies.

Yadav [4] focuses on optimizing the flame detection by identifying gray cycle pixels nearby the flame, which is generated because of smoke and of spreading of fire pixel and the area spread of flame. These techniques can be used to reduce false alarms along with fire detection methods. The novel system simulates the existing fire detection techniques with above given new techniques of fire detection and give optimized way to detect the fire in terms of less false alarms by giving the accurate result of fire occurrence.

In this study, fire detection was carried out using the YCbCr, RGB, and HSV map approach. YCbCr stands for the three colors components in the scheme. Y describes the level of brightness (luminance) of the pixel. Cb describes the difference in color between blue and brightness levels. And Cr describes the difference in color between red and the brightness level. As with YCbCr, RGB and HSV are also abbreviations for the color rules that represent the scheme. The RGB scheme is determined by the combination of the intensity of the three primary color components, namely red (R), green (G) and blue (B). While the HSV consists of a hue component (H), which describes the color type measured in degrees, saturation (S) which describes the richness of the colors in the image, and value (V) which describes the brightness level of the image. The offered system uses color segmentation as a component of fire detection analysis. These three colors space segments will then be extracted to determine the presence of fire in the image used.

II. Methods

Fire detection using image processing in this study was carried out in several stages. The stages consist of image acquisition, image pre-processing, image segmentation and extraction, and image classification. If the image processing simulation has been completed, then a Graphical User Interface is created in MATLAB to facilitate future research.

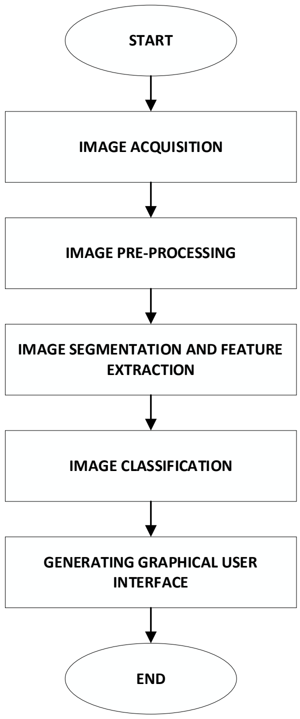

Fig 1 Fire Detection System Process

1. Image Acquisition

This stage consists of taking pictures using a camera and the internet which are listed as digital formats. The accepted image format is in .jpg format with a standard 8MP resolution. The images taken consist of several lighting conditions to analyze the performance of the system being created. Pictures taken in dark and bright light conditions. The more images analyzed, the more consideration for further research.

Fig 2 Image Acquistion

2. Image Pre-processing

In this stage, improvement and enhancement of the image is carried out. Images must be ensured to be clean from noise before entering the image processing stage so that system performance is maximized. The image will be filtered and converted into RGB format and then converted into YCbCr and HSV color space.

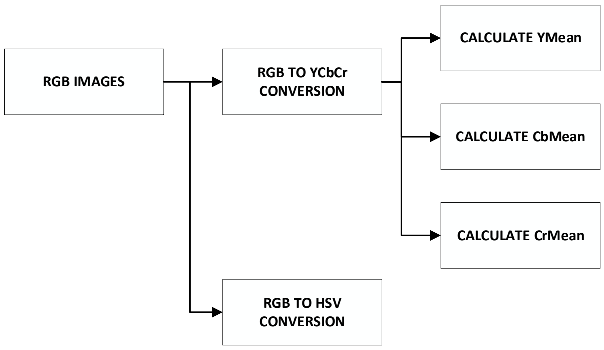

Fig 3. Image Pre-Processing

3. Image Segmentation

Image segmentation is one of the most important stages of image processing. At this stage the image will experience separation of the background and foreground components. Image segmentation stage can be passed with several techniques. Among them are morphological operations, edge detection, compression, and others. Thresholding is done to separate the target image from its background. In the fire detection process, the process will include fire area segmentation and thresholding using MATLAB. In this process the histogram plays an important role in finding the best threshold value.

RGB image is an image that is composed of three colors channels, namely the red channel, green channel, and blue channel. In a 24-bit RGB image, each color channel has a pixel intensity value with an 8-bit bit depth, which means that it has a color variation of 2^8 = 256 degrees of color (0 to 255). Each pixel in an RGB image has an intensity value which is a combination of R, G, and B values.

YCbCr is a family of color space, a way of encoding RGB information that is often used in the coloring section of video and digital photography. It is divided into 2 components, namely the luma component (Y) of the luminance and the chroma component (Cb and Cr), which is the difference between blue and red. The color of YCbCr is determined from CB and CR, Y is used to determine the amount of luminance so that every different Y, the color mapping of Cb and Cr will be different.

This color model was developed to anticipate the development of video-based information, so this model is widely used in digital video. In general, it can be said that this color model is part of space color video transmission and television. YCbCr color model separates the RGB values into luminance information and chrominance which is useful for image compression applications.

The formula developed to convert RGB to YCbCr is:

Table 1. RGB to YCbCr Formula

Formula
$Y = 0.299R + 0.587G + 0.114B$ $Cb = B - Y$ $Cr = R - Y$

HSV defines color in terms of hue, saturation and value. The advantage of HSV is that there are colors that are the same as those captured by the human senses. Meanwhile, the colors formed by other models, such as RGB, are the result of a mixture of primary colors.

The formula developed to convert RGB to YCbCr is:

Table 2. RGB to HSV Formula

Formula
$H = \tan\left(\frac{3(G-B)}{(R-G)+(R-B)}\right.$ $S = 1 - \frac{\min(R,G,B)}{V}$ $V = R + G + \frac{B}{3}$

4. Feature Extraction

Feature extraction is the stage where the pixel data representing the processed image is entered into groups. The set of features will extract relevant information according to the desired task. It can be seen that fire colors consist of orange, yellow, and also have high level of brightness. For this project, fire pixels had been extracted by using three color spaces. The rules are listed below.

Table 3. Extraction Rules

Color Space	Rules
RGB	$R(i,j) > 180$
	$R(i,j) > G(i,j) > B(i,j)$
YCbCr	$Y(i,j) \geq Ymean \cap Cb(i,j) \leq Cbmean \cap Cr(i,j) \geq Crmean$
HSV	$S \geq 255 - R(0.0001)$
	$0.8 < V < 1$

RGB color space is used to separate the red color from the other colors in the image. Because red is the color that is synonymous with fire. YCbCr color is used to detect information about brightness because it can distinguish bright images more effective than the other models. HSV is used to detect color and brightness in images.

5. Image Classification

In this stage, detection of fire in RGB, YCbCr, and HSV color space will be combined together for the result to be accurate. In the sense, that the input image must meet predetermined criteria. In this project, the image output from this fire classification is an image with the values of two binary numbers, namely 1 and 0. After the fire image is identified, the next step is to perform edge detection. Edge detection with the sobel method is carried out to provide boundaries on the object that is used as a target.

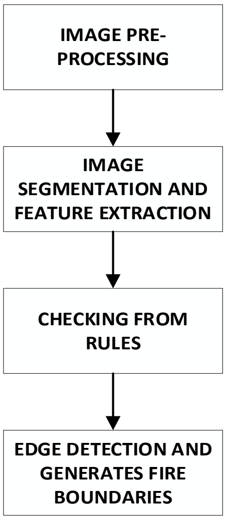

Fig 4. Image Clasification

6. Making Graphical User Interface

A graphical user interface (GUI) is a system of interactive visual components for computer software. With the GUI, we can know that what we input has been received and the response is shown visually easily. The discovery of the GUI provides a solution to the response problem felt by the user. The GUI designed makes it easy for users to import fire images and the results can be seen immediately.

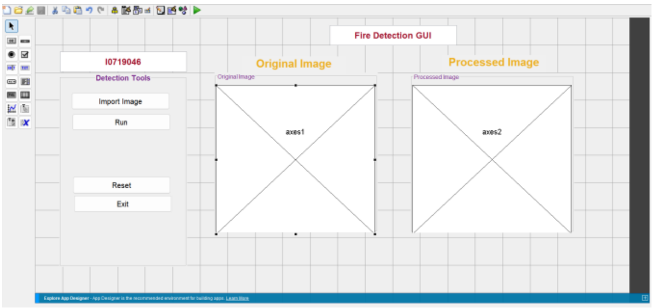

Fig 5 . Making of Fire Detection GUI

III. Results and Discussion

Several sets of images containing fire from the internet were taken to carry out this experiment. Therefore, a rule which consist of five rules had been constructed for classification of a pixel classified as fire. If a pixel satisfies these five rules, the pixels belong to fire class. The image below shows the GUI program that was created successfully. In the top left image box is the original image that was successfully imported from a laptop/PC. The top right image is an image resulting from predefined rule processing. The bottom image is the result of identifying the fire in that image.

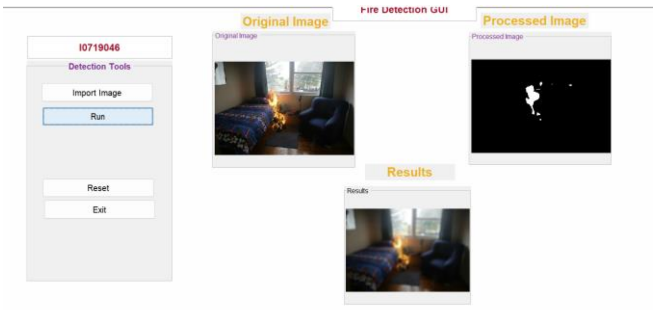

Fig 6. GUI of Fire Detection

Fig 7. Results of GUI Programme of Fire Detection (Image from internet)

Fig 8. Results of GUI Programme of Fire Detection (Image from internet)

Fig 9. Processed Image

Performance testing is carried out by inputting fire images for 30 conditions. Performance is judged based on how many errors are generated when detecting fire.

Table 4. Performance Criteria

Performance	Score
Very good (fire is detected and non-fire is not detected)	100%
Good (fire was detected and there was a slight non-fire detected)	75%
Fair (Fire detected and some non-fire detected)	50%
Poor (Fire is not too detectable and a lot of noise)	25%
Very Poor (Fire not detected)	0%

The input fire image comes from five different conditions, including bright conditions and dark conditions.

Table 5. Input Condition

Condition	Amount
Bright conditions (image from internet)	15
Dark conditions (image from internet)	15

Based on the experimental results, it was found that the fire detection performance in bright room conditions was 88.3%. Meanwhile, in a dark room condition, the performance is 87.5%. Some of the weaknesses of this system have been identified, including the color that has a resemblance to fire. Colors similar to fire can come from the image of the fire itself or from other objects of a similar color.

Yadav[4] perform several methods of fire detection. Result shows that the system performance for fire detection comprising of only color detection is 81.74% The RGB color pattern is analyzed to produce a threshold that can distinguish fire from other components in the image. By adding YCbCr and HSV color spaces to the proposed system, fire can be detected with an accuracy of above 85%. There are several aspects of development that can be carried out, such as gray scale detection, area dispersion detection, and others.

IV. Conclusion

In conclusion, the proposed system can detect fire under conditions of light and dark conditions based on the 30 images tested. The combination of rules based on YCbCr and RGB color spaces successfully separates the flames from the background. The performance obtained in detecting fire with this method is above 85%. Of course, this method still needs further development to eliminate components other than fire in the image. There are several aspects of development that can be done to improve system performance, including fine tuning of the threshold on the color spaces used and exploring other image processing techniques such as machine learning with convolutional neural networks.

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References

[1] M. Li, W. Xu, K. Xu, J. Fan, and D. Hou, "Review of fire detection technologies based on video image," *J. Theor. Appl. Inf. Technol.*, vol. 49, no. 2, pp. 700–707, 2013, [Online]. Available: http://dx.doi.org/

[2] T. Celik, H. Demirel, H. Ozkaramanli, and M. Uyguroglu, "Fire detection using statistical color model in video sequences," *J. Vis. Commun. Image Represent.*, vol. 18, no. 2, pp. 176–185, 2007, doi: 10.1016/j.jvcir.2006.12.003.

[3] Y.-J. Kim and E.-G. Kim, "Image based Fire Detection using Convolutional Neural Network," *J. Korea Inst. Inf. Commun. Eng.*, vol. 20, no. 9, pp. 1649–1656, 2016, doi: 10.6109/jkiice.2016.20.9.1649.

[4] G. Yadav, V. Gupta, and V. Gaur, "Optimized Flame Detection Using Image Processing Based," *Indian J. Comput. Sci. Eng.*, vol. 3, no. 2, pp. 202–211, 2012.

[5] E. Hassan and A. Aboshgifa, "Detecting Brain Tumour from Mri Image Using Matlab GUI Programme," *Int. J. Comput. Sci. Eng. Surv.*, vol. 6, no. 6, pp. 47–60, 2015, doi: 10.5121/ijcses.2015.6604.

[6] M. S. Nasution and N. Fadillah, "Deteksi Kematangan Buah Tomat Berdasarkan Warna Buah dengan Menggunakan Metode YCbCr," *InfoTekJar (Jurnal Nas. Inform. dan Teknol. Jaringan)*, vol. 3, no. 2, pp. 147–150, 2019, doi: 10.30743/infotekjar.v3i2.1059.

[7] G. Nagalakshmi and S. Jyothi, "Image Acquisition , Noise removal , Edge Detection Methods in Image Processing Using Matlab for Prawn Species Identification," no. May, pp. 325–331, 2015.

[8] G. Li, G. Lu, and Y. Yan, "Fire detection using stereoscopic imaging and image processing techniques," in *2014 IEEE International Conference on Imaging Systems and Techniques (IST) Proceedings*, 2014, pp. 28–32. doi: 10.1109/IST.2014.6958440.

[9] V. Venugopal, "Image Processing Based Forest Fire Detection," *Int. J. Adv. Res. Eng. Technol.*, vol. 2, 2012.

[10] N. Ibraheem, M. Hasan, R. Z. Khan, and P. Mishra, "Understanding Color Models: A Review," *ARPN J. Sci. Technol.*, vol. 2, 2012.

[11] O. Marques, "Morphological Image Processing," *Pract. Image Video Process. Using MATLAB®*, vol. 8491, pp. 299–334, 2011, doi: 10.1002/9781118093467.ch13.

[12] N. Ya'acob, M. S. M. Najib, N. Tajudin, A. L. Yusof, and M. Kassim, "Image Processing Based Forest Fire

Detection using Infrared Camera," *J. Phys. Conf. Ser.*, vol. 1768, no. 1, p. 12014, Jan. 2021, doi: 10.1088/1742-6596/1768/1/012014.

[13] M. A. I. Mahmoud and H. Ren, "Forest Fire Detection Using a Rule-Based Image Processing Algorithm and Temporal Variation," *Math. Probl. Eng.*, vol. 2018, p. 7612487, 2018, doi: 10.1155/2018/7612487.

[14] P. Chmelar and A. Benkrid, "Efficiency of HSV over RGB Gaussian Mixture Model for fire detection," in *2014 24th International Conference Radioelektronika*, 2014, pp. 1–4. doi: 10.1109/Radioelek.2014.6828426.

[15] J. Seebamrungsat, S. Praising, and P. Riyamongkol, "Fire detection in the buildings using image processing," in *2014 Third ICT International Student Project Conference (ICT-ISPC)*, 2014, pp. 95–98. doi: 10.1109/ICT-ISPC.2014.6923226.

[16] M. Waghmare and P. M. Annamalai, "Fire Detection Based on Color , Shape and Motion," *Int. Res. J. Eng. Technol.*, vol. 4, no. 7, pp. 1804–1806, 2017, [Online]. Available: https://irjet.net/archives/V4/i7/IRJET-V4I7383.pdf