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Multi Color Feature, Background Subtraction and Time Frame Selection for Fire Detection

Guruh Fajar Shidik[1], Fajrian Nur Adnan[2], Catur Supriyanto[3],
Ricardus Anggi Pramunendar[4], Pulung Nurtantio Andono[5]

Faculty of Computer Science, Universitas Dian Nuswantoro, Semarang 50131
[1]E-mail: guruh.fajar@research.dinus.ac.id
[2]E-mail: fajrian@research.dinus.ac.id
[3]E-mail: caturs@research.dinus.ac.id
[4]E-mail: ricardus.anggi@research.dinus.ac.id
[5]E-mail: pulung @research.dinus.ac.id

***Abstract*— the importance of early fire detection can help in providing warnings and avoid disaster that led to the economic damage and loss of life. Fire detection techniques with conventional sensors have limitations, which require a long time to detect a fire, especially in a large room and cannot work in the open area. This study proposed a fire detection method, to detect the possibility of fire based on visual sensor using multi-color feature such as color, saturation, luminance, background subtraction and time frame selection for fire detection. The evaluation in this studies conducted by calculating the error rate of the fire detection.**

***Keywords*— Fire Detection, Background Subtraction, RGB, HSV, YcbCr, Time Frame Selection**

I. INTRODUCTION

Fire is the energy source that can potentially cause harm both economically and ecologically that claimed casualties. Based on data from the Indonesian National Disaster Monitoring at least 55 fires incident have occurred in the area of Jakarta Indonesia, in 2012 which caused the greatest loss had burned 394 homes and 1271 people lost their house [1].

The importance of early fire detection [2] can help provide disaster warning and avoid causing huge economic losses and loss of human life. There have been many techniques of early fire detection that have been done in the conventional way, where fire detection is based on the sample of particles, temperature, average humidity, and smoke analysis using ultraviolet and infrared detectors [3] [4]. However, the conventional method requires long time to detect a fire in a large room and cannot work in an open space [5]. Fire detector in the conventional way is not able to provide additional information about the position of the fire spots, the size of fire, and growth of fire. Conventional sensors is also sometimes gives a high error detection (false alarm) [6].

Visual detection can be used as solution for fire detection [6], in many conditions, where the conventional way cannot work [7]. The usage of camera surveillance that placed in many building, recently is only used for object tracking, detection of abnormal events and character recognition. In the field of computer vision, fire detection based on visual camera surveillance also can be applied and become important field research in managing fire disaster [8]. Visual fire detection research can be done by utilizing the existing camera, then differentiate the recorded images of each frames. The previous research in image processing of fire detection are classified into two types, one is focuses on color image [9], [10], [11], [12], [13], [14], and the other on the gray scale image [15], [16], [17].

Patel [18], in his research using two key features there are color in CIE-RGB format and movement of the object. Next, Yadev [19], conducted a study of fire detection by using color features, lighting and movement. The researchers only use red RGB color to detect fire and Y, Cb, Cr to detect illumination image.

Refer to Cetin, et al [20], the improvement technique in detecting fire has evolved, not only used color and movement detection. Several researcher also uses another technique such as dynamic texture analysis, flicker energy wavelet, spatial difference analysis, disorder analysis and training models with classification technique.

Based on the information above, there has been no any research that used RGB, HSV and YCbCr as Multi-Color Feature that combined with Background Subtraction to produce Fire Segmentation area. Than the segmentation area will be smooth using morphological and time frame selection to produce less error of fire detection area.

The reminder of this page could be seen as follow : chapter two talking about the fundamentals of its technique, chapter three describing the methodology we used to detect the fire, chapter four describing the result and analysis of the experiment, the last chapter is conclusion and future work of this research.

II. FUNDAMENTALS

A. Background Subtraction

Background subtraction is a process commonly used to find objects in the picture. The concept of this method is to identify a condition characterized as a background for the model, then compare the images against the background of the model which has been obtained previously to detect the presence of objects, also known as the foreground. To identify the presence of an object, this technique is usually performed on two images taken at the same location at different times. Background models obtained from area that have consistent situation, but still able to adapt to environmental changes. Foreground detection stage can be calculated by using the formula (1).

$$R(x,y)=I(x,y)-B(x,y) \tag{1}$$

Where R is the results from Background Subtraction, I is an image that will be explored for position object or changed condition, B is a background image. Comparison are execute in same pixel position (x, y). Since this method should capable to tolerance with any position changes, it required tolerance level or threshold of any changes pixel. R is the pixel that changes and far from toleration level.

B. Morphology

Morphology is a broad set of image processing operations that process images based on shapes. Morphological operations apply a structuring element to an input image, creating an output image of the same size. Morphological operation, compare the corresponding pixel in the input image with its neighbors to find out the value of each pixel in the output.

The most basic morphological operations are dilation and erosion. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the *structuring element* used to process the image. From two basic operation morphology can be combine become several operation such as Opening, Closing, Thinning, shrinking, pruning, thickening, dan skeletonizing. The detail explanation could be seen in [21].

C. Time Frame Selection

The technique in time frame selection is selecting any frame by time sequentially that will be choose in fixed time to refresh and gather an update of fire detection frame.

For example, we are looking for multiples of 3 frames, by searching frame using modulus operation. Each frames that have value *mod (3) = 0* will be select, then we give some process such as morphology, AND operation and subtraction of segmentation frame that will be repeat every time.

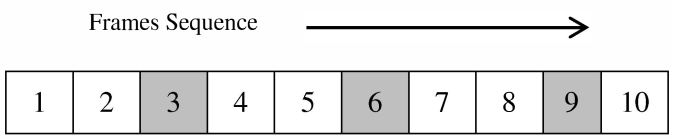


Fig.1. Time frame selection illustration

D. RGB

RGB color space is a color concept using the three primary colors of red, green and blue, which make up the formation of another color. RGB color space is often used in research in the field of computer graphics. RGB represented in 3 dimensional Cartesian diagram, where the fusion of the three values will form different colors as shown in the table 1.

TABLE 1: COMPOSITION COLOR RGB

Color Range	*R (0-255)*	*G(0-255)*	*B(0-255)*
White	255	255	255
Yellow	255	255	0
Cyan	0	255	255
Green	0	255	0
Magenta	255	0	255
Red	255	0	0
Blue	0	0	255
Black	0	0	0

Although RGB is best to be used in computer graphics, but it is not efficient to represent real image. To represent in a different color space, RGB can be transformed using linear and nonlinear transformations. [22]

E. HSV

HSV, represents another color space from RGB in three dimensions, namely Hue (green), Saturation (dark green), and Value (lighting or intensity). HSV color space based on cylindrical coordinates. HSV color space is better than the RGB in representing human view and describe the sensation of color. HSV color space has a color range from 0 to 1 which can be obtained from the transformation of the RGB by using nonlinear transformation formula as shown in (4-7) [23].

$$H = \begin{cases} \theta & if\ b \leq g \\ 360^0 & if\ b > g \end{cases} \tag{4}$$

$$\text{where } \theta = cos^{-1} \frac{\frac{1}{2}[(r-g)+(r-b)]}{[(r-g)^2+(r-b)(g-b)]^{1/2}} \tag{5}$$

$$v = \max(r, g, b) \tag{6}$$

$$s = (v - \min(r, g, b))/v \tag{7}$$

F. YCbCr

YCbCr color space consists of luma component (Y) which states the light or brightness of an image, and two chroma components (Cb and Cr) which states the color of the image. Transformation RGB to YCbCr color space can be calculated as follows (8).

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.257 & 0.504 & 0.098 \\ -0.148 & -0.291 & 0.439 \\ 0.439 & -0.368 & -0.071 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} \tag{8}$$

III. RESEARCH EXPERIMENT

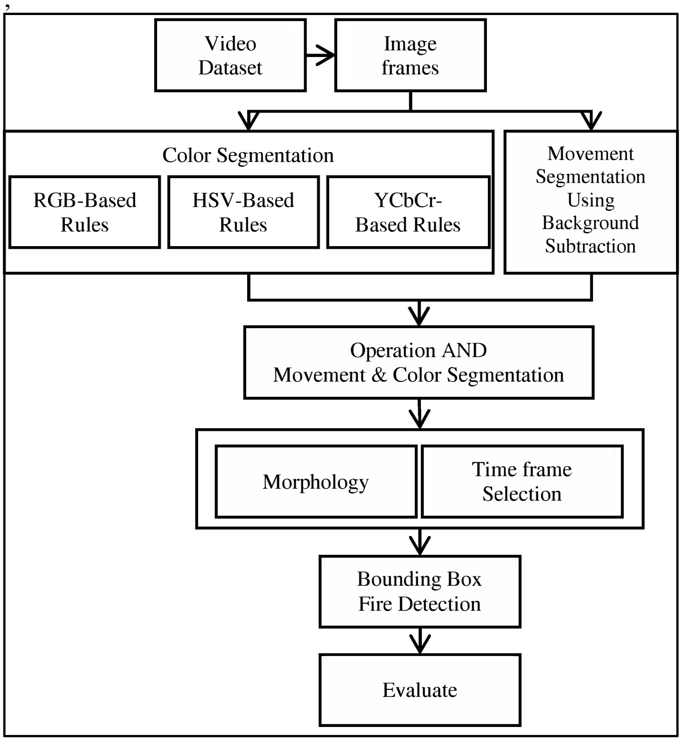


Fig 2: Experiment Process

A. Video Dataset

Video dataset we used are from existing research, there are KMU Fire & Smoke Database: *http://cvpr.kmu.ac.kr/Dataset/Dataset.htm*, Bilkent EE Signal Processing group: *http://signal.ee.bilkent.edu.tr/VisiFire/Demo/SampleClips.html* and Fire Research Laboratory's Fire Research Division at NIST: *http://fire.nist.gov*. Format of standard video dataset we used are AVI, FLV and MPG.

B. Image Frames

In this phase all video datasets will be extract into image frame. The number of frame will be extract is around 24 – 30 frame per second. After this process is complete, each image will be processed to produce a feature based of color segmentation and movement of each frame.

C. Color Segmentation

In the color segmentation process, researchers used three features that taken from several color space as forming of multiple features that is RGB, HSV and YCbCr. Each color space, formed into multiple rules then used as a feature that will be used in the segmentation process.

The rules for segmenting fire feature in color space RGB could be seen as below, denoted as *R1(i,j)*:

$$R1(i,j) = 1 \quad \text{If } r(i,j)>g(i,j) \ \&\& \ g(i,j)>b(i,j) \ \&\& \ (r(i,j) > 200 \ \&\& g(i,j) >130 \ \&\& \ b(i,j) < 120 \qquad (9)$$

The rules in color space HSV will take saturation level from image, where the rules could be seen as below, denoted as *R2(i,j)*:

$$R2(i,j) = 1 \quad \text{If } h(i,j)>=0.13 \ \&\& \ h(i,j)<0.46 \ \&\& \ s(i,j)>=0.1 \ \&\& \ s(i,j)<=0.34 \ \&\& \ v(i,j)>=0.96 \ \&\& \ v(i,j)<=1 \ \&\& \ r(i,j)>=g(i,j) \ \&\& \ g(i,j)> b(i,j) \ \&\& \ (r(i,j) > 180) \ \&\& \ g(i,j) >130) \ \&\& \ (b(i,j) < 120 \qquad (10)$$

The last rules in color feature space is YCbCr. It used to differentiate level luminous between one object with others by selecting the level luminance that close with fire object, denoted as *R3(i,j)*.

$$R3(i,j) = 1 \quad \text{If } y(i,j)>cr(i,j) \ \&\& \ cr(i,j)>=cb(i,j) \ \&\& \ y(i,j)>=180 \&\& \ y(i,j) < 210 \ \&\& \ cb(i,j)>=80 \&\& cb(i,j)<=120 \ \&\& cr(i,j)>=80 \&\& \ cr(i,j)<=139 \ \&\& r(i,j)>=g(i,j) \&\& \ g(i,j)>b(i,j) \ \&\& \ r(i,j) > 190 \ \&\& \ g(i,j) >110 \ \&\& \ b(i,j) < 180 \qquad (11)$$

Results of the three rules above are merged using the formula (12), where *i* and *j* are Row and Colom of matrix.

$$R4(i,j)= R1(i,j) \cup R2(i,j) \cup R3(i,j) \qquad (12)$$

(a) (b)

Fig 3: (a). Frame from source image, (b). Result of segmentation Multi Color Feature

D. Movement Segmentation

In this step, Background Subtraction technique is used to segmenting the movement object, where each image frames will be compared with the previous frame to get a change conditions or movement object that captured on video as showed in Fig. 4. The formula of the background subtraction can be seen in (1), where the results of movement segmentation will be denoted as *R5(i,j)*.

(a) (b) (c)

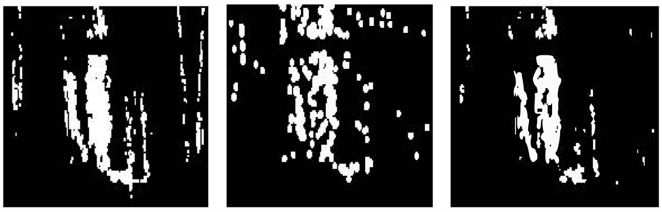
Fig. 4: (a). Image from previous frame -1, (b). Image from current frame, (c). Result of Background Subtraction

E. AND operation of Movement and Color Segmentation

At this stage, the segmentation process is carried out to produce a fire detection area, between slices results of the Color Segmentation *(R4)* and Movement Segmentation *(R5)*. The following formula is used to make objects move on a fire to be detected as fire spots.

$$R6(i,j) = R4(i,j) \cap R5(i,j) \quad (13)$$

This rule is also used to detect the changing conditions, and filter out the objects that are not fire.



(a) (b) (c)

Fig.5. (a). Result from segmentation of Multi Color Feature (b). Result from Background Subtraction, (c). Result from AND operation from source (a) and (b)

F. Morphology

Morphology is used to emphasize the results of the segmentation. We obtain more precise segmentation image of fire and eliminate outlier points or areas that are not fire spot also detected. In this research Erosion, Dilation and Closing are used to minimize outlier pixels and the results of segmentation that are not connected can be connected.

$$R7(i,j) = \text{Erosion}\ (\ R6(i,j)\ ) \quad (14)$$

$$R7(i,j) = \text{Closing}\ (\ R7(i,j)\ ) \quad (15)$$

G. Time Frame Selection

The selection frame based on modulus operation is used to updating the condition of frame repeatedly time by time. The time frame selection will give less error detecting fire area. The detail selection rules in time frame selection could be seen at formula (16-19).

$if\ mod\ 3 == 0$,	R8(i,j) =R6(i,j) – R7(i,j), R8= Dilation (R8)	(16)
$if\ (mod\ 4 == 0$ or $mod\ 7 == 0)$	if R8(i,j)==1 && R4(i,j)==1, then R7(i,j) == 0;	(17)
$if\ mod\ 20 == 0,$	R6(i,j) = R6(i,j) * 0	(18)
$if\ mod\ 10 == 0,$	R6(i,j) = R6(i,j) $\cap$ R7(i,j)	(19)

H. Fire Detection Bounding Box

At this stage, the region of the bits that have value 1, it will be labeled with box area to indicate these areas have been detected as fire spots. Picture below is showed the Bounding Box boxes were detected in the fire area.

(a) (b) (c)

Fig 6. (a). Result before morphology and time frame selection, (b). Result Segmentation after morphology and time frame selection, (c) Results of *Bounding Box* fire detection area with original image frame

Bounding Box also has a utilities on the process of evaluation in this research, where the error rate is calculated based on the number of false detection fire spot area. So it can be measured in quantitatively the performance of this method. The results of all fire video dataset that has been detect using this method, could be seen in Fig 7.

IV. RESULT AND DISCUSSION

This part explain the performance results of our model that used to detect the fire regions. The performance is measured quantitavely using a calculation derived from Lee [24] that used to evaluate detection algorithm in detecting region of smoke.

$$Error\ Detection\ Avg = \frac{N\ false\ detect}{N\ Fire\ Spot\ Bounding\ Box}\ x\ 100\% \quad (20)$$

The evaluation formula has been modified to measures the performance of fire spots, by calculating the number of wrong *Fire Spot Bounding Box* that detected as *false detect* in random image frames. The formula to evaluate the average error rate could be seen in (20).

$$Error\ Detection\ Avg = \frac{16}{105}\ x\ 100\% = 15{,}2\%$$

The segmentation of multi-color feature and background subtraction capable to detect fire region, but in several data set we still find false detection area. To cover this problem, the uses of combination morphology and time frame selection in this study capable to reduce false detect. The results have showed the performance of average error detection of this method is around 15.2%. This means the use of these methods are promising in detecting fire spot in indoor or outdoor.

TABLE 2: PERFORMANCE OF FIRE DETECTION

Video Dataset	False Detect	Bounding Box of Fire Spot Detect
barbeq.avi	0	7
candle.flv	0	1
fire1.avi	0	1
flame1.avi	0	2
fbackyard.avi	3	5
flame2.avi	0	3
forest1.avi	0	7
forest2.avi	0	5
controled1.avi	0	5
controlled2.avi	2	12
forest3.avi	1	5
forest4.avi	0	6
forest5.avi	0	4
forestfire.avi	0	5
wfds_tree.avi	10	37
Total	***16***	***105***

V. CONCLUSION

This research has been successful in detection of fire, with error rate around 15,2%. The performance of proposed model capable to reduce the false detection of fire spots area, when morphology and time frame selection are applied after Multi Color Feature and Background Subtraction that given impact to the small error rate. In the next research, we will improve the performance of fire detection using machine learning and classify which type of fire that potential to burn.

References

[1] Badan Pantauan Bencana Nasional, "Data Kejadian Bencana Kebakaran Permukiman," 2012. [Online]. Available: http://geospasial.bnpb.go.id/pantauanbencana/data/datakbmukimall.php.

[2] L. M. Garcia, G. S. Perez, M. Nakano, K. T. Medina, H. P. Meana and L. R. Cardenas, "An early fire detection algorithm using IP cameras.," *Sensors (Basel, Switzerland),* pp. 12(5), 5670–86. doi:10.3390/s120505670, 2012.

[3] W. G. T. Cleary, "Survey of fire detection technologies and system evaluation/certification methodologies and their suitability for aircraft cargo compartments," *US Department of Commerce, Technology Administration, National Institute of Standards and Technology,* 1999.

[4] K. N. W. Davis, " NASA fire detection study," *US Department of Commerce,Technology Administration, National Institute of Standards and Technology,* 1999.

[5] Z. Xu and J. Xu, "Automatic Fire smoke Detection Based on Image Visual Features," 2007.

[6] C. Kao and S. Chang, "An intelligent real-time fire-detection method based on video processing," in *IEEE 37th Annual 2003 International Carnahan Conference onSecurity Technology*, 2003.

[7] T. Celik, H. Demirel, H. Ozkaramanli and M. Uyguroglu, "Fire detection using statistical color model in video sequences.," *Journal of Visual Communication and Image Representation,* pp. 18(2), 176–185. doi:10.1016/j.jvcir.2006.12.003, 2007.

[8] K. H. Cheong, B. C. Ko and J. Y. Nam, "Automatic fire detection system using CCD camera and Bayesian Network," *SPIE Digital Library,* pp. Vol. 6813 68130S-1, 2008.

[9] Y. C. L. M. a. A. Mecocci., "An Intelligent System For Automatic Fire Detection in Forests," in *3th Internationa Conference on Image Processing and its Application*, 1989.

[10] D. G. Healey, T. Slater, B. Lin, Drda and A. D. Goedeke, "A System for Real Time Fire Detection," in *Conference on Computer vision and Pattern Recognition*, 1994.

[11] H. Yamagishi and J. Yamaguchi, "Fire Flame Detection Algorithm Using a Color Camera," in *International Symposium on Micromechatronics and Human Science*, 1999.

[12] M. S. W Philips III and N. d. V. Lobo, "Flame Recognition in Video," in *Fifth IEEE Workshop on Application of Computer Vision*, 2000.

[13] B. C. Arrure, A. Olero and J. R. M. d. Dios, "An Intelligent System for False Alarm Reduction in Infrared Forest Fire Detection," *IEEE Intelligent System,* pp. 64-70, 2000.

[14] W. B. Hong and J. W. Peng, "Realtime Fire Detection from Video: A Preliminary Report," in *14th IPPR Computer Vision , Graphic and Image*, 2001.

[15] S. Noda and K. Ueda, "Fire Detection in Tunnels Using an Image Processing Method," *Vehicle Navigation and Information System,* pp. 57-62, 1994.

[16] S. Y. Foo, "A Machine Vision Approach to Detect and Categorize Hydrocarbon Fires in Aircraft Dry Bays and Engine Compartments," *IEEE Transaction on Industry Application,* pp. vol 36, no2, p549-466, 2000.

[17] E. D. Breejen, "Autonomous Forest Fire Detection," in *third int'l conference Forest Fire Research*, Bellingham, 1998.

[18] T. Celik, "Fast and Efficient Method for Fire Detection Using Image Processing," *ETRI,* 2010.

[19] P. Patel and S. Tiwari, "Flame Detection using Image Processing Techniques," *International Journal of Computer Applications,* 2012.

[20] a. E. Çetin, K. Dimitropoulos, B. Gouverneur, N. Grammalidis, O. Günay, Y. H. Habiboğlu, B. U. Töreyin and a. S. Verstockt, "Video fire detection – Review," *Digit. Signal Process,* vol. 23, no. 6, p. 1827–1843, 2013.

[21] A. Bovik, The Essential Guide to Image Processing, Elsevier, 2009.

[22] J. Huajie, W. Lichun, S. Yanfeng and H. Yongli, in *Fourth International Conference on Digital Home*, 2012.

[23] X. Jie, H. Li-na, G. Guo-hua and Z. Ming-quan, "Real Color Image Enhanced by Illumination—R," in *International Conference on Information Technology and Computer Science*, 2009.

[24] C. Y. Lee, C. T. Lin, C. T. Hong and M. T. Su, "Smoke Detection Using SPATIAL AND Temporal Analyses," *International Journal of Inovative Computing, Information and Control,* Vols. vol 8, no 7A, pp. 4749-4770, 2012.

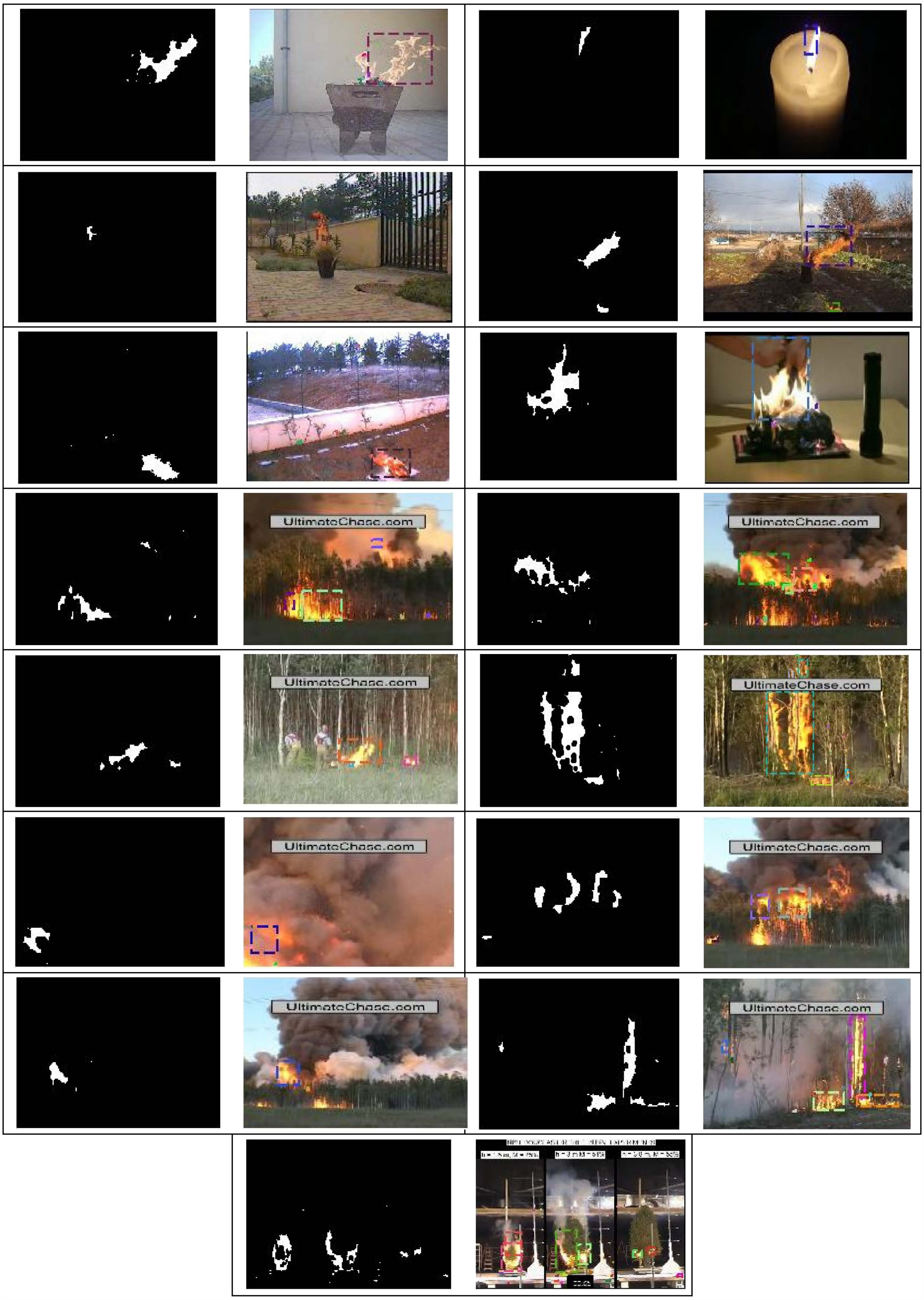


Fig.7. Result of Fire Detection