MIPFD Algorithm for Image Fire Detection

Bojan Prlinčević[1], Zoran Milivojević[2], Darko Brodić[3]

Abstract – **Image Processing Fire detection (IPFD algorithm) and its modification in the part of detection of fire pixel is described in the first part of the paper. The second part of the paper presents the testing of MIPFD algorithm efficiency during the detection of fire pixels. The results of testing are presented both in tables and graphics. Finally, the comparative analysis with IPFD algorithm was conducted.**

Keywords – **Fire detection, RGB model, Test image, Image processing, Chromatic feature.**

I. INTRODUCTION

Fire is a hazard inflicting enormous damage in all spheres of the society, ecological systems (a significant factor in environmental protection because it causes great ecological damage), infrastructure and human lives [1]. Therefore, an early detection of fire and fast reaction for its extinguishing is very important. Due to rapid development of technology of digital cameras and digital image processing and video content, there is a strong tendency to conventional systems (fire detection sensors, thermometers etc.) be replaced by computer system of fire detection by digital image processing [2].

Success of fire detection greatly depends on implemented algorithm. There is a large number of proposed algorithms for fire detection in which in detection process the analysis of color image is performed. Fire detection process implies value analysis of luminance and chrominance characteristics of each pixel and accordingly the classification of fire pixels. During the classification an errors can occur (positive and negative errors), which in final balance determines the performances of the algorithm. Errors imply the following decisions: a) there is fire-detection says there is no fire and b) there is no fire-detection says there is fire, (while correct detection implies fire detection when there is really a fire). The quality of the algorithm can be described by percentage success of properly detected fire pixels.

During the analysis of color images a few systems are used; presentation of images, RGB (Red, Green, Blue), YUV and YCrCb. In the paper [3] for fire detection the YUV model is used for presentation of video content, where Y component is used for identification of potential fire pixel, while final decision is made according to U and V components. In the paper [4] normalized RGB values for formation of generic model of flame are used. Generic model is obtained by usage of statistic analysis conducted in R-G, R-B and G-B region.

Pixel is qualified as fire pixel if found in the area of triangle defined by three lines R-G, R-B and G-B. In regard to YUV algorithm from [3], RGB algorithm from [4] provides mitigation of the effect in the changes of luminance component Y. In the paper [5] was proposed algorithm for fire and smoke detection by analyzing YC_bC_r components of the image. This algorithm has a very high success rate of detection fire pixels.

In this paper is proposed an algorithm for image fire detection that was created by modifying the Image Processing Fire Detection (IPFD) algorithm [6]. Modified, MIPFD (*Modified Image Processing Fire Detection*) algorithm has been tested by images processing from the image database [7]. Also, for the needs of comparison with IPFD algorithm, the original Test image was created. For the purpose of efficiency of proposed MIPFD algorithm, the Test image was created, which consists of 36 fields grouped in three units: a) 12 fire segments, b) 12 smoke segments and c) 12 segments with no fire and smoke. Obtained results are compared with results obtained in the paper [6].

The paper is organized in the following way: section II describes algorithms IPFD and MIPFD; section III describes testing results and comparative analysis. Conclusion is given in section IV.

II. ALGORITHMS

A. *IPFD algorithm*

Analyzed IPFD algorithm for detection of fire pixels in image can be executed in the following steps:

Input: RGB image X_{MxN}.
Output: Fire_Flag (1 fire, 0 no fire).

Step 1:

```
FOR x=1:M
    FOR y=1:N
    IF (R(x,y)>G(x,y)>B(x,y)) & (R(x,y)>S_r1 & ...
        R(x,y)<S_r2 & G(x,y)>S_g1 & G(x,y)<S_g2 & ...
        B(x,y)>S_b1 & B(x,y)<S_b2);
        R_1(x,y)=1;
        IF R(x,y)>=C_b(x,y))&(C_r(x,y)>=C_b(x,y)) ...
            & (Y(x,y)>=Y_mean) & C_b(x,y)<=C_bmean & ...
            C_r(x,y)>=C_rmean) & (|C_b(x,y)-_r(x,y)|>=Th) ...
            & (C_b(x,y)<=S_cb & C_r(x,y)>=S_cr));
                R_2(x,y)=1;
        ELSE
                R_2(x,y)=0;
        END
    ELSE
        R_1(x,y)=0;
    END
    END_y
END_x
```

[1]Bojan Prlinčević, Polytechnic School for vocational studies, Nušićeva 6, Zvečan, Serbia, E-mail: b.prlincevic@vts-zvecan.edu.rs.

[2]Zoran Milivojević, College of Applied Technical Sciences, A. Medvedeva 20, 18000 Nis, Serbia, zoran.milivojevic@vtsnis.edu.rs.

[3]Darko Brodić, University of Belgrade, Tehnical faculty Bor, V. Jugoslavije 2, 19210 Bor, Serbia, E-mail: d.brodic@tf.bor.ac.rs.

Step 2:

```
Fire_Flag=0;
FOR x=1:M
    FOR y=1:N
        IF R1(x,y)==1 & R2(x,y)==1;
            Fire_Flag=1;
        END
    END
END.
```

Y, C_b and C_r components are generated from RGB components by transformation:

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 0.2568 & 0.5041 & 0.0979 \\ -0.1482 & -0.2910 & 0.4392 \\ 0.4392 & -0.3678 & -0.0714 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix}, \quad (1)$$

where Y luminance, C_b Chrominance Blue and C_r Chrominance Red components.

Values S_{r1}, S_{r2}, S_{g1}, S_{g2}, S_{b1},S_{b2}, S_{cb} and S_{cr} are determined by using histograms of R, G, B, Cr and Cb components. Value Th was experimentally determined and presents the value in which the relation of correctly detected and false detected fires the highest.

Mean values of components Y, C_b, C_r designated as Y_{mean}, C_{b_mean} and C_{r_mean} have been calculated in the following way:

$$Y_{mean} = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} Y(x, y), \quad (2)$$

$$C_{b\_mean} = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} C_b(x, y), \quad (3)$$

$$C_{r\_mean} = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} C_r(x, y). \quad (4)$$

*B. **MIPFD** algorithm*

Applied IPFD algorithm has been modified in the part of decision making and detecting of fire pixels. First step is detecting of fire, it is detected if value of difference Cb and Cr is grether then Th. If conditions in step two are fulfil the fire is confirmed. Modified algorithm is executed in the following steps:

Input: RGB image X_{MxN}.
Output: Fire_Flag (1 fire, 0 no fire).

Step 1:

```
R1(1:M,1:N)=0;
FOR x=1:M
    FOR y=1:N
    IF (|Cb(x,y) - Cr(x,y)|>=Th);
    R1(x,y)=1;
    ELSEIF (R(x,y)<1.3*G(x,y)) | (Cr(x,y)>Scr2) | ...
           (Cb(x,y)>Scb2));
           R1(x,y)=0;
    END
    END
    ENDy
ENDx
```

step 2:

```
Fire_Flag=0;
FOR x=1:M
    FOR y=1:N
        IF R1(x,y)==1;
            Fire_Flag=1;
        END
    END
END.
```

III. Experimental results and analysis

A. Experiment

For the purpose of determination of IPFD (section II.A) and MIPFD (section II.B) algorithms, the experiment has been conducted within which the image processing from image database and purposefully created Test image was executed. Comparison of Test image and processing results of Test image, in accordance with hypothesis (fire, no fire) and outcomes of the tests, the following is determined: TP (True Positive), FP (False Positive), TN (True Negative) and FN (False Negative) (Table I). By comparative analysis of TP, FP, TN, FN the decision on efficiency of algorithm has been made. The processing has been made for different values of Th.

TABLE I
THE PRINCIPLE OF ERROR CLASSIFICATION

		Real	
		Fire	No fire
Detected	Fire	(TP) True Positive	(FN) False Negative Negative
Detected	No fire	(FP) False Positive	(TN) True Negative

B. Image database

The following is used in experiment a) image database [7] and b) Test image containing 36 fields grouped in three units: a) 12 fire segments, b) 12 smoke segments and c) 12 segments with no fire and smoke.

C. Results

Fig. 1 displays Test image and testing results of Test image for: a) Th=30, b) Th=65 i c) Th=90. Fig. 2 displays visual results of detection efficiency of fire pixels, image X1, by algorithms IPFD and MIPFD and R, G, B, Y, C_b and C_r components.

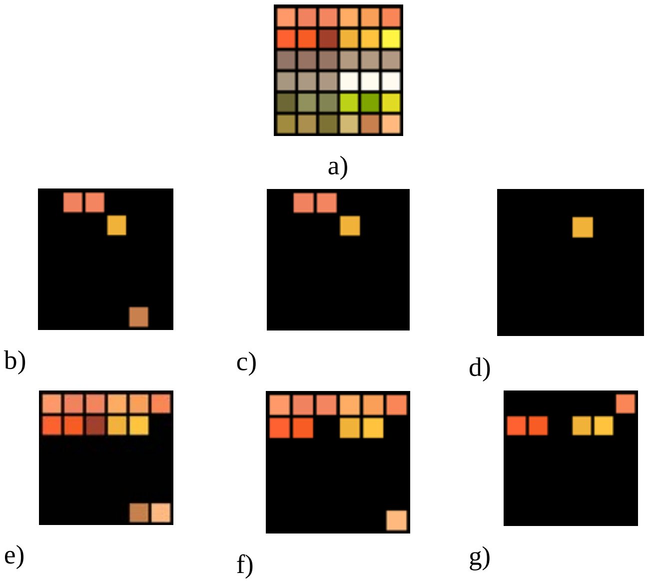

Fig. 1. a) Test image and results of processing of Test image: b) for Th=30 (IPFD), c) for Th=65 (IPFD), d) for Th=90 (IPFD), e) for Th=30 (MIPFD), f) for Th=65 (MIPFD), g) for Th=90 (MIPFD)

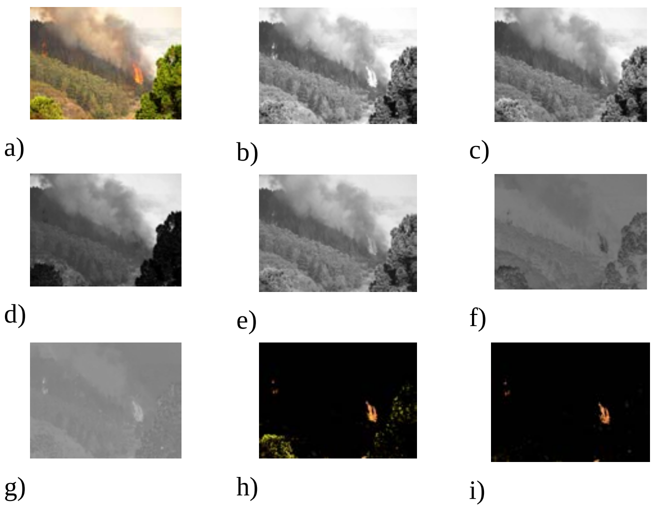

Fig. 2. Results of processing of fire image X1: a) original image, b) R-component, c) G-component, d) B-component, e) Y- component, f) Cb- component, g) Cr- component, h) fire image (IPFD) and i) fire image (MIPFD) for Th=65

Fig. 3 displays visual results of detection efficiency of fire pixels, image X2 and X3, by algorithms IPFD and MIPFD. Results of TP, FP, TN and FN depending on Th for both algorithms are graphically presented on Fig. 4. Diagrams displayed on Fig. 5. are presented FP, TP, FN, TN of applied algorithms depending on Th. Percentage values of TP, FP, TN and FN depending on Th for algorithms IPFD and MIPFD are given in Table II.

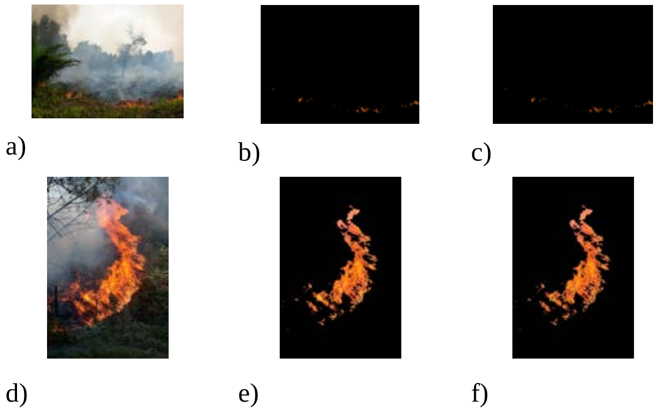

Fig. 3. Results of fire image processing X2 and X3: a) original image-X2, b) fire image-X2 (IPFD), c) fire image-X2 (MIPFD), d) original image-X3, e) fire image-X3 (IPFD) and f) fire image-X3 (MIPFD), for Th=70

TABLE II
PERCENTAGE VALUES OF TP, FP, TN AND FN DEPENDING ON TH FOR IPFD AND MIPFD ALGORITHMS

Algorithm	Error	Th							
		0	10	20	30	40	50	55	60
IPFD	TP	25	25	25	25	25	25	25	25
	FP	75	75	75	75	75	75	75	75
	FN	4,2	4,2	4,2	4,2	4,2	4,2	4,2	4,2
	TN	95,8	95,8	95,8	95,8	95,8	95,8	95,8	95,8
MIPFD	TP	91,7	91,7	91,7	91,7	91,7	91,7	91,7	91,7
	FP	8,3	8,3	8,3	8,3	8,3	8,3	8,3	8,3
	FN	16,7	16,7	16,7	8,3	8,3	8,3	8,3	8,3
	TN	83,3	83,3	83,3	91,7	91,7	91,7	91,7	91,7
		65	70	75	80	85	90	95	100
IPFD	TP	25	25	25	25	8,3	8,3	8,3	0
	FP	75	75	75	75	91,7	91,7	91,7	100
	FN	4,2	0	0	0	0	0	0	0
	TN	95,8	100	100	100	100	100	100	100
MIPFD	TP	91,7	83,3	83,3	83,3	58,3	41,7	33,3	25
	FP	8,3	16,7	16,7	16,7	41,7	58,3	66,7	75
	FN	8,3	4,2	0	0	0	0	0	0
	TN	91,7	95,8	100	100	100	100	100	100

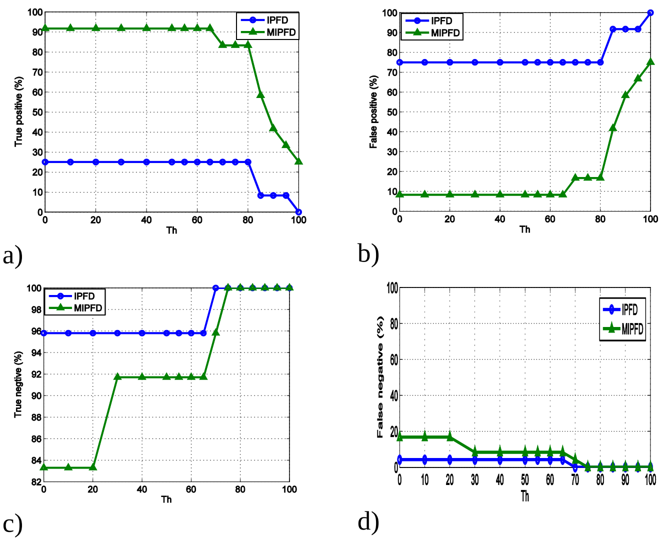

Fig. 4. Dependence diagram of TP, FP, TN, FN parameters of applied algorithms depending on Th: a) True Positive, b) False Positive, c) True Negative i d) False Negative

D. Analysis of results

According to results presented on Figs 1-4 and Table II, the following can be concluded:

a) optimal value is Th=65, which can be concluded according to Table II,

b) the percentage of successfully detected fire pixels (TP) is significantly better at MIPFD algorithm. At Th=65, the percentage of successfully detected fire pixels is 91.7%, and in analyzed IPFD algorithm the percentage of successfully detected fire pixels is 25%.

c) the percentage of false detected fire pixels (FP) in MIPFD algorithm at Th=65 is 8.3%, and in IPFD algorithm the percentage of false detected pixels is 75%,

d) the percentage of successfully detected pixel (TN) of environment in MIPFD algorithm at Th=65 is 91.7%, and in IPFD algorithm 95.8%, and with the increase of Th=75 the percentage of successfully detected pixels of the environment increases up to 100%,

e) percent of false detected pixels (FN) of the environment in MIPFD algorithm at Th=65 is 8.3%, and in IPFD algorithm is 4.2% and with the increase of Th=75 the percentage of false detected pixels of the environment decreases to 0% in MIPFD algorithm.

According to previous analysis it can be concluded that MIPFD algorithm is more efficient than IPFD algorithm. In addition, its numerical complexity is significantly smaller, and therefore is suitable for implementation into systems for real time operation.

IV. Conclusion

The efficiency of the proposed MIPFD algorithm for detection of fire pixels in the image was analyzed in the paper. Analysis was conducted for Test image at varying Th=0-100. The optimal value for Th=65 has been determined. Thorough analysis of the parameters for detection of fire pixels in the image has shown an extreme efficiency of MIPFD algorithm. In analyzed Test image, at Th=65 (optimal value) the fire pixel (TP) was successfully detected in 91.7%, of the cases, which is for 66.7%, better result comparing to analyzed IPFD algorithm. Also, MIPFD algorithm demonstrated extreme efficiency in detecting environment (TN) and false fire pixels (FP), the efficiency of MIPFD algorithm has been significantly improved in detecting of false fire pixels (FP) compared to IPFD algorithm. Due to its efficiency and small numerical complexity MIPFD algorithm is suitable for implementation into systems for real time operation.

References

[1] J.R. Gonzalez, M. Palahi, A. Trasebores, T. Pukkala, “a fire probability model for forest stands in Cataonia (north-east Spain)”, Annals of Forest Science, pp.169-176, 2006.

[2] E. Kuhrt, J. Knollenberg, V. Mertens. “An Automatic Early Warning System for Forest Fires”, Annals of Burns and Fire Disasters, vol. XIV, pp. 151-154, 2001.

[3] G. Marbach, M. Leopfe, T. Brupbacher, “An image processing technique for fire detection in video images”, Fire Saf. J. 41 (4), pp 285-289,2006.

[4] T. Celik, H. Demirel, H. Ozkaramanli, “Automatic Fire detection in video sequences”, Proceedings of European Signal Processing Conference, September 2006.

[5] T. Celik, H. Demirel, H. Ozkaramanli, “Fire and smoke Detection without Sensors: Image Processing Based Approach”, Proceedings of 15th Eiuropean Signal Processing Conference, Poland, September 3-7, 2007.

[6] V. Vipin, “Image Processing Bassed Forest Fire Detection”, International Journal of Emeging Technology and Advanced Engineering, ISSN 2250-2459, Vol.2, Issue 2, February 2012.

[7] Forest fire images: http://www.flickr.com.