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Forest Fire Smoke Detection in Video Based on Digital Image Processing Approach with Static and Dynamic Characteristic Analysis

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Abstract— **In this paper, propose a method for forest fire smoke detection in video based on digital image processing approach with static and dynamic characteristic analysis. The proposed method is composed of four steps. The first step is to detect the area of change in the current input frame against the background image. Second step is to locate regions of interest (ROIs) by connected component algorithm, calculate area of ROI by convexhull algorithm and segment the area of change from image. Third step is to analysis and calculate static and dynamic characteristic. Finally, we decide whether the objects that have changed in that picture is the smoke or not. The experimental result with simulated forest fire smoke and the moving object video show that our method effectively and accuracy detect fire smoke.**

Keywords- static and dynamic characteristic; regions of interest; connected component algorithm; convexhull algorithm

I. INTRODUCTION

Forest fire monitoring system can be done several ways such as using people who have a fire tower for observation combined with the actual inspection, satellite images and both of video surveillance and image processing. The forest fire monitoring system using people can be diagnosed correctly than other methods, but there is a problem if people can not work continuously. For the monitoring system using satellite images its non real time system and a high budget [1]. The monitoring system with method of image processing has received more and more attentions from researchers [2-4] because it have low cost, real time system and in addition have other supporting technologies can work together. Then the forest fire monitoring system with images from video surveillance and image processing is appropriate method in the present.

The most of research proposed many techniques and method for the forest fire monitoring system with image from video surveillance by analysis many characteristic of forest fire such as flaming color, moving direction and color of smoke. Research of image based forest fire detection using dynamic characteristics with artificial neural networks [1] proposed to area analysis of flaming for classify fire similarly objects. Research of forest fire detection based on video multi feature fusion [5] proposed to analysis color of flame with region growing. There are also another groups research proposed method for detect forest fire with feature of smoke such as color, area of change to analysis and decide weather that is fire or not.

In this paper, propose a method for forest fire smoke detection in video based on digital image processing approach with static and dynamic characteristic analysis. The structure of this paper is composed as follows. Section I, introduction of forest fire smoke detection method and other research related. Section II, forest fire smoke characteristic and digital image processing are presented. In this section show the meaning of static and dynamic characteristic of smoke and how to smoke detection with digital image processing. Section III, propose forest fire smoke detection approach. Section IV, the experimental. This section show detail of input image for experiment, step and approach of experimental. Section V, the experimental result. Finally, is the conclusion and future work.

II. CHARATERISTIC OF SMOKE AND DIGITAL IMAGE PROCESSING

Forest fire smoke detection based on digital image processing will be use characteristics of smoke to analysis. But the smoke has certain and uncertain characteristics. Then, its difficult to decide whether smoke or not. We will classify both of certain and uncertain characteristic into two groups.

A. Static Characteristc

Static characteristic is certain characteristic or value of smoke. In this research interested about color. The most of smoke is gray. Light gray or dark gray are gray color. We calculate this value and use to classify smoke from other similar object

B. Dynamic Characteristc

Dynamic characteristic is uncertain characteristics or value of smoke such as area of smoke, moving direction, shape and growth of region. In this research interested about area of smoke because its will be continue change. The most of other object have shape or area certain but the smoke can not define shape. Then we will be analysis and calculate this value to classify smoke from other similar object

Forest fire monitoring system based on digital image processing is used. It can work in wide area, long distance and real time. Both of characteristics are used to analysis and calculate with digital image processing approach.

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III. Forest Fire Smoke Detection Approach

Proposed method is composed four steps. There is improvement of [1] and [7] to define and classify smoke from similar object. A flow chart of the proposed is show in Fig. 1

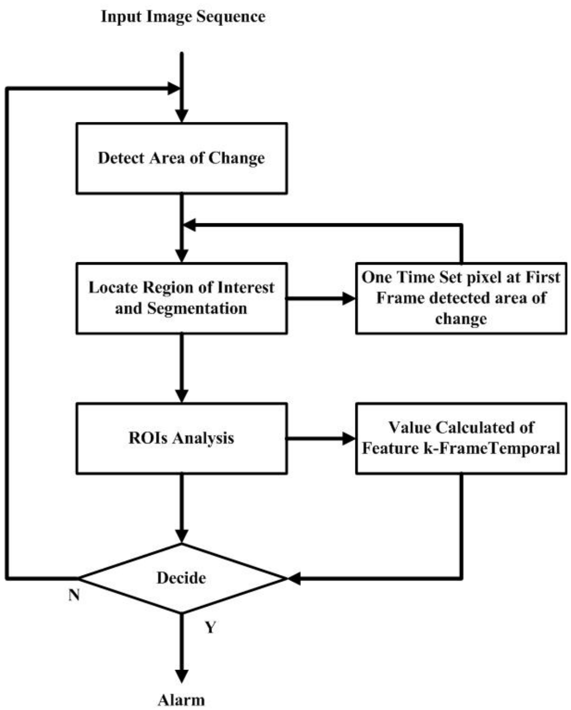


Figure 1. Flow chart of proposed method.

In this paper we use RGB and YUV color model. An input image sequence from a surveillance camera will be converting from RGB to YUV. The camera is often mounted on a pan/tilt device and no movement.

A. Detection Area of Change

The first step of the method proposed is detection area of change. An image processing will use the value of Y color model. Process starting from the first frame to read and save image as background imBG(t,x,y), then read the second frame or current image and save to imIN(t,x,y). Next, convert imBG(t,x,y) and imIN(t,x,y) from RGB to YUV color model. The absolute value of differential image is calculated as equation (1)

$$imDF(t,x,y) = |imBG(t,x,y)-imIN(t,x,y)| \quad (1)$$

If the smoke appear or other object are moving in an image at t and t-1. That is current input image imIN(t,x,y) has difference from previous input image imBG(t,x,y). The calculated value will keep into imDF(t,x,y). But if not difference all values in imDF(t,x,y) are zero.

B. Locate Region of Interest and Segmentation

The second step, after we have difference image imgDF(t,x,y) we use this image to locate region of interest (ROIs) and segment area of change. The imDF(t,x,y) will be changed into the binary image which records significant change is obtained by equation (2).

$$imBN(t,x,y) = \begin{cases} 1 \text{ if } imDF(t,x,y) \geq Th \\ 0 \text{ otherwise} \end{cases} \quad (2)$$

The connected component algorithm is applied to find regions of connected pixels which have the same value. The erode and dilate operation can be applied to remove small size area of change of binary image imBN(t,x,y).

To segment ROIs, we use convexhull algorithm to draw polygon enclose area of change and draw rectangle using data from imBN(t,x,y). From rectangle area we know imBN(t,x_0,y_0) and imBN(t,x_1,y_1) where (x_0,y_0) is left top pixel position, (x_1,y_1) is right bottom pixel position. Then we can segment area of change in imBN(t,x,y). The number of image segmentation in imBN(t,x,y) is N where N = 2, 4, 6, 8, ... and position of each section is P_{ij} where i = 1 to n on x axis and j = 1 to m on y axis. Now we can load area of change to process in next step.

C. ROIs Analysis

The third step, we will be calculate static and dynamic characteristic of ROI. The polygon area, rectangle area and pixel color value are calculated. To analysis pixel color is using equation (3)

$$\alpha_{xy} = (R_{xy} + G_{xy} + B_{xy})/3 \quad (3)$$

Equation (3) α_{xy} is average color value of RGB in each pixel. α_{xy} is used to find gray color by absolute difference of RGB and compare with TH follow equation (4)

$$\begin{aligned} &\text{if } |R_{xy}-\alpha_{xy}| \,\&\, |G_{xy}-\alpha_{xy}| \,\&\, |B_{xy}-\alpha_{xy}| < TH \quad (4) \\ &\qquad \text{gray color} \\ &\text{else} \\ &\qquad \text{not gray} \end{aligned}$$

Static characteristic is value of gray pixel if number of gray pixel in rectangle if more than 1/4 of rectangle area its can be TRUE, otherwise is FALSE. Dynamic characteristic is value of polygon area if it alternative change can be TRUE, otherwise is FALSE. We consider segmentation area of change P_{ij} if the calculated values are keep in the feature temporal for k input image frame where k = 30 are consecutive position its can be TRUE.

D. Classification of Smoke

In final step, we use the rule to decide whether ROI is smoke or not by consider the calculation values from step III. The rule show in equation (5)

$$\begin{aligned} &\text{if}((GrayColor)\&(AreaChanged)\&(ConPosition)) == TRUE \\ &\qquad \text{smoke} \quad (5) \\ &\text{else} \\ &\qquad \text{not smoke} \end{aligned}$$

Equations (5) is the rule used to classification or decide smoke. The 1st condition if number of gray pixel is TRUE and the 2nd condition if area is change for 30 frame consecutive is TRUE and the 3rd condition if position of image segmentation is TRUE then we can decide whether that is smoke. If some condition is FALSE we will be decide whether that is not smoke.

IV. THE EXPERIMENTAL

The experiment, we use 3 video records. The first is example video which no smoke and no moving object, the second record is video with moving object and the third record is simulated video of forest fire smoke. All videos are recorded from video recorder and it mounted on device pan/tilt and no move. The input image will be get from stationary camera. We set image resolution to 10 mega-pixel, set image size 640x480 pixel, and set frame rate to 30 frame/second. All of video records are captured into image has file extension name to JPEG. File size of each an image around 95 KB. We use 100 image from video recorded for experiment and time difference from t and t-1 is 1 second. Then, time to read input image we can adjust to seemly. Our program is implemented using MATLAB. Figure 2-5 below are example image captured from video records 1-3 consecutive.

Figure 2. The example image captured from video records 1.

Figure 3. The example image captured from video records 2.

Figure 4. The example image captured from video records 3.

The experiment started with the first step, the first frame will be read and save image as background imBG(t,x,y), then read the second frame or current image and save to imIN(t,x,y). Next, convert imBG(t,x,y) and imIN(t,x,y) from RGB to YUV color model and calculate absolute difference image value follow equation (1). The calculated values are save to imDF(t,x,y).

The second step, we use imDF(t,x,y) to locate region of interest (ROIs) and segment area of change. The imDF(t,x,y) is changed into binary image follow equation (2) with Th=4. The connected component algorithm is applied to find regions of connected pixels which have the same value and erode and dilate operation are applied to remove small size area of change with square 8x8 pixel in erode function. Next, we use convexhull algorithm to find area of area of change and draw rectangle cover it by button right and top left pixel position. Now we can know P_{ij} and use P_{ij} to load sub area of next image to process.

The third step is ROI analysis. P_{ij} is sub image that use to calculate. The 1st calculated value is pixel color follow equation (3) and (4) by define TH=0.1. The 2nd calculated value is area of smoke which cover with rectangle. Both of values are keep into feature k-frame temporal where k=30.

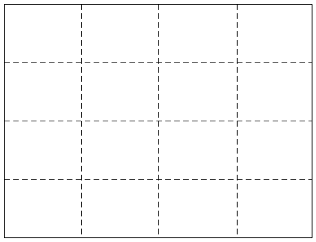
Final step is decide whether ROI is smoke or not by the rule in equation (5). We can decide that is smoke if all value of each an image will be TRUE for 30 frame consecutive if not the system will read input image number 31 save to imIN(t,x,y) and start system in first step again.

V. THE EXPERIMENTAL RESULTS

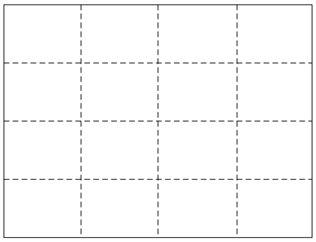
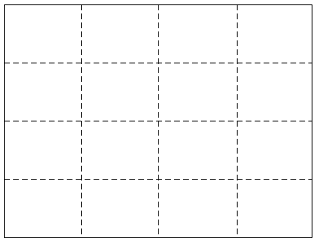
The experiment result from video record 1-3. We show result of detected area of change and segmentation where N=12. Next, show that statistic graph comparison of each video and show statistic table of experiment.

A. Detect Area of Change

Figure 5 (a) show detection area of change of video record 1 at t=1. Figure 5(b)–(d) show segmentation at t=20, 50 and 90 second. Program is not load image to process because its can't detect area of change.

(a) Detection area of change t=1 (b) segmentation t=20

(c) Segmentation t=50 (d) segmentation t=90

Figure 5. Detect area of change and segmentation from video records 1.

Figure 6(a) show detection area of change of video record 2 at t=1. Figure 6(b)–(d) show segmentation at t=20, 50 and 90 second. Program is load image segment P_{ij} where i=1 to 1 and j=1 to 4. At t=20, after load image segment P_{ij} is not area of change, t=50 have a little area of change and t= 90 have area of change but not smoke.

(a) Detection area of change t=1 (b) segmentation t=20

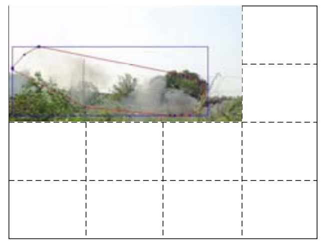
(c) Segmentation t=50 (d) segmentation t=90

Figure 6. Detect area of change and segmentation from video records 3.

Figure 7(a) show detection area of change of video record 3 at t=1. Figure 7(b)–(d) show segmentation at t=20, 50 and 90 second. Program is load image segment P_{ij} where i=1 to 3 and j=1 to 2. At t=20, after load image segment P_{ij} for t=2 to 100 continues have area of change and it is smoke.

(a) Detection area of change t=1 (b) segmentation t=20

(c) Segmentation t=50 (d) segmentation t=90

Figure 7. Detect area of change and segmentation from video records 3.

B. Statistic Graph Comparison

The experimental result of this section show statistic graph comparison of each video record.

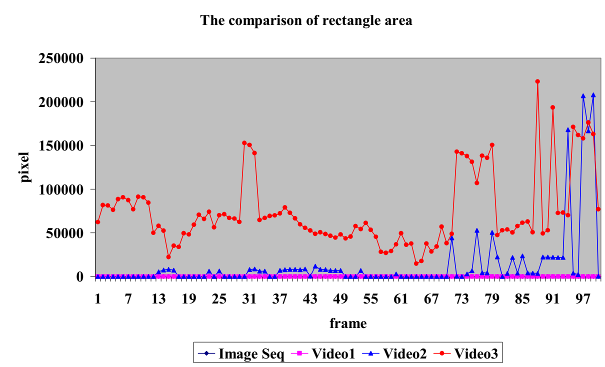


Figure 8. The comparison of video records 1-3 with rectangle area.

Figure 8 show the comparison of rectangle area cover area of change. We can see number of pixel value in video record 3 its continuous and significant change. Number of pixel value in video 1 and 2 are small change and discontinuous.

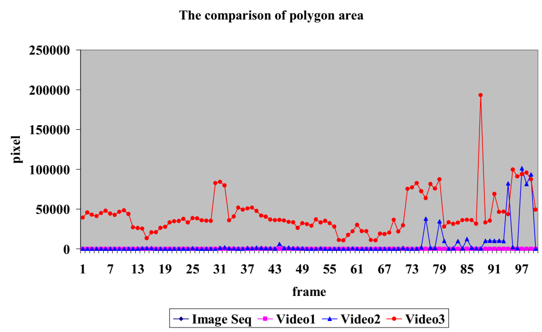


Figure 9. The comparison of video records 1-3 with polygon area.

Figure 9 show the comparison of polygon area of ROI. We can see number of pixel value in video record 3 its continuous and significant change. Number of pixel value in video 1 and 2 are small change and discontinuous.

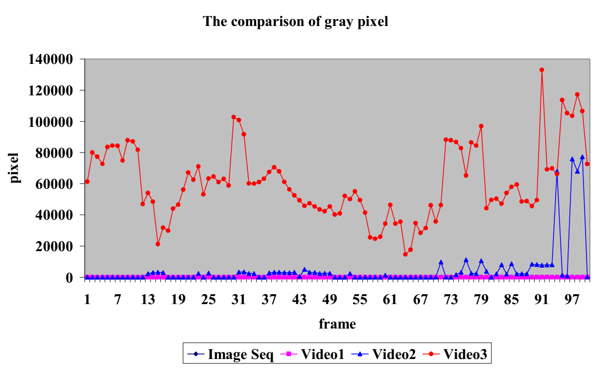


Figure 10. The comparison of video records 1-3 with gray pixel.

Figure 10 show the comparison of gray pixel. We can see a lot of number of gray pixel in video record 3. But the gray pixel in video 1 and 2 are small number.

C. *Statistic Table of Experimental*

The experimental result of this section show statistic table of static and dynamic characteristic of ROIs are calculated. The values are used to analysis and decide whether smoke or not show in TABLE I.

TABLE I. SMOKE DETECTION RESULT

Video Seq.	***1st Frame Detected***	***# Frame Area of Change***	***#Frame of Area/4 ≤ Graypixel***	***Max # of Segment Loaded Consec.***	***#Total of Frame***
Video1	2	17	17	2	100
Video2	2	90	24	13	100
Video3	1	100	79	87	100

From TABLE I. Video record 3 is simulated forest fire smoke. We can detect 1st frame area of change at t=1, number frame area of change is 100, number of gray pixel more than rectangle area/4 is 79 frame and maximum number of segment loaded consecutive is 87 frames.

VI. CONCLUSION AND FUTURE WORK

In our experiment, we consider forest fire smoke detection in three video records using digital image processing approach with static and dynamic characteristic analysis. The experimental result show that the proposed method can detect smoke effectively and accuracy. To analysis calculated value will use n frame where if n is very most the result is high accuracy and on the other hand if n is very little the result is low accuracy. Threshold value can be adjust to seemly with input image. Proposed method strict to input image will be get from stationary camera and the first frame set to background will be considered select.

Future work, to develop other input image such as the clouds are moving and improvement method to detect smoke with long distance and slow moving.

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