Video Based Smoke Detection Algorithm Using Image Processing Techniques

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Abstract

In this paper, we present an image based algorithm for detecting smoke from the videos of forest fire. Proposed algorithm consists of following steps for features extraction for detecting smoke. A live video is acquired and chopped with size of 120 frames. The first frame of video is set as reference frame and image difference is calculated for current frame using background extraction technique. Potential objects for smoke in a frame are extracted using the calculated difference image. All required parameters like grey pixel, area change and position change are calculated for every object identified. Final decision to declare segment/object as smoke or non-smoke is carried out after evaluating parameters extracted for an object. The proposed technique is tested with 5 different videos, and results have shown 99% accuracy in detecting the fire smoke with no false alarms.

Keywords— forest fire smoke detection, image processing, characteristic parameters, region of interest, smoke pixels position algorithm, MATLAB.

I. Introduction

Forest fire smoke detection can be done in several ways such as using lookup towers, satellite images, wireless sensors network, unmanned air vehicles and video based image processing. Human observation is used in lookup towers, which requires continuous human intervention. Satellite images cannot be used for smoke detection due to its high cost [1]. Deployment of sensors to large area makes wireless sensors networks impractical and costly. [2]. An Unmanned air vehicles fire detection system also requires continuous monitoring. The popularity of image processing methods for monitoring systems has gain exponential attentions among researchers. Advantages of image processing monitoring systems are low cost, real time monitoring and integration to other system. These advantages make it an appropriate method for fire detection (smoke detection) [3-5].

In literature, artificial neural networks image based fire detection is used by analyzing flame change area [1]. Video multi feature fusion, used fire pixel classification for flame to detect smoke [7]. Other features such as spatial, spectral and temporal are used for optimized results [8]. Other techniques such as adaptive background subtraction using moving blob classification [9], virtual environment based on cellular model [10] and fuzzy logic through color features has provided significant results [11].

In this paper, a video based smoke detection algorithm has been presented to detect forest fire. The structure of this paper is as follows: Section II gives an overview about our proposed algorithm and discuss proposed algorithm in detail; which includes background subtraction, ROI extraction, grey scale algorithm, smoke pixel position algorithm and decision based upon characteristic parameters of smoke. Section III show experimental results with sample and live videos. Section IV shows conclusion, recommendations and future work.

II. Proposed Algorithm

In case of forest fire, smoke is the first indicator; hence using certain characteristics of smoke, it is possible to determine fire in early stages. Characteristics include colour of smoke (mostly smoke is of grey colour), continuous area change and position variation. Block diagram below show the working principle of algorithm. The acquisition block first extracts the reference frame from video stream input. The reference frame stays constant throughout the system process. The extracted current frames and reference frame are converted into binary image in pre-processing block. The background subtraction method is used for binary image conversion. The potential Region of Interest (ROI) objects from binary images are estimated in ROI extraction block. The parameters extraction blocks determine the grey scale level, area change and variation in pixels position of the ROI objects. The classification of objects as smoke is based on the extracted parameters.

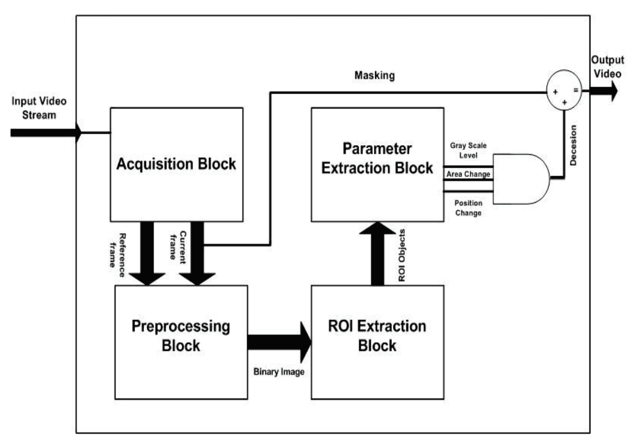


Figure.1 Block diagram of proposed algorithm

A. Input video Stream

Camera is fixed at a specified remote location to capture the live streaming video. The live video streaming is segmented into chunks with size of 120 frames each. One decision is generated after processing a single video chunk.

B. Acquisition Block

i. Reference Frame

The first frame of video is reference frame (*imref*) in RGB color space. The *imref* stays constant throughout the system processing.

ii. Current Frame

Every next frame apart from first frame will be the current frame (*imcurr*) in RGB color space is used with *imref* for features extraction.

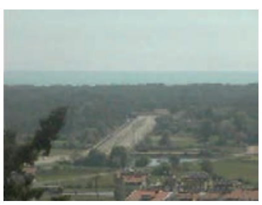
Features i.e. frame number, grey value, area change and position of the pixels will be extracted for each current frame. The extracted features will then be used to deicide presence of smoke.

C. Preprocessing Block

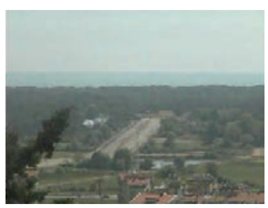
i. Binary Image

The current frames (*imcurr*) and reference frame (*imref*) is converted from RGB to YCbCr color space. Now reference frame (*imref*) will be compared with all other frames (*imcur*) one by one to calculate absolute difference using following equation [12].

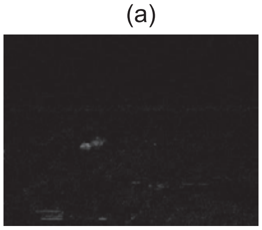
$$imdiff\,(t,x,y) = |mref\,(t,x,y) - imcurr\,(t,xmy)| \qquad (3)$$



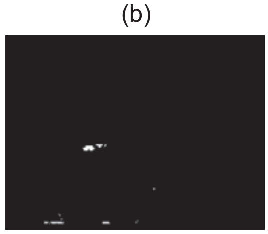
(a)



(b)



(c)



(d)

Figure.2 (a) Reference Image, (b) Current image, (c) Absolute difference of (a) and (b), (d) Binary image

The binary frame is estimated according to following equation [12].

$$\begin{aligned} &\text{if} \\ &imdiff\,(t,x,y) \geq Th \\ &imbin(t,x,y) = 1 \\ &\text{else} \qquad (4) \\ &imbin\,(t,x,y) = 0 \end{aligned}$$

Where ***Th*** is the specified threshold value used to define the limit of motion identified, in our case it is set to 40. And *imdiff* is absolute difference of reference image and current frame. Morphological operation are applied on the binary image to refine the segments by removing unwanted spurs, filling holes, removing tiny areas, or thinning lines.

D. Region of Interest

The blob analysis identifies potential Region of Interest (ROI) using grey pixel as showing in figure 3. The grey pixel along with area change and position change of ROI are also estimated for decision making process. The blob analysis extracts ROI. Certain properties i.e. area, position of pixels of ROI has been calculated as well. A rectangle has been drawn to show the ROI in figure 3, two objects are detected as a potential candidate for smoke. As both the objects identified have pixel in grey colour for area marked with green rectangular box. Final decision regarding smoke presence will be taken after evaluating the area change, grey colour and position of pixels within ROI.

Figure. 3 Rectangle indicating ROI

E. Parameters Extraction

i. Grey Scale Algorithm

In order to determine the grey colour, average colour values of RGB in each pixel is calculated for objects extracted of current frame (*imcurr*). This average colour value along with the determined threshold used to determine grey scale value [1].

ii. Area Change Algorithm

In order to determine the area change, the area of object extracted of current frame is compared with the area of that object in previous current frame. If change in area exist either increase or decrease it means it's not a fixed shaped object so the area change parameter is set true for that object.

iii. Position Change Algorithm

The position change of objects is estimated if grey scale and area change algorithm result true for those objects. We have proposed an algorithm to identify change in position of objects extraction in consecutive frames.

The algorithm works on the features calculated of objects identified in consecutive frames, the detail of algorithm is as follow:

I. Extract x and y values for objects for each frame

ii. Eliminate objects with same x and y values using histogram count

iii. Define window to calculate change in position of object

iv. If objects is not within defined window

Position Change is True

Else

Position Change is False

To experiment our algorithm we check it on the same video from where we have extracted images in figure 1 and 2. We were getting following data in which all grey values where true because of things similar to smoke.

TABLE I

FEATURE STRUCTURE FROM FRAME 610 TO 1590

Frame	Grey value	Area	X- Position	Y- Position
610	1	94	123.500	230.574
620	1	77	134.103	228.883
870	1	101	83.504	226.930
1360	1	81	84.753	231.716
1370	1	136	98.838	226.992
1390	1	164	125.969	226.457
1410	1	90	87.9444	225.977
1440	1	86	86.488	228.7446
1450	1	78	66.769	228.115
1470	1	76	89.539	231.710
1530	1	90	113.122	137.000
1540	1	93	113.494	136.935
1550	1	89	113.370	136.910
1560	1	107	113.000	137.028
1570	1	109	112.908	136.944
1580	1	121	112.710	137.297
1590	1	124	112.887	137.032

Now we can see in Table I that all grey values are 1 i.e. grey parameter TRUE and have significant area change as well, which make them potential object of smoke. But as we can see that X-position is changing continuously with no significant pattern. After implementing our proposed smoke pixels position algorithm we got values as in Table II.

TABLE II

FUTURE STRUCTURE FOR SMOKE PIXELS

Frame	Grey value	Area	X- Position	Y-Position
1530	1	90	113.122	137.000
1540	1	93	113.494	136.935
1550	1	89	113.370	136.910
1560	1	107	113.000	137.028
1570	1	109	112.908	136.944
1580	1	121	112.710	137.297
1590	1	124	112.887	137.032

This indicates that our proposed algorithm deletes the values that are potential candidate for smoke but actually they are not a smoke object.

F. Classification

Final decision regarding smoke presence is taken based upon the grey colour, area change and positions of pixels. To identify object as smoke based upon grey colour only than there is high chance of wrong detection. The prime factor for declaring an object as smoke is pixel colour and another characteristic of smoke is that it does not maintain its shape thus has a continuous change in area. But as seen in Table I these two factors may not be enough to declare any object as smoke. The most important factor is the position of pixels in potential smoke objects. Smoke cannot change its position very quickly, thus variations in smoke pixels position cannot be very significant in consecutive frames. We proposed smoke pixels position algorithm which will eliminate any such wrong results.

i. Smoke Objects

For declaring an object as smoke all three parameters (grey level, area change and position change) need to be checked. An object is classified as smoke if and only if it has grey colour, its area is changing continuously and position pixels have very less variations.

ii. Non-Smoke Objects

If an object fails to qualify any of the three parameters (grey level, area change and position change) it will be declared as non-smoke object. An object is classified as non-smoke if don't have grey pixels or its area remain same for a series of frames.

III. Results

For experiment we have used five different video samples. The detailed results are in Table III, to make a decision that there is a smoke in a video the proposed algorithm need to process 120 frames. The set of 120 frames is a window in our case and after processing a window the decision for smoke in this window is declared. For example in video (a) we have 198000 number of frames it mean we have 165 windows and there will be 165 decisions for smoke in this video. As explained earlier an object will be declared as smoke if it have grey pixel, show change in area and retain its positions for at least 10 consecutive frames in a window of 120 frames. Details result of the sample videos processed is shown in Table III.

S/No	Video	Total frames	Potential smoke objects/ frames	Actual smoke objects/ frames	Visual verify objects/ frames	False Alarm
1	a	198000	837	682	682	0/165
2	b	7200	358	356	356	0/60
3	c	1320	68	68	68	0/11
4	d	3840	757	756	75	1/32
5	e	3840	0	0	0	0/32

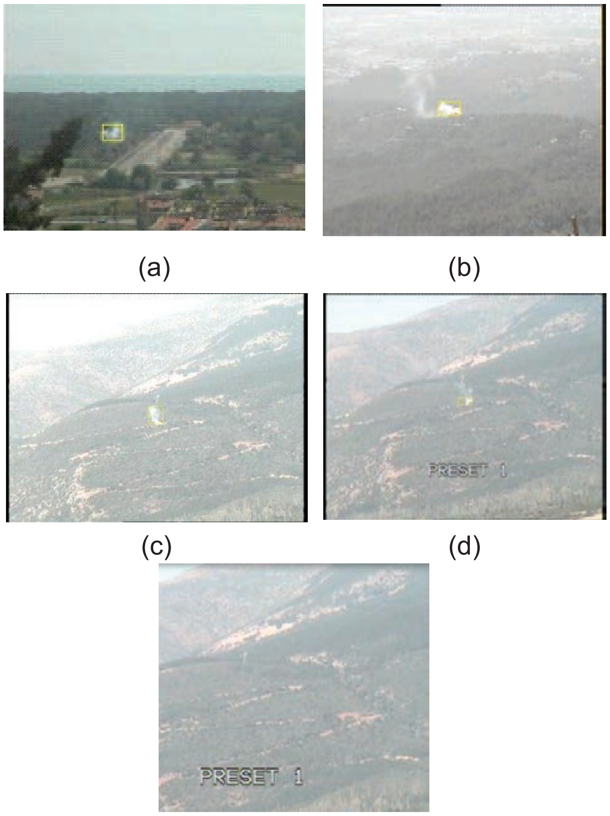


Figure.4 Video Samples

As seen from Table III for sample video (a) system has identified 837 frames having potential candidate for smoke object based on grey pixels criteria and exhibiting continues change in area. So if an algorithm based just on these two parameters will declare them as smoke object. Whereas when we applied our position change algorithm on these objects it was declared only 682 frames as smoke, this was verified by visual inspection of each frame declared as smoke the result was 100%. The objects declared were actually smoke objects no false detection was made.

Similarly other videos were tested and the result was 100% for video (b) and (c). There was just one false decision out of 32 smoke objects detected in video (d) and video (e) was tested to ensure the algorithm behaviour in case there appears no smoke in any of the frames in a video and algorithm made 100% correct decision.

Position change algorithm have shown radical effects to reduce the number of false detection, as there is probability to have grey pixel object in a difference image but when we add the area change with positioning constraints on the object any false potential objects to qualify this criteria. Because object need to qualify these criteria for series of frames. In figure 5 and 6 a graph chart is presented to show the variation of object positioning in case of a smoke object and non-smoke object. In video (a) 837 frames were found potential candidate for a smoke objects but in actual smoke has been detected in 682 frames. Those false objects are detected because of grey colour resemblance and continuous area change, position change algorithm than look for the position variation in x-coordinates to determine smoke. If variation in x-coordinates is within the threshold defined, only than it will be declared as smoke object. As shown in Figure 5 the change in position of x-coordinates is consistent; therefore objects at these positions will be concluded as smoke objects.

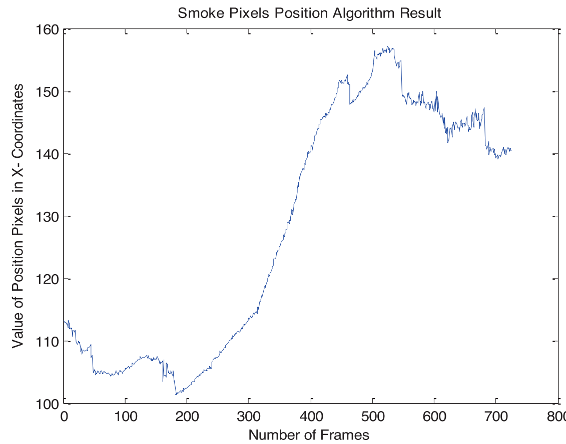


Figure. 5 Positions of x-coordinates in case of actual smoke objects

In Figure 5 it can been seen that x-coordinates of an object shows a steady variation over the number of frames indicating the object is not changing its position frequently. A moving object with grey colour will not be able to pass this criterion as we known once a smoke arise it will never change its position rapidly.

Where in figure 6 it can be seen that potential smoke object shows a rapid change in x-coordinates and the change is random as well. This indicates that it's a moving or a flying object with grey colour. Normally any moving or flying object with grey colour will pass the grey level parameter and area change parameter testing. This phenomenon is explained in figure 6 the graph is for object that exhibit grey colour and changes its area. But when we calculated the position change of the object it shows random behaviour in variation of x-coordinate of object detected.

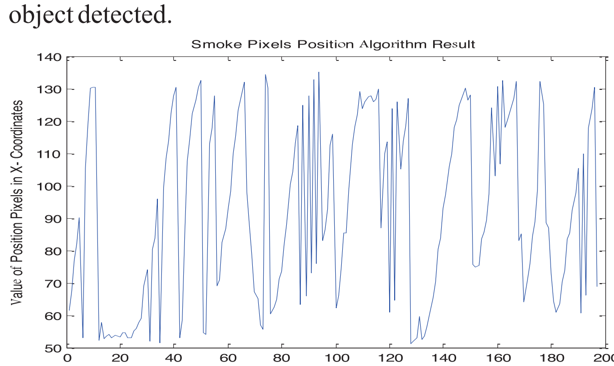


Figure. 6 Positions of x-coordinates in case of actual smoke objects

Our proposed solution performs in-depth testing on an object before declaring it as smoke or non-smoke object. Ensuring that the detected object with parameters defined above must remain in series of frame to eliminate the chance of detecting any random grey pixel object, one can't make a decision for smoke object by simple single frame comparison.

IV. Conclusion

Our proposed algorithm has been checked with five different video clips. As seen from experimental results in Table III and efficiency of our proposed Smoke Pixels Position Algorithm in Figure 5 and 6, it can be concluded that our algorithm works efficiently for long distance smoke videos. Currently the proposed algorithm needs parameter modification if video acquisition position is altered, need to work auto tuning of parameter using video itself. And also currently its taking about 12sec time period of playing and processing a 8 sec video chunk in case of smoke detection, so algorithm optimization need to be done.

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