Colour based fire detection method with temporal intensity variation filtration

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Abstract. Development of video, computing technologies and computer vision gives a possibility of automatic fire detection on video information. Under that project different algorithms was implemented to find more efficient way of fire detection. In that article colour based fire detection algorithm is described. But it is not enough to use only colour information to detect fire properly. The main reason of this is that in the shooting conditions may be a lot of things having colour similar to fire. A temporary intensity variation of pixels is used to separate them from the fire. These variations are averaged over the series of several frames. This algorithm shows robust work and was realised as a computer program by using of the OpenCV library.

1. Introduction
For the early fire detection in areas of high fire risk, it is necessary to monitor such areas regularly. Improvement of monitoring systems can go in several directions: increasing possibility of fire detection at the earlier steps, reducing the cost of monitoring, reducing the influence of the human factor, etc.

Development of video, computing technologies and computer vision gives a possibility of automatic fire detection on video information. Such a system was implemented as a computer program, which uses and processes video information from a video camera with the goal of fire detection. Only task of computer operator in that process—to react to the signals of alarm system in proper time.

Different algorithms was implemented to find a more efficient way of fire detection. Fire detection speed was selected as one of the most important criteria. It gives the possibility to work in a real time.

That work was held under the project called "Program-technical system of detection and prediction of large-scale wildfires".

2. State of the art
Detection of moving objects are often used to find possible fire regions. For this purpose, mainly two ways are used: consecutive frames subtraction and background subtracting [1]. In the first method changes are calculated in the images during the transition from one frame to another. The problem of this method is, that the overlapping area of the images can be mistakenly taken as a background. In the process of background subtraction dynamic regions are extracted from a static background image.

The problem of this method is, that the extracted region can be quite inaccurate if the background image cannot be updated on time or at all. For example, for the forest fire detection this method is not applicable because of moving of trees, which is caused by wind. In that case the most parts of the image becomes dynamic.

Colour selection is another way of finding fire areas. Celik et al. [2] described the colour model of fire in RGB colour space. Decision whether colour pixel belongs to fire is made on the basis of the rules of two groups of inequalities. Chen et al. [3] allocated fire area in RGB colour space using three rules within which each possible fire pixel intensity have to be greater than threshold value. Celik et al. [4] proposed a model to determine the colour of fire pixels in the colour space YCbCr. To decide whether the pixel is a fire pixel a fuzzy inference system is used. System parameters obtained as a result of processing a large number of images with fire. Phillips et al. [5] uses the test data in which the fire manually selected for machine learning to create the necessary colour table. So it is possible to increase the detection accuracy for a specific fire type.

In addition to colour information, the dynamic characteristics of fire are important features, which are usable to separate fire from similar coloured objects.

Phillips et al. [5] calculated temporary intensity variations over several frames. If the temporary variation of definite pixel is more than a certain threshold value (which is typical for flame) the pixel is defined as a fire pixel. Zhang et al. [6] used the fact that the height of the fire varies with time due to movements of the flames, so that feature is taken as the main dynamic characteristics of fire. Torein et al. [7] kept track of the history of changes in the red channel of each RGB pixel of the image belonging to the contour of the fire within a short period of time and uses this data as the input wavelet method.

3. Tools and computing system

As the main tool for video data processing OpenCV was used. It is a popular open source library of computer vision, image processing and general-purpose numerical algorithms.

The fire detection software was implemented in C++ language. Open source integrated development environment (IDE) Eclipse was used as a development environment.

4. Algorithm

The first step of the implemented algorithm described below is a pixel based colour filtration. The system uses stabilized camera. Therefore described algorithm does not use background subtraction as a separate step. Methods with a similar realization have the following advantages:

- high processing speed, which makes it possible to use the algorithm in real-time video system;
- the lack of a background image subtraction remove the need of updating it, and thus, gives the possibility of using the algorithm for the detection of forest fires;
- relative ease for implementation.

Next steps include temporary intensity variation filtration and making decision step. The complete block scheme of the algorithm is shown in figure 1. Figure 2 and figure 3 show some examples of correct detected fire situations by using the described algorithm.

4.1. Colour filtration

At the first step the colour analysis is applied. An analysis of the space of abstract mathematical colour models is used, which are sets of 3 or 4 channels. As a colour model the RGB colour space is used. At the first step algorithm searches pixels which have typical fire colour in RGB colour space.

It is determined whether definite pixel is a possible fire pixel by the following equations [2]:

$$\left.\begin{array}{c} R(x,y) > R_{mean}, \\ R_{mean} = \frac{1}{K}\sum_{i=1}^{K} R(x_i,y_i) \\ R(x,y) > G(x,y) > B(x,y) \end{array}\right\} \quad (1)$$

where K is the total pixels number, R_{mean} is the mean value of the red colour at the whole image, *R(x, y), B(x, y)* and *G(x, y)* are the values of the red, blue and green channel of the definite pixel *(x, y)*.

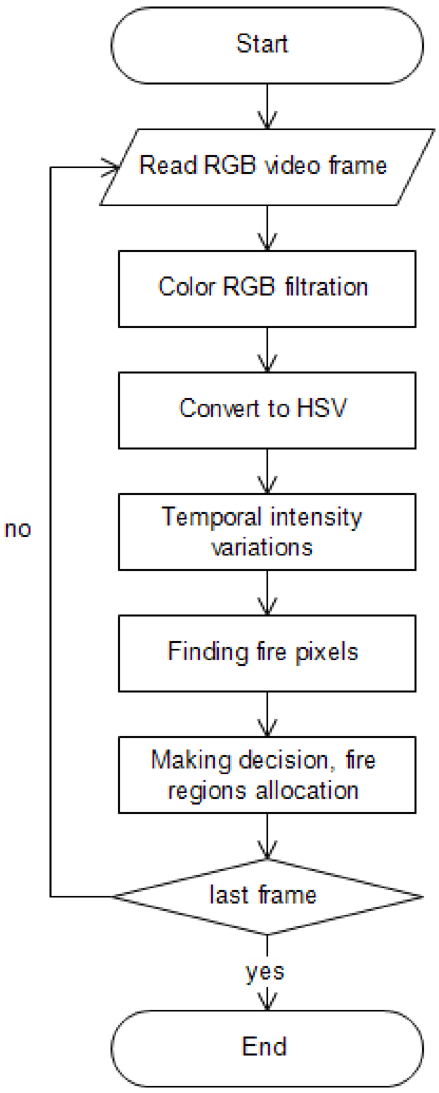

Figure 1. Algorithm block scheme.

Figure 2. Example 1 of fire detection.

Figure 3. Example 2 of fire detection.

These conditions work for most of the fire pixels. Thus if the RGB value of the pixel is within these three conditions, it is supposed that the current pixel is a fire pixel. That information is stored in the fire pixels separate image. Its dimension is equal to the size of one frame of the input video. When the pixel belongs to the RGB colour specified range, the filtered image is calculated as follow:

$$I_{fire}(x, y, i) = 1 \tag{2}$$

where $I_{fire}(x, y, i)$ is the pixel of the *i*-th frame with the coordinates of x and y. Otherwise the pixel is equal to zero.
Figure 4 shows the result image after the first step of algorithm applied on the colour pixels with conditions described above. White pixels are image elements which are equal to one and black ones are equal to zero.

Figure 4. Original snapshot from video (left) and colour filtered image (right).

4.2. *Averaging, fire pixels calculation*

By nature fire is translucent. Therefore, the estimation of fire colour is averaged for a short period of time. First, each frame is estimated by colour accessories. The last n frames are processed to make a decision whether the pixel is a pixel of fire.

To calculate the probability that a colour pixel belongs to the fire, the average value for the last n frames is calculated:

$$I_{av}(x, y) = \frac{\sum_{i=1}^{n} I_{fire}(x,y,i)}{n} \tag{3}$$

with n as the number of averaged frames.

If a pixel value of I_{av} is more than a threshold value k_1, then it is supposed that the pixel is a fire pixel. Thus the new image is calculated:

$$I_{colour}(x, y, i) = \begin{cases} 1 \text{ } if \text{ } I_{av}(x, y, i) > k_1 \\ 0 \text{ } if \text{ } I_{av}(x, y, i) \le k_1 \end{cases} \tag{4}$$

where k_1 is a definite threshold value.

Figure 5 shows a comparison of images I_{fire} and I_{colour}. For our example $n = 5$ and $k_1 = 0.2$. Thus if one pixel of I_{av} image appeared in the last 5 frames at least twice times, then that pixel is a fire pixel and the corresponding element of image is equal to one. As seen from the comparison, the areas of the new image are more saturate than in I_{fire} image because of the data averaging in the series of frames. That step is also useful for the reduction of noise pixels.

4.3. *Temporary intensity variations*

Colour information is not always enough to properly detect fire on video information. The main reason is that there can be many objects in observation conditions, which have a colour similar to fire. To distinguish them from fire, temporary changes of intensity of pixels calculated in a series of shots are used.

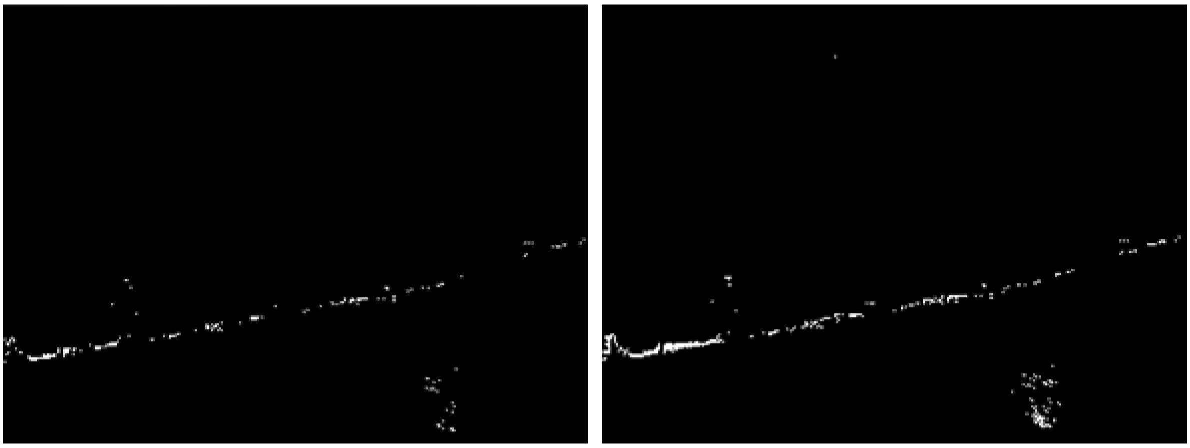

Figure 5. Colour filtered matrix (left) and averaged matrix (right).

In RGB colour space all three channels are colour values and there are no channels with information about the intensity of pixels. One way to solve the problem is to change the colour space to HSV. In this colour space the V channel has information about intensity.

The first using information from V channel of HSV colour space in the form of the temporary intensity variations over *n* shots, which are calculated for each pixel:

$$I_{diff}(x,y) = \frac{\sum_{i=2}^{n} |V(x,y,i) - V(x,y,i-1)|}{n-1} \tag{5}$$

where $V(x,y,i)$ and $V(x,y,i-1)$ is the intensity (V channel of HSV colour space) of pixel with x and y coordinates of current and previous frame respectively.

However, this change of intensity can be wrong, for example in the case where in addition to the intensity flickering of fire pixels overall image intensity changes because of changing lighting conditions. Therefore average intensity change is also calculated for each non-fire pixel of image:

$$I_{diff_a} = \frac{\sum_{x=1}^{m} \sum_{y=1}^{p} I_{diff}(x,y)}{\sum_{x=1}^{m} \sum_{y=1}^{p} 1} \tag{6}$$

where m and p are numbers of horizontal and vertical pixels respectively for which $I_{colour}(x,y) = 0$. At the next step the overall average intensity change I_{diff_a} is subtracted from each pixel of the matrix $I_{diff}(x,y)$:

$$\Delta I(x,y) = I_{diff}(x,y) - I_{diff_a} \tag{7}$$

Matrix ΔI is the actual temporal variation of the intensity of pixels in video information. The influence of environment light condition changes is crucially reduced.

4.4. Fire pixel detection

At that stage it is possible to definitively identify the pixels of fire. If the pixel is a possible fire pixel (using colour condition) and the actual temporal intensity variation $\Delta I(x,y)$ is larger than the threshold value k_2, it means that the pixel is a pixel of fire:

$$I_f(x,y) = \begin{cases} 1, if\ I_{colour}(x,y) = 1\ and\ \Delta I(x,y) > k_2 \\ 0, otherwise \end{cases} \tag{8}$$

Figure 6 shows the final image I_f of fire detection on a video information. In our example $k_2 = 10$. It can be seen from the example that the described algorithm correctly removes pixels with colour which is similar to fire but do not belong to fire. And there are only fire pixels in the final image.

Figure 6. Original source image (left) and final result of detection (right).

4.5. Making decision

The final step in fire detection is to decide whether there is a fire in this video image or not. The easiest way is to count the number of fire pixels detected at previous steps and a further comparison of the amount counted from the threshold value. If quantity of fire pixels is above the threshold, then this means that there is a fire on the video with a high probability. In this case, using the decision, it is possible to display an alarm message on the screen of the computer.

Figure 2 and figure 3 show some examples of correct detected fire situations by using the described algorithm.

5. Conclusion

Development of computer systems and computer vision technologies has made it possible to use an alternative method for monitoring areas where the probability of fire occurrences is high. That algorithm does not require expensive high performance equipment and it can works in real time on a regular personal computer by using a cheap video camera. This algorithm shows robust work and was realised as a computer program by using the OpenCV library.

References

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