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Comparison of Different Methods used for Fire Detection

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Abstract

Fire Detection system plays an important role in surveillance and security systems. Fire detection systems are primarily designed to warn occupants of fire so that they may safely evacuate the premises. Correctly maintained and operating systems are effective and proven life saving devices. The available methods are based on mainly color and motion based methods, which detects fire using the color and motion features of fire. We can also use several classifiers to classify the fire pixels from non-fire pixels. The combination of several classifiers for the training process will give high performance. The system which uses the complementary information, based on color, shape variation, and motion analysis, will give better recognition compared to other methods.
Keywords- Fire detection, Multi-Expert Systems, motion based methods, color based methods

I. INTRODUCTION

Fire detection systems play an important role in security systems. Fire detection systems are primarily designed to warn occupants of a fire so that they may safely evacuate the premises. Correctly maintained and operating systems are effective and proven life saving devices. Failure to take advantage of this early warning, due to poor performance of an automatic fire detection system, has cost people their lives. There should take care about the fire detection and other redemption measures. It is important especially in large building, metropolitan cities, where there is large crowd of peoples. Systems that are not properly installed or maintained may cause unwanted detection activations. This has a negative effect on occupant's responses to genuine detections and as a result downgrades their effectiveness.

There are a number of these detection systems are available to detect these fire and smoke. Fire detection by analyzing videos acquired by surveillance cameras gives better efficiency in the detection process. This scientific effort focused on improving the robustness and performance of the proposed approaches, so as to make possible a commercial exploitation.

This fire and smoke detection is performed by analyzing several features such as color, shape, movement and several other features. So that a strict classification of these methods are not possible. The two main classes can be distinguished, depending on the analyzed features: color based and motion based. The methods using the first kind of features are based on the consideration that a flame, under the assumption that it is generated by common combustibles, such as wood, plastic, paper, or others, can be reliably characterized by its color, so that the evaluation of the color components in RGB (Red, Green, Blue), YUV (Luminance, Chrominance) or any other color space is adequately robust to identify the presence of flames. This simple idea inspires several recent methods: for instance, in some algorithms fire pixels are recognized by an advanced background subtraction technique and a statistical RGB color model: a set of images have been used and a region of the color space has been experimentally identified so that if a pixel belongs to this particular region, then it can be classified as fire. The main advantage of such algorithms lies in the low computational cost allowing the processing of more than 30 frames/s at Quarter Common Intermediate Format (176 X 144) image resolution.

The main problem for the RGB and HSV based approaches is that they are particularly sensitive to the changes in brightness, thus causing a high number of false positive due to the presence of shadows or to different tonalities of the red.
This problem can be mitigated by switching to a YUV color space. In this, a set of rules in the YUV space has been experimentally defined to separate the luminance from the chrominance more effectively than that in RGB, so as to reduce the number of false positives detected by the system. Another algorithm using this YUV color space is information coming from the YUV color is combined using a fuzzy logic approach to consider the implicit uncertainties of the rules introduced for thresholding the image. A probabilistic approach based on YUV has been also exploited, where the thresholding of potential fire pixels is not based on a simple heuristic but instead on a support vector machine (SVM), able to provide a good generalization without requiring problem domain knowledge. Although this algorithm is less sensitive to variations in the luminance of the environment, its main drawback compared with other color based approaches lies in the high computational cost required as soon as the dimensions of the support vector increase.

The wavelet transform has been also used to properly detect the temporal behavior of flame boundaries. It is worth pointing out that the methods based on the wavelet transform, differently from those based on the color, cannot be used on still images and, in general, require a frame rate sufficiently high, higher than 20 frames per second (fps), to guarantee satisfactory results, thus limiting their applicability.

A video is a sequence of a number of frames. These frame-to-frame changes are analyzed and the evolution of a set of features based on color, area size, surface coarseness, boundary roughness, and skewness is evaluated by a Bayesian classifier. The wide set of considered features allows the system to consider several aspects of fire, related to both color and appearance variations, thus increasing the reliability in the detection. The thresholding on the color, performed in the RGB space, is improved by a multi resolution 2-D wavelet analysis, which evaluates both the energy and the shape variations to further decrease the number of false positive events. In particular, the shape variation is computed by evaluating the ratio between the perimeter and the area of the minimum bounding box enclosing the candidate's fire pixels. This last strategy is as simple and intuitive as promising if the scene is populated by rigid objects, such as vehicles. On the other side, it is worth pointing out that the shape associated with non-rigid objects, such as people, is highly variable in consecutive frames, think for instance, to the human arms that may contribute to significantly modify the size of the minimum bounding box enclosing the whole person. This evidence implies that the disordered shape of the person may be confused with the disordered shape of the fire, thus consistently increasing the number of false positives detected by the system.

Another important idea of combining several classifiers to obtain a more reliable decision has been generalized and it will give a good performance. Fire-colored pixels are identified using a hidden Markov model, temporal wavelet analysis is used for detecting the pixel flicker, spatial wavelet analysis is used for the non-uniform texture of flames, and finally, wavelet analysis of the object contours is used to detect the irregular shape of the fire. The decisions taken by the above mentioned algorithms are linearly combined by a set of weights that are updated with a LMS strategy each time a ground-truth value is available. This method has the advantage that during its operation, it can exploit occasional feedback from the user to improve the weights of the combination function. However, a drawback is the need to properly choose the learning rate parameter to ensure that the update of the weights converges and that it does so in a reasonable time.

II. FIRE DETECTION

The subject of fire detection is as old as computer vision, both because of the practical importance of the topic and theoretical interest from cognitive scientists. Several methods are used, which all mainly utilizes the features of fire such as color, Movement and Shape. Some methods are also used which uses sensors to detect the fire.
The different such techniques are explained here:

A. Color Based Fire Detection

Color based detection is done by comparing the color of fire pixels with color of candidate pixels. This is done based on the assumption that, the fire pixels will be having a red-yellow color. The methods which use these kinds of features are mainly under the assumption that, the flames are generated by the common things like wood, plastic, paper and others. So that its color can be reliably characterized by the color components in RGB (Red, Green and Blue), YUV (Luminance, Chrominance) or any other color space is adequately robust to identify the presence of flames.

In [1] T. Celik, H. Demirel, H. Ozkaramanli, and M. Uyguroglu, proposes a method, a real-time fire-detector that combines foreground object information with color pixel statistics of fire. Foreground information is extracted using adaptive background subtraction algorithm which segments the fire candidate pixels from the background. Simple adaptive background model of the scene is generated by using three Gaussian distributions, where each distribution corresponds to the pixel statistics in the respective color channel. Then it verify with the statistical color model, which is generated by statistical analysis of sample images, to detect the fire. The algorithms is having a 98.89 % of detection rate and have a very less computational cost. But the system is more complex and smoke will not detected. This are sensitive to the changes in brightness, thus causing a high number of false positive due to the presence of shadows or to different tonalities of the red.

In [2] Y.-H. Kim, A. Kim, and H.-Y. Jeong proposed a method on wireless sensor networks are used for the application of monitoring forest fires, and developed the fire bug system. These networks used the mobile agents to find the fire source which made the network with greater flexibility. The main steps the system includes detection of moving pixels or regions in the current frame of a video. Color detection of moving pixels and Blob analysis. Application layer gateway will deliver the sensor data from the link layer of wireless sensor network protocol to the network layer of IP protocol over the Internet. The system is having a less computational cost. But this fire detection on wireless sensor networks, is still in the laboratory stage. And these are sensitive to the changes in brightness, thus causing a high number of false positive due to the presence of shadows or to different tonalities of the red.

In [3] T. elik and H. Demirel, a rule based generic color model for flame pixel classification is proposed. The proposed algorithm uses YCbCr color space to separate the luminance from the chrominance more effectively than color spaces such as RGB or rgb. The performance of the proposed algorithm is tested on two sets of images, one of which contains fire, the other containing fire-like regions. The method proposes to use the YCbCr color space to construct a generic chrominance model for flame pixel classification. The steps in the system include, initially pick sample images and then segment its fire pixels with green color. Then we calculate mean values of R, G, and B planes in the segmented fire regions of the original images. It is clear that, on the average, the fire pixels show the characteristics that their R intensity value is greater than G and G intensity value is greater than the B. The proposed method achieves up to 99% fire detection rate and having lower false alarm rate. But the disadvantage is Illumination dependence, means that if the illumination of image changes, the fire pixel classification rules cannot perform well.

In [4] T. elik, H. Ozkaramanli, and H. Demirel, proposes logic enhanced generic color model for fire pixel classification. The model uses YCbCr color space to separate the luminance from the chrominance more effectively than color spaces such as RGB or rgb. Concepts from fuzzy logic are used to replace existing heuristic rules and make the classification more robust in effectively discriminating fire and fire like colored objects. Further discrimination between fire and non-fire pixels are achieved by a statistically derived chrominance model which is expressed as a region in the chrominance plane. The performance of the model is tested on two large sets of images which are one set contains fire while the other set contains no fire but has regions similar to fire color. The model achieves up to 99.00% correct fire detection rate with a 9.50% false alarm rate. The classification more robust in effectively discriminating fire and fire like colored objects. But the system is more complex and computationally expensive too.

In [5] Y. Habiboglu, O. Gnay, and A. E. etin, proposes a novel descriptor based on spatio temporal properties is introduced. First, a set of 3-D blocks is built by dividing the image into 1616 squares and considering each square for a number of frames corresponding to the frame rate. The blocks are quickly filtered using a simple color model of the flame pixels. Then, on the remaining blocks, a feature vector is computed using the covariance matrix of 10 properties related to color and to spatial and temporal derivatives of the intensity. Finally, an SVM classifier is applied to these vectors to distinguish fire from non-fire blocks. The main advantage deriving from this choice is that the method does not require background subtraction and thus can be applied also to moving cameras. However, since the motion information is only considered by considering the temporal derivatives of pixels, without an estimation of the motion direction, the system, when working in non-sterile areas, may generate false positives due to flashing of red lights.

B. Sensor-Based Fire-Detection Method

Fire detection is very important in lots of areas such as mining areas and all. Therefore, having a warning system that is capable of detecting fire and generating an alarm is important. Sensor based fire detection methods are capable of detecting fire by makes use of sensors. The use of sensors generally gives high performance in all kinds of detection processes. The sensors sense the features such as heat, light etc. to take the decision.

In [6] B. C. Ko, K.-H. Cheong, and J.-Y. Nam proposes a new vision sensor-based fire-detection method for an early-warning fire- monitoring system. The different steps include candidate fire regions are detected using methods, like the detection of moving regions and fire-colored pixels. Next, since fire regions generally have a higher luminance contrast than neighboring regions, a luminance map is made and used to remove non-fire pixels. Thereafter, a temporal fire model with wavelet coefficients is created and applied to a two-class support vector machines (SVM) classifier with a radial basis function (RBF) kernel. The SVM classifier is then used for the final fire-pixel verification. To detect fire pixels proposed method uses the red channel threshold, which is the major component in an RGB image of fire flames and saturation values. After determining the candidate fire pixels, the non-fire pixels are removed by analyzing the frame difference between two consecutive images. Moving object that has a similar color to a real fire region are done using temporal luminance variations. The remaining pixels are classified as fire regions or non-fire regions using SVM. The system uses relatively low cost for equipments and having fast response time and fast confirming through the surveillance monitor And also there occurs problems due to temporal variation of pixel are eliminated, which is more robust to noise, such as smoke, and subtle differences between consecutive frames. But the miss rate in fire regions are detected in some cases and also computation time is high.

In [7] C. Yu, Z. Mei, and X. Zhang proposes an algorithm based on foreground image accumulation and optical flow of the video. Accumulation images are calculated of the foreground images which are extracted using frame differential method. The flame regions are recognized by a statistical model build by foreground accumulation image, while the optical flow is calculated and a motion feature discriminating model to recognize smoke regions is used. The algorithm detect mainly in 3 cases which are fire with flame and none smoke, fire with smoke and none flame and fire with both flame and smoke. In the system, foreground image accumulation help to suppress the noise in the video. But, most disturbances like lights and other fire-like color objects can be differentiate from flame efficiently using foreground accumulation image, except that the lights are turned on and off in a same frequency like flame which is found.

C. Color and Movement Based Evaluation

Color based evaluation will help to identify the fire pixels but, it will not be that much accurate in highly populated areas. This is due to these pixels are taken only based on their color. There can be things which match with the same color of fire. So if we are adding the feature, movement along with color based evaluation, it will be more accurate. This is based on the assumption that the fire pixels will be continuously moving nature. So it will be comparing each frame with its previous and next frame for the analysis. So that the fire detection will be little more accurate.

In [8] Xiaojun Qi and Jessica Ebert proposes an algorithm not only uses the color and movement attributes of fire, but also analyzes the temporal variation of fire intensity, the spatial color variation of fire, and the tendency of fire to be grouped around a central point. A cumulative time derivative matrix is used to detect areas with a high frequency luminance flicker. The fire color of each frame is aggregated in a cumulative fire color matrix using a new color model which considers both pigmentation values of the RGB color and the saturation and the intensity properties in the HSV color space. A region merging algorithm is then applied to merge the nearby fire colored moving regions to eliminate the false positives. The spatial and temporal color variations are finally applied to detect fires. The proposed system is effective in detecting all types of uncontrolled fire in various situations, lighting conditions, and environment. It also performs better than the peer system with higher true positives and true negatives and lower false positives and false negatives. Due to, the system does not considering the shape variations, reduced efficiency.

In [9] A. Rahman and M. Murshed proposes a system for detecting the presence of multiple dynamic textures in an image sequence by establishing a correspondence between the feature space of dynamic textures and that of their mixture in an image sequence. Image sequences of smoke, fire, etc. are known as dynamic textures. Accuracy of our proposed technique is both analytically and empirically established with detection experiments yielding 92.5% average accuracy on a diverse set of dynamic texture mixtures in synthetically generated as well as real-world image sequences. Method is computationally inexpensive. This feature-based detection method, when coupled with an efficient segmentation method, will facilitate the deployment of the recognition process in real time. The proposed technique does not prohibit using global motion compensation to work with sequences captured by a moving camera.

In [10] B. U. Treyin, Y. Dedeoglu, U. Gdkbay, and A. E. etin proposes a novel method to detect fire and/or flames in real-time by processing the video data generated by an ordinary camera monitoring a scene. In addition to ordinary motion and color clues, flame and fire flicker is detected by analyzing the video in the wavelet domain. Quasi-periodic behavior in flame boundaries is detected by performing temporal wavelet transform. Color variations in flame regions are detected by computing the spatial wavelet transform of moving fire-colored regions. Another clue used in the fire detection algorithm is the irregularity of the boundary of the fire-colored region. All of the above clues are combined to reach a final decision. It drastically reduces the false alarms issued to ordinary fire-colored moving objects as compared to the methods using only motion and color clues. The algorithm not only uses color and temporal variation information, but also checks flicker in flames using 1-D temporal wavelet transform and color variation in fire-colored moving regions using 2-D spatial wavelet transform. But Methods based on only color information and ordinary motion detection may produce false alarms in real scenes where no fires are taking place.

D. Multi-Expert Evaluation

Multi-Expert Evaluation will take the decisions from multiple experts to finalize a decision. In the current scenario, for the fire detection it takes the features of fire such as, Color, Movement and shape as experts and evaluates each of that features. Color is one of the important features used because of the unique color of fire. To improve the performance we can add some of the other features such as movement and shape. Movement is evaluated based on the feature that the flame is continuously moving nature and shape is takes as because the shape of the flame is changes in every minute seconds. So if we take adjacent frames, the flame pixels will have a rapid change in their values. This property is making used in the Multi-Expert Systems.

In [11] Pasquale Foggia, Alessia Saggese, and Mario Vento proposes a real time fire detection by analyzing videos acquired by surveillance cameras. The two main novelties have been introduced. First, complementary information, based on color, shape variation, and motion analysis, is combined by a multi-expert system. And second is a novel descriptor based on a bag-of-words approach has been proposed for representing motion. The system which includes different stages such as, moving object detection, Background subtraction , Connected component labeling analysis, Blobs Evaluation and MES Classifier (Decision making). Blob evaluation is done taking different features such as color, shape and movement. The main advantage of the proposed approach is real time fire detection, better performance and computationally low cost. Here, in this smoke detection is not performed.

III. CONCLUSIONS

This paper summarizes the most popular and accepted methodologies applicable to the various fire detection methods. The methods mainly include color based and motion based techniques. We can also use several classifiers to classify the fire pixels from non-fire pixels. The combination of several classifiers for the training process will give high performance. The system which uses the complementary information, based on color, shape variation, and motion analysis, will give better recognition compared to other methods.

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