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REVIEW OF FIRE DETECTION TECHNOLOGIES BASED ON VIDEO IMAGE

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ABSTRACT

Because of high fire frequency and huge damage, the early fire detection is becoming more and more important. Due to the rapid development of image processing technology, video image in the application of detection technology has become more and more widely. Video based fire detection technology is becoming the focal point of research with its advantages of high intuitive, speed and anti-jamming capability. This paper reviewed the fire detection methods based on video images in recent years. Through the review, it is clear to see that video based fire detection technology can be divided into two main areas: the characteristics detection of flame and smoke. This fire detection method can improve the accuracy of the fire alarm, real-time and robustness. If the optimal algorithms can be adopted for each part of detecting motion area and extracting fire characteristics, the system performance will be further improved.

Keywords: *Video Image; Video Based Fire Detection; Flame Detection Methods; Smoke Detection Methods*

1. INTRODUCTION

With the faster and faster urbanization process, more and more high-rise buildings appear around us. This also can make the frequency of fire increase and bring great losses to people's lives and property. According to the data from fire station, 125402 fires had happened only in 2011 in our country. These caused 1106 people killed and 1.88 billion yuan lost.

As the damage caused by fires is so tremendous that the early fire detection is becoming more and more important. Recently, some fire detectors have been used in many places, they used the smoke, temperature and photosensitive characteristics to detect fires. But they are too worse to meet the needs in a large space, harsh environment or the outdoor environment etc. Up to now, video surveillance is widely used in commercial and military fields [1] such as traffic [2] and portable applications [3]. Video fire detection has also become a hot research topic in the field of fire detection. Automatic fire detection in images and videos is crucial for early fire detection which can solve the aforementioned problems. Video-based systems can detect uncontrolled fires at an early stage before they turn into disasters. With the video image, we can solve the prominent defects such as high error rate, strong dependence on the environment, and sometimes it can not be processed in real time.

The advantages of fire detection technology based on the video image can be summarized as the following points: first, detection techniques are very intuitive. Second, due to the speed of light transmission and induction is far higher than the smoke and temperature, such fire detection with high real-time has no delay caused by induction time. Third, the remote surveillance cameras can be adjusted freely and not to be confined to the indoor and outdoor space. So its detection range is larger other methods. Fourth, the image can save more scene information through color and texture, which promotes the diversification of the fire detection method greatly. Fifth, it is convenient for people to verify, record or query the fire with the saved video monitor screen, so this technology has a higher reliability and real-time performance.

2. FIRE DETECTION TECHNIQUES

When the fire broke out, the two obvious features are the appearance of flame and smoke. so the fire detection technology based on video can be classified into two categories: fire flame detection and fire smoke detection in video according to detected object.

2.1 Fire Flame Detection in Video

In many ways, flame detection is used to provide fast response to growing fires and

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activation of suppression and safety shut-down systems. Video image flame detectors represent a relatively new technology that has been gaining popularity and using in many applications. There are several methods in the literatures developed for fire flame detection from video images. Almost all of the current methods use motion and color information to detect the flame.

The color feature of the flame can be used as a basis for fire detection. Soe et al.[4] used the static image characteristics of the light blue flame to detect fires. The image is grabbed in the memory and fire-suspected regions are defined by using the region of interest (ROI) technique. The blue flame character pixels which are commonly found in gas fire are then checked in each ROI by using color intensity composition detection algorithm. If at least one ROI has the threshold amount of blue flame character pixels, this ROI is assumed to have a fire breakout. Furthermore, the average light intensity of the whole image is also calculated in order to use different threshold values of the blue flame for different background lights. This method can detect the gas fire flame with a less number of false alarms. But with only one feature to test fire also has some limitations. Since the conventional smoke-based fire detectors tend to exhibit high false alarm behavior, Wirth, M[5]explored a simple algorithm for flame detection based on the use of a modified histogram back projection algorithm in YCbCr color space.

Some other flame comprehensive features can be used to improve the recognition rate of the fire detection. SunJae Ham et al.[6] proposed a fire-flame detection method using probabilistic membership function of visual features and Fuzzy Finite Automata (FFA). In this method, moving regions are detected by analyzing the background subtraction and candidate flame regions then identified by applying flame color models. As flame regions generally have an irregular pattern continuously, membership functions of variance of intensity, wavelet energy and motion orientation are generated and applied to FFA. Since FFA combines the capabilities of automata with fuzzy logic, it not only provides a systemic approach to handle uncertainty in computational systems, but also can handle continuous spaces. However, in order to maintain the equivalence relation of fuzzy language between the fuzzy finite automata after minimization and the original one, it is necessary to consider how to deal with the relationship between the the fuzzy membership and status equivalence. And it is one of the difficulty problems in minimization. Literature [7] proposed a video-based fire detection system which uses color, spatial and temporal information. The system divides the video into spatio-temporal blocks and uses covariance-based features what is extracted from these blocks to detect fire. Feature vectors take advantage of both the spatial and the temporal characteristics of flame-colored regions. The extracted features are trained and tested using a support vector machine (SVM) classier. The system does not use a background subtraction method to segment moving regions and can be used, to some extent, with non-stationary cameras. It is shown to outperform a previous method in terms of detection performance. As flame detection remains a challenging issue due to the fact that many natural objects have similar characteristics with fire, a new algorithm for video based flame detection, which employs various spatio-temporal features such as color probability, contour irregularity, spatial energy, flickering and spatio-temporal energy was presented by Dimitropoulos et al.[8]. Various background subtraction algorithms are tested and comparative results in terms of computational efficiency and accuracy are presented. A 3D visualization tool for the estimation of the fire propagation is outlined and simulation results are presented and discussed in this method. But the cost of 3D visualization tool is higher, and the technology is in development stage. So there are some difficulties in popularity of the 3D visualization tool. An effective fire detection algorithm proposed by Xuan Truong et al.[9]is composed of four stages: (1) an adaptive Gaussian mixture model to detect moving regions, (2) a fuzzy c-means (FCM) algorithm to segment the candidate fire regions from these moving regions based on the color of fire, (3) special parameters extracted based on the tempo-spatial characteristics of fire regions, and (4) a support vector machine (SVM) algorithm using these special parameters to distinguish between fire and non-fire. This method outperforms other state-of-the-art fire detection algorithms in terms of fire detection accuracy, providing a low false alarm rate and high reliability in open and large spaces. But learning rate and the capacity to distinguish the moving shadow of adaptive Gaussian mixture model are slow. In Chu et al[10], a system based on image processing for flame detection is proposed. This method in the first step finds one or more bright objects in the images that are captured from videos. The next step is flickering state of a bright object. To verify existence of a flame, subsequent additional images

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from the instant that a bright object first appears are utilized and similar steps are applied to them. After the aforementioned steps have been performed a flame could be detected if the analyzed results are positive .

In China, there are also a lot of researches in this regard. Literature [11,12,13,14,15] used flame color to detect fires. Literature [11] put forward the algorithm that extracts the suspected flame region through the conditions of three visible lights. And the algorithm based on the four kinds of color space: RGB, YCbCr, HSI, and HSV. And the system used the flame detection algorithm based on the YCbCr color space to extract the suspected region of the flame in the visible light conditions. It is not only able to extract the flame region accurately, but also can exclude the interference of the objects whose color is similar to the flame. For infrared video, using a simple algorithm to extract the suspected region of the flame, at the same time add some restrictions to exclude the interference of reflective objects in the algorithm. Wang et al.[12] introduced a kind of the new method of extraction flame object based on the threshold of the area. Firstly, adaptive threshold generated by iterative method is used to segment the image. Secondly, we use knowledge of set theory to extract object contour. Finally, it can judge whether fire occurs from the fire flame color, fire spreading etc characteristic information. A new color model used to detect flame in an image is found in literature [13]. The model is based on the features that were linear transformed from RGB of the image color. Flames in video sequences are detected by using the features of color and its distribution. The analysis and extraction of flame color in the RGB color space are proposed by Chen Juan et al. [14]. Literature [15] proposed a fast and practical real-time image-based fire flame detection method based on color analysis. They first build a fire flame color feature model based on the HSI color space by analyzing 70 training flame images. Then, based on the above fire flame color features model, regions with fire-like colors are roughly separated from each frame of the test videos. Besides segmenting fire flame regions, background objects with similar fire colors or caused by color shift resulted from the reflection of fire flames are also extracted from the image during the above color separation process. To remove these spurious fire-like regions, the image difference method and the invented color masking technique are applied. Finally, the fire flame burning degree is estimated so that users could be informed with a proper fire warning alarm. The reaction time of the system is very fast. The color information is really an important static feature of the flame. But only with the color feature to detect fires may decrease the recognition rate of the system.

Flame shape characteristics were used in literature [16,17,18]. Literature [16] proposed a detection algorithm based on the flame shape characteristics, which in the video image is shown as images with multi-layer closed contour (the temperature gradient between the flame core and flame gas). There are one or more sharp corners on the contour line. And it is a shape characteristic of the flame. The number of cusps in the suspected flame region can be obtained to determine whether the region has the shape characteristics of flame or not. Because of most current video flame detection algorithms on the features of color spectrum and spatial augmentation are always successful in extracting the flame region from environment in the image, while helpless against the potential interference sources, such as heat or light sources, motion resembling flame and moving operations of people and vehicles, Zhang Xi et al.[17] put forward an intelligent video flame detection algorithm to distinguish flame from other lighting nuisances by a designed fire risk assessment model based on the analysis of static and dynamic characteristics of flame sharp angle and flame contour. The method in literature [18] to extract the contour feature of a flame image is developed based on threshold of flame area. The edges of the burning flames jitter continuously, but their contour are similar each other. The method to detect flames in video sequences is proposed here based on flame's dynamic contour.

There are also many scholars use the comprehensive characteristics of flame to detect fires. Jianzhong Rong et al.[19] proposed a robust fire detection algorithm based on the color, motion and pattern characteristics of fire targets. Which including few aspects as follows: (1) a rule-based generic color model was developed based on analysis on a large quantity of flame pixels; (2) from the traditional GICA (Geometrical Independent Component Analysis) model, a Cumulative Geometrical Independent Component Analysis (C-GICA) model was developed for motion detection without static background and (3) a BP neural network fire recognition model based on multi-features of the fire pattern was developed. The approach can apply to different fire scenes, but it relates to a lot of algorithms. Literature [20]

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combined fire flicker and color clues to reach a final fire decision. First the image difference method and color analysis technique based on the HSI color model are applied to extract the fire-like moving region between two consecutive frames. Then the spectrum of the fire-like region flickering could be got by the Discrete Fourier Transform of the fire-like moving region sequence. Finally, a simple method is devised to estimate the fire alarm grade so that users could be informed with a proper alarm. Zhang Jinhua et al.[21] analyzed the physical flame characteristics in the burning process in detail. Combined with static and dynamic flame features, a flame detection algorithm based on multi-feature fusion is designed to quickly recognize fire flame using the theory of the degree of belief. Lei, Wanzhong et al.[22] analyzed the status in the fire detection technology, and designs a structure to detect the early fire in coalmine. Firstly, image which comprises the potential fire region the potential fire region is detected by using frame differencing of monitor video, and denoised by median filter. Secondly, flame region is extracted by color information. Finally, Bayes classifier is employed to recognize fire combined with the dynamic features.

From the review of above literatures, we found that most of the flame detection methods face several major problems, including the video image acquisition method, a motion area detecting method and the extraction algorithms of flame characteristics. If the optimal algorithms in all these aspects are adopted, the recognition rate, real-time and anti-interference ability of flame detection will be improved.

2.2 Fire Smoke Detection in Video

In addition to the flame, smoke detection is also playing an important role in fire detection. Video smoke detection is a good option when smoke does not propagate in a “normal” manner, such as in tunnels, mines, and other areas with forced ventilation, or in areas with air stratification, such as hangars, warehouses, etc. Researchers have used a lot of features for the study of video smoke detection in recent years.

Different kinds of moke characteristics were used to detect fires in different literatures. Ha, Changwoo et al.[23] proposed block-based smoke detection algorithm consists of three basic steps, which has simple operation and provides good performance. In the first step, they discover motion vector utilizing several motion estimation schemes and discern the suspect as smoke region. This process does not require huge computational cost because of using the H.264/AVC during the recoding in DVR system. In the second step, they conduct block based chromatic detection. In the third step, they employ motion information for detecting the correct smoke block by using the characteristics that smoke goes almost upward. In literature [24], feature vectors are composed of optimal mass transport (OMT) velocities and R,G,B color channels. The classifier is implemented as a single-hidden-layer neural network. Sample results show probability of pixels belonging to fire or smoke. In particular, the classifier successfully distinguishes between smoke and similarly colored white wall, as well as fire from a similarly colored background. In Xiong’s [25] study, they thought that smoke and flames were both turbulent phenomena, the shape complexity of turbulent phenomena might be characterized by a dimensionless edge/area or surface/volume measure. Recently, Celik et al. proposed a generic model for fire color [26]. The authors combined their model with simple moving object detection. The objects are identified by the background subtraction technique. Later on they have proposed a fuzzy logic enhanced approach which uses predominantly luminance information to replace the existing heuristic rules which are used in detection of fire-pixels [27]. YCbCr color space is used rather than other color spaces because of its ability to distinguish luminance from chrominance information. The implicit fuzziness or uncertainties in the rules obtained from repeated experiments and the impreciseness of the output decision is encoded in a fuzzy representation that is expressed in linguistic terms. The single out-put decision quantity is used to give a better likelihood that a pixel is a fire pixel. The fuzzy model achieves better discrimination between fire and fire like-colored objects. Turgay celik et al. [28] use different color models for both fire and smoke. The color models are extracted using a statistical analysis of samples extracted from different type of video sequences and images. The extracted models can be used in complete fire/smoke detection system, which combines color information with motion analysis.

Use a smoke characteristic to detect fires is an great method. But if we detect fires only with one feature may cause the system recognition rate to be low. So we can fuse the characteristics of the smoke to improve the accuracy of fire detection. There are many other fire detection methods

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including integrated features of smoke and extraction algorithms are being researched by foreign scholars. Grech-Cini [29] used more than 20 image features, such as the percentage of image change, correlation, variance etc., extracted from both reference images and current images, and then used a rule-based or a rule-first-Bayesian-next analysis method to differentiate smoke motion from non-smoke motion. Xiong et al. [30] set a smoke detection technology based on background subtraction, flashing smoke, smoke contour recognition. Literature[31] presented a smoke-detection method whose basic strategy of smoke-pixel judgment is composed of two decision functions: a chromaticity based decision function in static characteristic and a diffusion-based decision function in dynamic characteristic. The chromatic decision rule is deduced by grayish color of smoke and the dynamic decision rule is dependent on the diffusion attribute of smoke. To give an appropriate alarm, a fuzzy scheme is introduced to enhance the reliability of alarming by checking if the quantity of smoke extracted increases with the checking time. A forest fire smoke detection method based on static and dynamic characteristic analysis is proposed by literature [32], which 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 (ROI) 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 successive processing steps of real-time algorithm used by Ho, Chao-Ching and Kuo, Tzu-Hsin[33]are using the motion history segmentation algorithm to register the possible fire smoke position in a video and then analyze the spectral, spatial and temporal characteristics of the fire smoke regions in the image sequences. The spectral probability density is represented by comparing the fire smoke color histogram model, where HSI color spaces are used. The spatial probability density is represented by computing the fire smoke turbulent phenomena with the relation of perimeter and area. Statistical distribution of the spectral and spatial probability density is weighted with the fuzzy reasoning system to give the potential fire smoke candidate region. The temporal probability density is represented by extracting the flickering area with level crossing and separating the alias objects from the fire smoke region. Then, the continuously adaptive mean shift (CAMSHIFT) vision tracking algorithm is employed to provide feedback of the fire smoke real-time position at a high frame rate.

In China, fire smoke detection is also a hot topic in this field. Some literatures use the single smoke characteristic to complete the identification of fires. Yuan [34] used an accumulated model of block motion orientation to realize real-time smoke detection, and his model can mostly eliminate the disturbance of an articial lights and nonsmoke moving objects. Cui [35] combined tree-structured wavelet transform and gray level co-occurrence matrices to analyze the texture feature of fire smoke, but real-time detection was not considered. Literature [36] using wavelet transformation to get the edge-area-information of the scenes. First make a video processing platform by VC-Programming, and design some smoke experiments. Then use the platform to process the smoke videos and get the total energy of each frame. So we can judge the smoke or non-smoke by monitoring the power of the edge area. This method is ideally suited for early fire-detection in long-term unattended fire place. As fire and smoke always exist together in forest. Both fire and smoke are important features for fire detection. So Dengyi, Zhang et al. [37]presented a novel method to detect fire and smoke in two steps and obtain areas of fire and smoke together. With the help of Otsu method taking gray value and red value as inputs, fire and smoke regions are segmented from the background, and regions with very small areas are deleted as noises; then fire is segmented from the left large and continuous regions.Wei Yingzhuo et al. [38] use the multi-spectral imaging system to obtain image sequence in specific spectral range of smoke and mist. Then it can be judged whether it is the presence of smoke in accordance with the spectral features. The technology can even distinguish between mist and smoke.

Integrated features can be used to detect the fire smoke in a high accuracy. The greatest characteristic of the method [39] is that both static and dynamic features of fire smoke are investigated. And the basic strategy is that we extract features of the moving target including growth, disorder, frequent flicker in boundaries, self-similarity and local wavelet energy as a joint feature vector which will be normalized, and then a BP artificial neural network is trained to recognize fire smoke. A smoke detection method based on smoke dynamics feature and color feature is proposed in literature [40]. The method can detect

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the early fire smoke and reduce the false alarms of the fire surveillance system. Wei, Zheng et al. [41] utilized an improved Gaussian mixture model positioning algorithm, an efficient target tracking algorithm as well as three effective static and dynamic smoke visual features: brightness consistency, motion accumulation and spread. The algorithm combined temporal and spatial information to assess the fire alarm algorithm is implemented by considering the performance requirements of the fire-alarming system.

3. CONCLUSIONS

Since fires can do so much damage and have devastating consequences, great efforts have been put into the development of systems for their early detection. Video-based systems of fire detection have great advantages and can be used to overcome the shortcomings of high false alarm rate, poor real-time performance and strong dependence on environment. In recent years, various fire detection systems in video have been proposed, but from the practical point of view, the most important fire detection systems are based on the characteristics of fire. The focus of this paper is to review different techniques for flame and smoke detection based on video images.

From the review of above literatures of flame and smoke detection, the emphasis of the two kinds of methods are detecting their respective characteristics. Both the flame or smoke detectors can be divided into the following five main parts: obtaining video images, processing video images, detecting motion area, extracting fire characteristics and determining fires. The hardest parts of them are obtaining ideal video images, detecting accurate motion area and finding the fire features extraction algorithms. If the optimal algorithms can be used for each hardest part, the recognition rate, real-time and anti-interference ability of fire detection will be improved.

As we know, most fires start at the smoldering phase in which smoke usually appears before flame. And in this case, smoke detection can give an earlier fire alarm. But compared to flame, the visual characteristics of smoke such as color and grads are less trenchancy, so that smoke is harder to be differentiated from its disturbances. So the extraction of smoke's visual features becomes more complicated. It can be considered that we can detect the presence of smoke first, then detect the flame, combining flame and smoke characteristics to detect the fire, which can shorten the alarm time.

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