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REVIEW ARTICLE

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SURVEY ON DIFFERENT FIRE AND SMOKE DETECTION TECHNIQUES USING IMAGE PROCESSING

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ABSTRACT
In Conventional fire detection systems physical sensors are used to detect fire. Chemical properties of particles in the air are acquired by sensors and are used by conventional fire detection systems to raise an alarm. But, Alarm is not issued unless particles reach the sensors to activate them, results in slow detection of fire. Therefore, they cannot be used in open spaces and large covered areas. A Fast and efficient Fire detection method is very important for the safety of the people. So in this paper, comparison of different models for smoke and fire detection using Image processing is provided. This paper describes different fire and smoke detection techniques, its advantages and disadvantages. Smoke is included because smoke is the good indicator of fire. A system that is able to detect fire by processing real-time video images would both work in open area and it doesn't need a high budget.

I. INTRODUCTION

Fire detection is very important for the safety of the people. The main causes of disasters are the failure in fire detection and lack of information. Smoke is the good indicator of fire. So fire detection with smoke detection is the better choice made in this paper. Smoke is a significant hint for early fire detection. Smoke becomes visible before flame in most of the times, and can detect fires in their early stages to reduce dangerous situation caused by fire. Fire can be detected effectively by using different image processing techniques. In image processing, images like video frames or photographs are the inputs and output may be either an image or image characteristics.

As part of an early warning mechanism, it is preferable that the system has the capacity to report the earliest stage of a fire. Currently, almost all fire detection systems use built-in sensors that depend primarily on the reliability and the positional distribution of the sensors. It is essential that these sensors are distributed densely for a high precision fire detection system. In a sensor-based fire detection system for an outdoor environment, coverage of large areas is impractical due to the necessity of a regular distribution of sensors in close proximity. Alarm is not issued unless particles reach the sensors to activate them. Therefore, they cannot be used in open spaces and large covered areas.

Detection methods based on image are more effective than other techniques which use certain sensor devices. Characteristics of smoke need to be considering when dealing with image information. Semi–transparency, response to environmental conditions, unsteady nature of smoke shape are the different characteristics of smoke. Smoke detection method is one of the efficient and challenging problems mainly in open environment, such as port, chemical plants and power plants as they cause harm to surrounding areas.

Due to the rapid developments in digital camera technology and developments in content based video processing, more and more vision based fire and smoke detection systems are introduced.

II. LITERATURE SURVEY

1. LIMITATIONS OF TRADITIONAL SYSTEM

Most of the available sensors used such as smoke detector, flame detector, heat detector and etc., take time to response. These sensors require product of combustion (example: smoke, CO2, temperature and etc.) from fire to reach the sensors before an alarm is issued. Because of that, it has to be carefully placed in a various locations [11][12]. Also, these sensors are not suitable for open spaces as products of combustion tend to spread away which can reduce the detection. However, this can also cause false alarms; for example, a person smoking in a room may trigger a typical fire alarm system. In a sensor-based fire detection system for an outdoor environment, coverage of large areas is impractical due to the necessity of a regular distribution of sensors in close proximity [12]. An important weakness of point detectors is that they are distance limited and fail in open or large spaces. So, traditional systems are not as much useful as system using image processing for fire detection.

2. FIRE AND SMOKE DETECTION USING IMAGE PROCESSING

Due to the drawbacks of sensor based fire detection system and due to rapid development of image processing techniques vision based fire and smoke detection system came into existence. Moreover vision based fire detection system offers several advantages. Firstly installation cost of this system is low as CCTV cameras are required. Secondly it has faster response time as it does not have to wait for the products of combustion to come near it this was not the case with sensor based systems. Thirdly in case of false alarm, confirmation can be done from the room by person without rushing to location of fire. Fourthly these systems can be used in open environment and on increasing the area to be covered the cost of the system is not much affected. Lastly fire detection technology based on video image can extract much more information from smoke and flame which is helpful for the detection.[11][12][14]

Fire has number of visual features such as color, motion, shape, smoke and growth etc. For detection of fire these feature are analyzed. During the occurrence of fire, smoke and flame both can be visualized. And with the increase in the intensity of fire visibility of both smoke and flame increases. Hence for fire detection, both smoke and flame needs to be analyzed. One reason to analyze both smoke and flame is that in the daytime, smoke analysis is the best approach for fire detection, since smoke is always associated with fire and becomes quickly visible even if the fire source is occluded and at night the visibility of smoke decreases but the detection capability of fire flames becomes high. Thus, fire flame extraction is effective for fire detection at night.[11][12][17][18].

III. FIRE DETECTION TECHNIQUES

Yong XU et al.[1] Propose a small-scale fire detection method. This fire detection method consists of two steps. The first step of the proposed method exploits the color and the intensity variation information of the pixels to determine the candidate to the fire region. The second step refines the results of the first step to obtain the ultimate fire region. The first and second steps have the following merits and effects: the first step is able to detect almost all of the true fire regions but it also takes some non-fire regions as the fire, which are referred to as ’false’ fire regions. On the other hand, the second step can greatly eliminate the ’false’ fire regions generated from the first step. The second step achieves this by using a learning method that first captures a number of training samples of the moment features of the true and false fire regions generated from the first step and then exploits the training samples and also use an improved K nearest neighbor (KNN) classifier to produce the ultimate detection result. The experimental results show that the proposed method performs very well in detecting small-scale fire.

The proposed two-step fire detection method has the following noticeable merits: first, the proposed two steps enable the color and pixel change information to be fully exploited in detecting the fire. In particular, the consecutive implementation of the first and second steps of the proposed method makes it able to produce a low false detection rate and low missing detection rate. Second, the proposed method integrates the motion segmentation, pattern classification and ma- chine learning technologies in a very good way. It seems that in the first step, the feature-based detection scheme plays an important role in achieving the low missing detection rate on the fire. The learning-based scheme, i.e. the designed improved KNN classifier contributes the most to the low false detection rate. As the improved KNN classifier has adjustable decision rules, it is more suitable and smart for the real-world applications where the priors of different classes are not clearly known. The experimental results support the above claims.

TurgayCelik[2]proposed another computer vision-based fire detection algorithm. The proposed fire detection algorithm consists of two main parts: fire color modeling and motion detection. The algorithm can be used in parallel with conventional fire detection systems to reduce false alarms. It can also be deployed as a stand-alone system to detect fire by using video frames acquiredthrough a video acquisition device. For the fire color modeling a novel fire color model is developed in CIE *L*a*b** color space to identify fire pixels. The first stage in this algorithm is the conversion from RGB to CIE *L*a*b** color space. The motivation for using CIE *L*a*b** color space is because it is perceptually uniform color space, thus making it possible to represent color information of fire better than other color spaces.

The proposed fire color model is tested with ten diverse video sequences including different types of fire. The proposed fire color model achieves a detection rate of 99.88% on the ten tested video sequences with diverse imaging conditions. The experimental results are quite encouraging in terms of correctly classifying fire pixels according to color information only. The overall fire detection system's performance is tested over a benchmark fire video database, and its performance is compared with the state of-the-art fire detection method.

The moving pixels are detected by applying a background subtraction algorithm together with a frame differencing algorithm on the frame buffer filled with consecutive frames of input video to separate the moving pixels from non-moving pixels. The moving pixels which are also detected as a fire pixel are further analyzed in consecutive frames to raise a fire alarm. In moving pixel detection, it is assumed that the video camera is stable, that is, the camera is still, and there is no movement in spatial location of the video camera. There are three main parts in moving pixel detection: frame/background subtraction, background registration, and moving pixel detection.

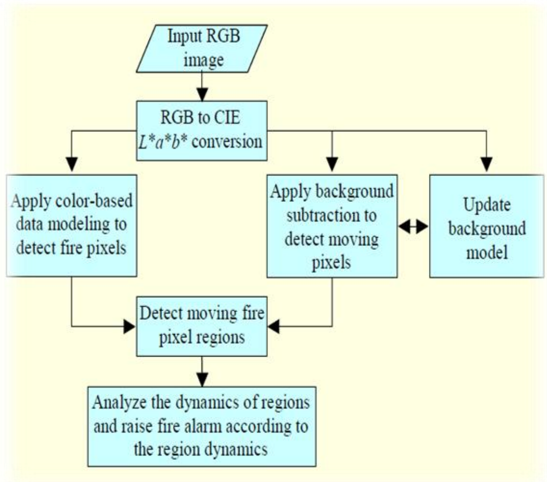

Fig.: Flow chart of proposed algorithm for fire detection in image sequences

The performance of the proposed fire detection system can be further improved by considering smoke at early stages of fire. However, detecting smoke is a challenging task and prone to high false detections caused from fog, different lighting conditions caused by nature, and other external optical effects. Such high false detections can be resolved by analyzing every smoke-like region. However, this yields a high computational load. The proposed system assumes that the fire will grow gradually in a spatial domain. This might not be the case in some situations.

Pietro Morerio, Lucio Marcenaro [3] proposed another approach to fire and smoke detection which is based on color features and dynamics analysis. In proposed system includes five main modules: 1] Change detection, 2] Motion detection, 3] Fire features extraction, 4] Smoke feature extraction and 5] Chaotic feature extraction. This module gives a well-known subtraction algorithm to obtained pixels which are different than normal pixels of the background picture. A motion detection algorithm is used for the detection of smoke and fire pixels. Pixel selection can be done according to dynamics of the area so as to reduce false detection. Fire and smoke pixels are separated using color information and feature extraction module. Separation of pixels is done with the YCbCr. Then pixels separated by change detection and feature extraction are joined together to get connected regions in region growing module. After that chaotic motion analysis is performed. The segmented blobs are wrapped in rectangle to reduce the amount of information and thus optimize elaboration speed.

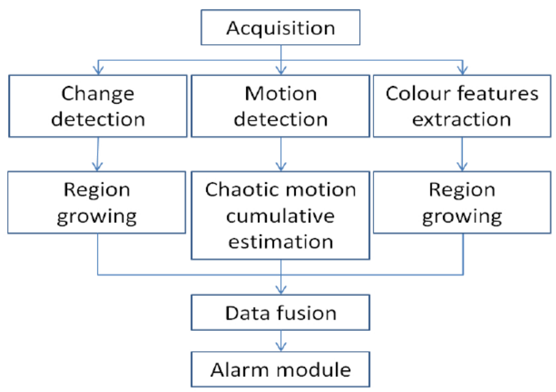

Fig. 1. Fire and smoke detection module's structure.

After Chaotic analysis, data fusion is done to generate a new pre-alarm. The main function of this module is to reject the false alarms caused due to other fire-like moving objects. It is done by the classifying pre-alarm rectangles with the help of a multi-layered perceptron (MLP). MLP consists of multi-layered network structure divided into input layer, some hidden layers and output layer. The three output neurons are used in this method which represents three possible pre-alarm states: pre-alarm of smoke type, pre-alarm of fire type and no pre-alarm.

IV. SMOKE DETECTION TECHNIQUES

Chen-Yu Lee et al. [4] proposed a smoke detection method using a spatial and temporal analysis. The proposed algorithm provides greater flexibility to smoke detection technique and more reliable to work under different conditions.

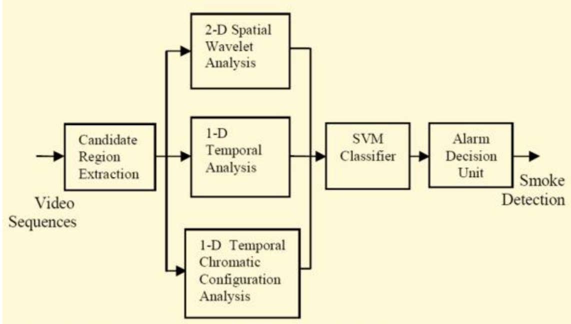

Fig. 2: System architecture of the Video Smoke detection

Fig. 2 shows the proposed system architecture of the video smoke detection includes four units: 1] Candidate-region extraction, 2] a feature extraction unit, 3] a classification unit and 4] a verification unit.

Feature extraction can be done by analyzing the spatial and temporal characteristics of video sequences for three main features: edge blurring, gradual energy changes and gradual chromatic configuration changes. This proposed algorithm were combined these three features using a temporal-based alarm decision unit (ADU) and a support vector machine (SVM) techniques to obtain more reliable experimental results. Temporal-based alarm decision unit is developed to decrease the false alarm rate and maintain a high detection rate with a short reaction of time. Support Vector Machine (SVM) algorithm is used to combine all the extracted analyzed features of fire. The SVM is trained with the classification and testing can be done fast using a C++ program which makes it suitable for many real-time applications. This proposed algorithm can process 30.98 frames per second.

The experimental results according to scientist Chen-Yu Lee is the proposed algorithm work very well in real environment; still there are some errors in the proposed method, such as continuous adjustment of the exposure value by the camera and the light reflections from the wet ground.

Mehdi Torabnezhad et al. [5] proposed another method that used image fusion technique to detect smoke. In this method, combine visual and thermal information to improve the rate of fire detection. The invisibility of smoke in LWIR image can distinguish smoke from smoke like objects. Infrared images do not detect smoke in the images but can detect smoke like object. By combining visible and IR images smoke can be distinguished. Based on characteristics of visual and thermal smoke images a potential smoke mask is created. In-order to reduce false alarms, PSM is further analyzed by dis-order measurements and energy calculations. For the detection of short range smoke visible and IR image fusion algorithm is used. Scope of this paper is to detect the smoke as an indicator of fire. Here visible and infrared images are combined together to distinguish smoke from smoke like objects. Earlier approach that uses sensor or visible images only gives false alarms.

Visible images capture both smoke and smoke like objects. Infrared images do not capture smoke. Integrating these images give correct information about smoke. Objective of this paper is to save people, forest from the fire. By this method generation of false alarm can be reduced to a great extent.

The proposed algorithm consists of two phases. In the first phase combine visual and thermal information of the smoke and potential smoke mask is generated. PSM is again analyzed to differentiate true and false alarms. This method is very efficient and detects smoke successfully. Improves the fire detection rate and reduces the generation of false alarm. The drawback of this method is Correct and punctual detection of fire is not possible and comparison is
required to identify smoke.

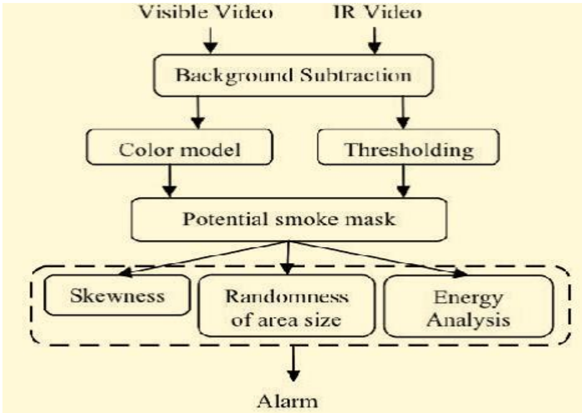

Fig.3. Flow chart of Smoke detection algorithm

B. UgurToreyin, YigithanDedeoglu, and A. EnisCetin[6] proposed another method for smoke detection . This paper proposes a novel method to detect smoke in video. It is assumed the camera monitoring the scene is stationary. The smoke is semi-transparent at the early stages of a fire. Therefore edges present in image frames start losing their sharpness and this leads to a decrease in the high frequency content of the image. The background of the scene is estimated and decrease of high frequency energy of the scene is monitored using the spatial wavelet transforms of the current and the background images. Edges of the scene produce local extrema in the wavelet domain and a decrease in the energy content of these edges is an important indicator of smoke in the viewing range of the camera. Moreover, scene becomes grayish when there is smoke and this leads to a decrease in chrominance values of pixels. Periodic behavior in smoke boundaries is also analyzed using a Hidden Markov model (HMM) mimicking the temporal behavior of the smoke. In addition, boundary of smoke regions are represented in wavelet domain and high frequency nature of the boundaries of smoke regions is also used as a clue to model the smoke flicker. All these clues are combined to reach a final decision.

Smoke detection algorithm consists of five steps:

1) Moving pixels or regions in the current frame of a video are determined,

2) The decrease in high frequency content corresponding to edges in these regions are checked using spatial wavelet transform. If the

edges lose their sharpness without vanishing completely
3) The decrease in U and V channels of them are checked,
4) Flicker analysis is carried out by HMMs which use temporal wavelet transform coefficients. Finally
5) Wavelet domain analysis of object contours are carried out. Moving objects in video are detected using the background estimation method developed by Collins et al. [7].

The method can be used for detection of smoke in movies and video databases as well as real-time detection of smoke. It can be incorporated with a surveillance system monitoring an indoor or an outdoor area of interest for early detection of fire. It can also be integrated with the flame detection method in [8] in order to have a more robust video based fire detection system.

V.CONCLUSION

Different smoke and fire detection techniques have been proposed for safety and protection of the people and environment. It is very crucial to develop an appropriate detection system to avoid dangerous situation caused due to fire. The proposed two step method enables the color and pixel change information to be fully exploited in detecting the fire. It seems that in the first step, the feature based detection scheme plays an important role in achieving the low missing detection rate on the fire. The KNN classifier contributes the most to the low false detection rate. The method works well when the fire is clearly visible and in close range. The fire detection method based on fire color modeling and motion detection using CIE $L^*a^*b^*$ color space to identify fire pixels improves the performance but The performance of the proposed fire detection system can be further improved by considering smoke at early stages of fire. Background subtraction method is used in this approach. The method based on color features and dynamics analysis, performsData fusion to generate a new pre-alarm. The main function of this module is to reject the false alarms caused due to other fire-like moving objects. Fire and smoke pixels are separated using color information and feature extraction module.

A smoke detection method using a spatial and temporal analysis provides greater flexibility to smoke detection by making use of feature extraction, classification, and a verification unit and is more reliable to work under different conditions. The image fusion technique to detect smoke is useful for the detection of short range smoke. Visible and IR image fusion algorithm is used. Visible images capture both smoke and smoke like objects. Infrared images do not capture smoke. Integrating these images give correct information about smoke. If the fire is small and far away from the camera the method perform poorly. This method is computationally efficient. The method for smoke detection in video using wavelets can be used for detection of smoke in movies and video databases as well as real time detection of smoke.

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