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Smoke detection in video using wavelets and support vector machines

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ABSTRACT

Early warning systems are critical in providing emergency response in the event of unexpected hazards. Cheap cameras and improvements in memory and computing power have enabled the design of fire detectors using video surveillance systems. This is critical in scenarios where traditional smoke detectors cannot be installed. In such scenarios, it has been observed that the smoke is visible well before flames can be sighted. A novel method for smoke characterization using wavelets and support vector machines is proposed in this paper. Forest fire, tunnel fire and news channel videos have been used for testing the proposed method. The results are impressive with limited false alarms. The proposed algorithm is evaluated for its characterization properties using motion segmented images from a commercial surveillance system with good results.

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1. Introduction

Automatic fire detection systems play a major role in the early detection and response of an unexpected fire hazard. Most sensor based fire alarms are designed for indoor use and are not applicable in outdoor scenarios and in large infrastructure settings such as aircraft hangers, large tunnels and exhibition buildings [1–3]. In 2006, Gottuk et al. [2] tested three commercially available video based fire detection systems against conventional spot systems in a shipboard scenario and found that the video based systems were far more effective in flame detection. In such scenarios, video based fire detection systems may be used effectively. These systems are economically viable as CCD cameras are already available for traffic monitoring [4] and surveillance [5] applications. Only the pattern recognition system has to be adapted for fire detection. Importantly, it is often observed that in outdoor scenarios, smoke is visible before the fire itself. This motivates us to build a system which detects smoke in the absence or presence of flame from a single frame of video.

The problem of video based fire detection has been recognized [1,6] but the rapid deployment of cameras for surveillance and availability of hardware resources in the past decade has enabled researchers to apply more concentrated efforts in this area. Several flame detection methods have been proposed and recently the focus has shifted to smoke detection. Most of the flame detection systems are either based on pixel intensity recognition or on motion detection. Toreyin et al. [7] carried out a comprehensive work on flame detection using wavelets and intensity based approaches. They tested their algorithm on many scenarios with impressive outcomes. Schultze et al. [8] analyzed dynamic characteristics of a flame using visual and audio features. Although they tested only one example, the approach is rather interesting. Marbach et al. [9] based their method on intensity based approaches with good results. Celik et al. [10] have proposed a new method of flame detection using a general color model to develop a rule based approach. These methods are targeted for flame detection and in general make use of the pixel color properties of the flame. Recently, Ko et al. [11] have proposed a non-linear classification method using support vector machines and luminescence maps, showing that the method is robust in several scenarios compared to features used earlier for flame detection.

Guillemant and Vicente [12] propose an algorithm based on fractals for smoke detection in forest fire scenario with impressive results. Thou-Ho et al. [13] propose a rule based system to detect smoke which is based on pixel intensity. They perform intensity based characterization of smoke. Xu et al. [14] use single stage wavelet energy and a back propagation neural network on a small dataset for smoke detection. The system requires high processing power which is unavailable in CCD camera networks. Piccinini et al. [15] propose a Bayesian framework for smoke motion detection using the wavelet energy of an 8×8 pixel block and intensity of the pixels. Vezzani et al. [16] propose a similar system in the context of ViSOR repository. Yang et al. [17] propose a support vector machine based approach using motion detection as the feature to detect the smoke contour. Recently, Yuan et al. [18] have reported a block by block approach based on chrominance

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and motion orientation. They propose a new fast algorithm for motion orientation estimation and test them on four videos. However, the chrominance based methods they use have a disadvantage in their dependence on the color of smoke. Also, the motion estimation algorithm is very time consuming in the context of smoke detection. All of these systems incorporate motion detection as a standard processing step. Ferrari et al. [19] have proposed a block based approach similar to the proposed approach for steam detection in oil sand mines. They use Wavelets and Hidden Markov Model for feature extraction and support vector machines for classification with very good accuracy of over 90%. However, the system is fine tuned to the oil sand application. Moreover, only steam is characterized in their approach where as this paper presents a novel algorithm for smoke detection which has the ability to detect smoke in various scenarios. Another important aspect of this work is the use of motion segmented images for smoke detection. Realistically, a smoke detection algorithm in commercially available CCD based systems has to run in parallel with many other surveillance processes. Hence, it is ideal to design a system incorporating the existing motion estimation methods or bypassing such motion estimation altogether. This forms the motivation for our work on characterizing smoke with robust and reliable features. The work is based on the characterization and detection of smoke observable from low quality fixed video surveillance, set at a distance from the potential fire location. The method is independent of atmospheric conditions at the time of filming—temperature, wind speed, wind direction and the time of the day. In this paper, we try to characterize smoke via a block based approach using discrete cosine transforms and wavelets respectively. We first evaluate a simple *k*-NN classifier with limited success and thus propose a final strategy to use wavelets along with a non-linear classifier such as support vector machines for smoke detection. We finally show the robustness of the system by testing it on motion segmented smoke images from a commercially available system.

Fig. 1. Forest fire smoke examples.

2. Methodology

The principal idea is to characterize smoke using efficient features and detection of the same using a suitable classifier by block processing. Basically, any single frame of a video stream is divided into small blocks of 32×32 pixels. Every block is checked for the presence or absence of smoke. The architecture is based on a standard pattern recognition approach with preprocessing, feature extraction and classification sub-units with training and testing phases.

2.1. Dataset and preprocessing

Seven bushfire videos were used for evaluating the proposed block based approach. Forest fire videos were captured in a forest scenario where the camera view encompasses land mass and clouds, where significant confusion is created due to color similarities between different elements of the scene and the feature of interest. An example image from the forest fire video is shown in Fig. 1. It can be clearly seen that the smoke disperses significantly at the top of the image which is an indication of a high wind scenario. There were seven such videos with a static camera and the input to our algorithm was a JPEG image from a frame of the video. The camera used was a normal CCD camera with low resolution, which is evident from the poor quality of the image in Fig. 1. Each video generated approximately 700 JPEG images. In the block based approach, the JPEG image is divided into 32×32 blocks and Fig. 2 shows the positive and negative samples in red and blue respectively. All the blocks which

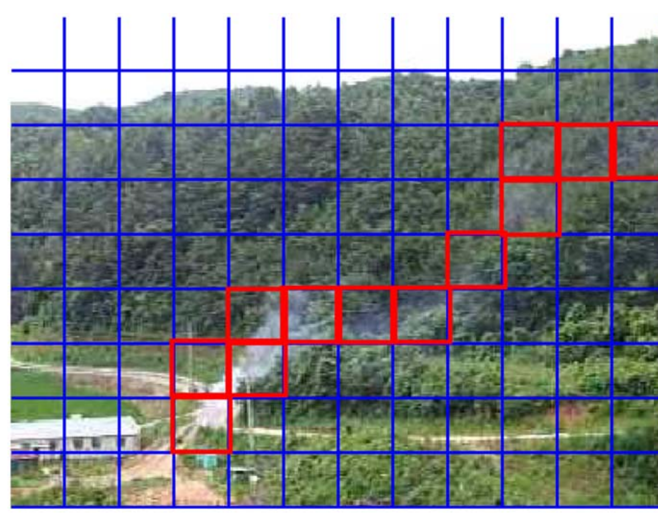

Fig. 2. Input image divided into 32×32 blocks. Red indicates blocks with smoke and blue indicates non-smoke blocks. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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