Video Processing Methods for Fire Detection

Introduction

One of the crucial steps in designing an autonomous residential fire-fighting robot is to be able to detect a fire flame and to localize the fire flame to a limited area that can then be interfered with by the robot. Even though conventional fire detectors can be used as one possible way to send an alarm to the robot, compared to video fire detection techniques, they are slower in detecting fire because of the transport delay air particles cause [7]. Conventional fire detectors also do not detect the exact source of the flame or smoke [1]. The literature concerning video fire detection techniques is divided into techniques for visible-range cameras and techniques for infrared cameras. This technical review briefly summarizes the algorithms for both visible-range cameras and infrared cameras, introduces some commercially available systems that use image and video processing methods for fire detection, and presents an overview of the implementation of video fire detection algorithms.

Commercial Applications of Video-Based Fire Detection

Current video-based fire detection systems that exist commercially are marketed as solutions for open area environments, where the accuracy and the speed of conventional fire detectors are challenged by environmental fluctuations. As such, they are generally not for individuals to purchase for their residences. The two main companies that manufacture these systems are Bosch and Fike.

Fike's Video Analytics IP Camera, which is priced at $3,000, includes video processing algorithms for flaming fires, smoke plumes, and ambient smoke [4]. The processor used in the system is TI TMS320DM642 and the resolution of the camera is 640x480. The lenses of the camera are 2.8 mm and 8 mm lenses with fixed irises and fixed fields of vision [4]. Performance-wise, the system can identify flame and/or smoke that is as far as 100 ft. (30.5 m) away [4].

Compared to Fike's Video Analytics IP Camera, Bosch's FCS-8000-VFD-B, which is priced at $3,318, offers a higher resolution at 1080p HD as well as the function of automatic iris control [5]. The implemented algorithm in the system makes it possible for this product to detect smoke that covers as little as 2.3% of picture width and flame that covers as little as 1.6% of picture width [5].

Technology Involved in Video Fire Detection

Algorithms for Visible-Range Cameras

First, a background subtraction algorithm is applied to the input video sequence from a visible-range camera to extract the movement in the video [1, 3]. The remaining part of the image is analyzed temporally to identify flickering characteristics [3, 7]. In this step, whether the flickering characteristic is that of flames can be determined by using Markov models and frequency domain techniques [3]. Frequency domain techniques rely on the fact that the flickering characteristic of flames is observed at around a 10 Hz frequency and this frequency does not change significantly even if the environmental situation around the fire changes [3]. After temporal analysis, spatial analysis can be used to determine whether the irregularities that would be expected from flames is present [3]. Color detection algorithms can also be incorporated into this system of algorithms to improve robustness. The simplest color detection algorithm relies on the fact that for a flame pixel, the RGB value obeys the rule R>G>B [2]. However, there are also more sophisticated types of color detection techniques like Gaussian smoothed color histograms, statistically generated color models, and blending functions [3].

Algorithms for Infrared Cameras

Since infrared cameras form images based on the temperatures of the objects in their field of vision, they can be used to reduce the false alarm rate of algorithms involving visible-range cameras especially in little or no light situations. One algorithm that can be used with infrared cameras is based on comparing global luminosity, which is calculated by adding the pixel intensities of any given frame, to a reference luminosity and a threshold luminosity [3]. This algorithm detects fire if the global luminosity is bigger than the addition of the reference luminosity and the threshold luminosity for multiple consecutive frames [3]. Another algorithm that can be used with infrared cameras looks for bright objects with rapid time-varying contours [3]. Since both the temporal and the spatial characteristics of an image are taken into account with this algorithm, it has the potential to decrease the false alarm rates of the luminosity-based algorithm.

Implementation

The implementation of a video fire detection algorithm requires a camera (visible-range or infrared), and a processor that has a powerful ability for data processing and the capability of interfacing with the camera of choice. As mentioned in the Commercial Applications of Video-Based Fire Detection section of this paper, Fike's Video Analytics IP Camera utilizes TI TMS320DM642 ($362.10), which fulfills both criteria [6]. It has three configurable ports, which support multiple resolutions and multiple video standards [6]. Another important point to consider for implementation purposes is that infrared cameras are generally more expensive than visible-range cameras [3]. As a result, an infrared camera should only be chosen over a visible-range camera if the performance of the algorithm with the infrared camera in a desired context justifies the higher price.

References

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