Chapter 48
Stereo-Vision-Based Fire Detection and Suppression Robot for Buildings

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ABSTRACT

A stereo-vision-based fire detection and suppression robot with an intelligent processing algorithm for use in large spaces is proposed in this chapter. The successive processing steps of our real-time algorithm use the motion segmentation algorithm to register the possible position of a fire flame in a video; the real-time algorithm then analyzes the spectral, spatial, and motion orientation characteristics of the fire flame regions from the image sequences of the video. The characterization of a fire flame was carried out by using a heuristic method to determine the potential fire flame candidate region. The fire-fighting robot uses stereo vision generated by means of two calibrated cameras to acquire images of the fire flame and applies the continuously adaptive mean shift (CAMSHIFT) vision-tracking algorithm to provide feedback on the real-time position of the fire flame with a high frame rate. Experimental results showed that the stereo-vision-based mobile robot was able to successfully complete a fire-extinguishing task.

INTRODUCTION

Fire incidents can cause loss of lives and damage to property. Damage due to fire has always been a major area of concern for museums, warehouses, and residential buildings. Conventional fire detection sensors (e.g., ionization and photoelectric detectors) and fire sprinkler systems monitor only particular points in space. In most cases, conventional point-type detectors are installed on walls or on a ceiling. The delays in the activation of fire detection sensors and sprinklers in large spaces are a major problem. Hence, the monitoring capabilities of point-type sensor devices are limited to a certain distance, and they are ineffective for monitoring large areas. These devices are not sufficiently flexible to detect fire incidents, and many fire-detection sensors and sprinklers are required to be installed very close to the monitoring areas. Comparatively, the video camera is a volume

DOI: 10.4018/978-1-4666-2038-4.ch048

sensor, and potentially monitors a larger area and has a much higher probability of successful early detection of fire flames. Video surveillance technology is suitable for early detection of fires due to its low detection delay, good resolution, and high localization accuracy. Early detection of fires can certainly expedite fire-fighting efforts, and consequently, fires can be extinguished before they spread to other areas. To monitor large spaces, the use of a mobile fire-fighting robot is a more flexible alternative than installing a large number of detectors and sprinklers. When a fire is detected, the fire-fighting robot can move to the position of the fire flame and safely evacuate an object from the fire area. Stereo vision systems can provide the robot with precise depth information about a target. Hence, the use of two cameras instead of one increases the suppression efficiency and adaptability of the robot while detecting and evacuating a burning object.

BACKGROUND

In recent times, research on the detection of fire flames using surveillance cameras with machine vision has gained momentum. The image processing approach involves the extraction of the fire flame pixels from a background by using frame difference technologies. Healey et al. (1993) presented a fire detection algorithm using a color video input with a pre-partitioning scheme under some restricted conditions, without rejecting the similar fire-like alias. Phillips et al. (2002) and Celik et al. (2007) conducted studies on computer vision by using spectral analysis and the flickering property of fire flame pixels to recognize the existence of fires at a scene. Hue and saturation are adopted as feature vectors to extract the fire pixels from the visual images (Chen, 2003). Fire flame features based on the HSI(hue, saturation, intensity) color model are extracted, and regions with fire-like colors are roughly separated from the image by the color separation method (Horng, 2005). Then, the image difference method based on chromatics is used to remove spurious fire-like regions such as objects with similar fire colors or areas reflected from fire flames. A fuzzy-based dominant flame color lookup table is created, and fire regions are automatically selected (Wang, 2006). However, either the solution does not consider the temporal variation of flames or the approach is too complicated to process in real time.

Fire suppression systems usually use water to extinguish fires due to its good ability to suppress fire. Chen et al. (2004) developed a water-spraying-based fire suppression system. The fire searching method is realized based on computer vision theory using one CCD camera that is installed at the end of a fire monitor chamber. However, it is necessary to calculate the changes in the space coordinates of the fire with displacement and the pivot angle of the CCD camera in the fire searching process. Ho (2009) proposes a fire-tracking scheme based on CAMSHIFT. The CAMSHIFT algorithm is applied to track the trajectory and compute the 2D positions of the specified moving fire-fighting robot in real time with the aid of a vision system. Yuan (2010) adopted the computer vision techniques to extract color and motion characteristics for real-time fire detection. However, the system was designed to move a water gun along a fixed path using computer-based control. Hence, the monitor ranges of the scene are limited and not sufficiently flexible.

FIRE DETECTION AND SUPPRESSION ROBOT

Issues, Controversies, Problems

The basic problems associated with conventional fire detection sensors are that they are not sufficiently reliable due to the time delay between the start of the fire and nonzero input in the detection sensor (Podržaj, 2008). A fire-fighting robot, equipped with vision-based fire detection technol-

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