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Novel outline features for pedestrian detection system with thermal images

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ABSTRACT

Recently, the need of pedestrian detection at night has gained more and more interest. However, the performance of traditional nighttime pedestrian detection systems remains poor because region of interest (ROI) generation and feature extraction are designed separately. Thus, this paper presents novel thermal imagery algorithms to enhance the performance of nighttime pedestrian detection systems. The proposed thermal image pedestrian detection system involves novel outline features, developed from the ROI generation method of pedestrians that are different from traditional features. A three-layer back-propagation feed-forward neural network is used as the classifier. Two databases, the OTCBVS database and our own are used to evaluate the performance of the proposed thermal image pedestrian detection algorithm. Experimental results show that the proposed outline features are effective, and the detection performance of a traditional pedestrian detection system at night is improved.

1. Introduction

Pedestrian detection is a critical research field because of the demands of applications such as home security surveillance, driver assistance systems, and robotics. Recently, the problem of pedestrian detection at night has gained increasing interest [1]. Pedestrian detection systems designed for use at night typically employ either near-infrared (NIR) images or far-infrared (FIR) images. FIR pedestrian detection systems work because human skin radiates strong FIR light, whereas NIR pedestrian detection systems work because human skin reflects strong NIR light [2]. However, NIR pedestrian detection systems require an external NIR light source and the detection distance is shorter than that of FIR systems. Therefore, the majority of pedestrian detection systems designed for use at night employ FIR images that are also called thermal images.

Most thermal pedestrian detection systems use a similar procedure [3–5]. Fig. 1 shows a flow chart of a typical thermal pedestrian detection system. During the learning stage, the system collects both positive and negative samples for feature extraction of pedestrians. Following feature extraction, the extracted features are sent to a classifier for training the pedestrian classifier. During the detection stage, the regions of interest (ROIs) are circled after the testing image sequence is imported. The ROIs circle candidates of pedestrians. The features in the ROIs are extracted and sent to the pedestrian classifier, which is trained during the learning stage. The pedestrian classifier classifies and locates the pedestrians. Conventional pedestrian classifiers include support vector machines (SVMs) [6,7], artificial neural networks (ANNs) [8] or boosting [9]. The histogram of oriented gradient (HOG) feature proposed by Dalal and Triggers [10] in 2005 is effective for use with an SVM classifier [11]. The majority of thermal pedestrian detection systems use the HOG feature or a HOG-based feature [5,6]. For example, Kim et al. proposed a histogram of local intensity differences (HLIDs) feature to improve the performance of the HOG feature [12].

Three primary methods for circling ROIs exist. First, image thresholding is a suitable method because pedestrians are usually warmer than their environment, and hence they appear brighter than the background [13]. For example, Nanda et al. presented a static threshold derived by performing Bayes classification on a set of templates known to contain pedestrians [14]. Second, identifying a foreground object is a suitable method because pedestrians are not present in the background image. For example, Masound et al. employed a foreground object method to circle ROIs [15]. Third, identifying an object in motion is suitable because pedestrians move. For example, Cutler et al. subtracted an image sequence to

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circle ROIs [16]. Among these three primary methods, identifying a moving object is more suitable than the other methods for circling ROIs in thermal images because image thresholding retains an excessive level of image noise, and identifying a foreground object requires a substantial number of calculations to establish the background image.

However, the ROIs that are circled by using traditional object-in-motion methods are typically miniscule and fragmented. Although image-closing is subsequently applied to the ROIs to ensure that each ROI covers the entire body of a pedestrian, the ROI is usually smaller or larger than the pedestrian. This substantially decreases the detection performance of the traditional thermal pedestrian detection systems because the HOG-based feature, which is the most common feature, is less-effective when the ROI cannot cover the exact area of the pedestrian. That is, the detection performance of the traditional thermal pedestrian detection systems remains insufficient because the ROI generation and feature extraction process are designed separately.

In Ref. [17], preliminary concept of the novel outline features developed from the ROI generation method of pedestrians is proposed [17]. A three-layer back-propagation feed-forward neural network is applied as the classifier [18]. Finally, a novel pedestrian detection algorithm that uses the discussed outline features and the corresponding system architecture for pedestrian detection system at night and simple experimental results is presented.

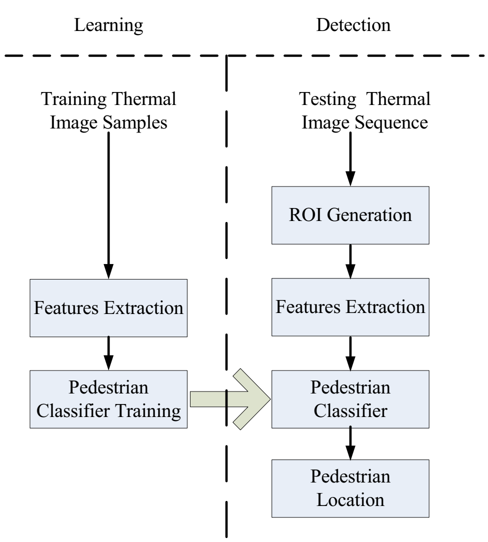

Fig. 1. Flow chart of thermal pedestrian detection system.

In this paper, detailed experiments and a discussion of the novel outline features for pedestrian detection system are presented. Three different kinds of pedestrian, along-street, across-street, and back-street pedestrians, are discussed. The method of choosing threshold *Th*, which affects the resulting extracted outline of the pedestrian, is described in detail. The effects of pedestrians' movement magnitude on detection performance are discussed. In addition, effects of pedestrian size on detection performance are also discussed. Finally, the proposed system is compared with five other existing thermal pedestrian detection systems.

The remainder of this paper is organized as follows. The system architecture is introduced in Section 2. The detection algorithm is introduced in Section 3. Experimental results and discussion are presented in Section 4. Section 5 draws the conclusion.

2. System architecture

Fig. 2 shows the architecture of the proposed pedestrian detection system. After the Thermal Image Capture system captures the images, the Thermal Image Processor immediately performs the proposed detection algorithm. During thermal image capture, the timing clock is sent to the Thermal Image Sensor by the Timing Drive Circuit, and hence the sensor can transform light energy into an analog electric signal. The Pre-amplifier Circuit amplifies this analog electric signal and then sends it to the Digital Processing module. In the Digital Processing module, the Timing Generator Circuit generates the timing clock to drive the sensor. An A/D converter (ADC) with a CDS circuit receives the analog electric video signal from the CCD Focal Plane Array module. The analog electric video signal is digitalized by a 12-bit ADC. Afterwards, the digital output signal is sent to the Thermal Image Processor in LVDS data format. Because the system architecture operates efficiently and LVDS data transfers at a high speed, the presented pedestrian detection system also operates efficiently.

3. Detection algorithm

The flow chart of the proposed pedestrian detection algorithm of thermal image is shown in Fig. 3. The procedure for the proposed detection algorithm is divided into the following three parts: (1) ROI generation, which separates the candidates of pedestrians from the

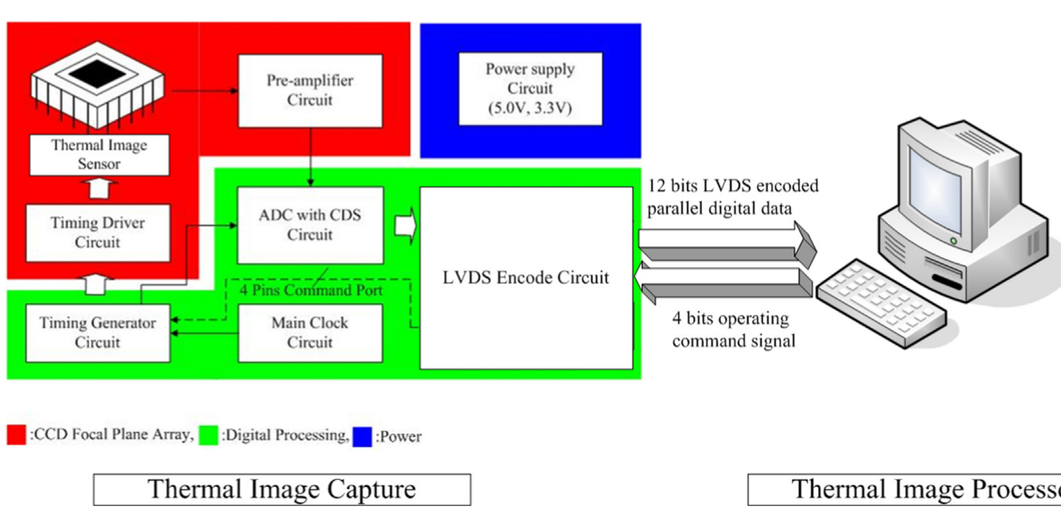

Fig. 2. Architecture of the proposed pedestrian detection system at night.