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Low resolution pedestrian detection using light robust features and hierarchical system

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ABSTRACT

The pedestrian detection is a popular research field in recent years, yet the low-resolution issue is rarely discussed for yielding detection accuracy for drivers. In this study, a hierarchical pedestrian detection system is proposed to cope with this issue. In which, two independent features, orientation and magnitude, are adopted as descriptors for pedestrians. Moreover, the proposed probability-based pedestrian mask pre-filtering (PPMPF) is utilized to initially filter out non-pedestrian regions meanwhile retaining most of the real pedestrians. In experimental results, the use of the two proposed features can provide superior performance than the former well-known histogram of oriented gradient (HOG; high accuracy) and the edgelet (high processing efficiency) simultaneously without carrying their lacks. Moreover, the PPMPF can also boost the processing efficiency by a factor of around 2.82 in contrast to the system without this pre-filtering strategy. Thus, the proposed method can be a very competitive candidate for intelligent surveillance applications.

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1. Introduction

Intelligent surveillance system has been widely-studied in recent years, in which how to deal with the prospective complexities of background and light conditions is still a key issue in this field. Consequently, it is important to establish a pedestrian detection system with high robustness and flexibility for coping with various environments. In contrast to some popular topics, such as facial recognition and license plate recognition, pedestrians do not inherently possess the predicable properties of color or brightness, thus it is relatively hard to be well modeled. Currently, the pedestrian detection methods can be separated into two categories according to whether it considers the temporal information. Normally, the methods with temporal information consider movement [1,2] or depth information [3]. Yet, apparently these methods have an inherent drawback that when the camera is moving or pedestrian is not standing still, the background and foreground will be misclassified. Conversely, the methods without temporal information simply consider each independent frame, suggesting that both of the above two issues are avoided. Yet, the latter group of methods normally requires a huge amount of computations, thus it is hard to meet the real-time requirement. Some instances such as the histogram of oriented gradients (HOG) [4–6] and Mohan et al.'s component-based approach [7] had demonstrated this issue. Nonetheless, the cascade system [8,9] can be employed to significantly ease this deficiency.

Various types of descriptors have been proposed for pedestrian detection. With common and intuitive features, e.g., color and brightness, the performance can be easily affected by the dresses of pedestrians or environmental lighting conditions. These factors seriously degrade the detection accuracy. From another point of view, an exclusive shape orientation descriptor is not easily affected by these factors since the shape orientations of the pedestrians are rather stable. Thus, a pedestrian model based upon this and also caters the Bayesian approach [10] was proposed. However, the shape of a pedestrian has diverse possibilities, and it requires huge computations to establish a complete model to meet all of the variations of pedestrians, increasing the difficulty to utilize them in practical systems. Another type of systems employ positive/negative samples to locate a threshold to distinguish whether a pedestrian exists or not. The methods in this category require many features to classify a sample, such as the Haar-like features [11–13] and the edgelet features [14,15]. The classifiers generated by these features coordinating with the integral image and AdaBoost can yield effective and efficient outcomes. Another way is to employ the local intensity as a feature, for instance the codebook feature [16,17] only performs the detection within the foreground regions of interest in successive frames. Another type is to use the magnitude of the local edge structure or the gradient orientation histogram to classify different samples, such as the HOG [4–6], scale-invariant feature transform (SIFT) [18], and local principal component analysis (PCA) of gradient [19]. Another way is the region covariance in the context of object detection [20,21]. Instead of using joint histograms of the image statistics, covariance is computed from several image statistics inside a region of interest. However, the computational

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complexity of these methods is too high, and thus it is hard to implement a real-time system. Following the feature extraction, a decision boundary is determined to separate the positive and negative samples, and then train the classifiers, such as the feed-forward multilayer neural networks [22], support vector machines (SVM) [6,15], and AdaBoost have been used in many researches to combine with the different features to construct pedestrian detection systems as described above.

This study presents a hybrid pedestrian detection scheme for significantly reducing detection time. Primarily, two topics are focused in this work: (1) The feature descriptors for pedestrians, and (2) the resolution of a pedestrian image. The former one determines the stability of pedestrian detection, and the latter one directly detection response time. In the first stage, the proposed probability-based pedestrian mask pre-filtering (PPMPF) filters out most of the non-pedestrian regions for reducing the entire detection time. In the second stage, the two key features, orientation and magnitude, are catered to solve the influence induced from complex lighting conditions. Considering the issue of camera movement such as driving, the temporal information is not considered, instead the AdaBoost algorithm is employed to generate weak classifiers for yielding high detection rate. Moreover, this study also focuses on developing a system which is able to cope with low resolution samples (pedestrian with far distance), and this consideration can further extend the possible detection distance away from the driver. Comparing to the former article [23], more details in coping with the lighting conditions and the completeness of the proposed system are provided. In addition, to provide a more concrete evidence of the overall system performance, one more public database is considered for comparison.

The rest of this paper is organized as follows. Section 2 discusses some practically-met problems in pedestrian detection. Section 3 introduces the proposed PPMPF, and Section 4 explains the proposed features as well as the training through the AdaBoost algorithm. Experimental results are demonstrated in Section 5. Finally, the conclusions are drawn in Section 6.

2. Problem descriptions

To clarify the motives, the met problems related to the properties of the adopted features as well as the practical issues are discussed in this section. The corresponding solutions are presented in the subsequent sections.

2.1. Features for pedestrian

The property of a pedestrian is quite different in contrast to other well-known targets, such as face and license plate. In the latter case, the targets are normally with regular colors. Conversely, the colors and textures of a pedestrian cannot be reasonably modeled with a constant pattern. Fig. 1 shows some apparent cases. Consequently, some of the well-known feature such as the Haar-like feature [11–13], considering the difference of intensity cannot perfectly handle this case theoretically. The features which are not robust against lighting changes are regarded as good candidates under this consideration. For instance, the well-known edgelet [14] which employs the edge and shape as features can yield a relatively better performance in this regard.

Fig. 2 shows the features for the edgelet, and features include various curves, curvatures, and angles. The feature value of the edgelet f (affinity) is formulated by three elements: M (magnitude), V^I (orientation) on images, and V_i^E (orientation) of the edgelet curve. It can be represented as

$$\tilde{f} = \frac{1}{k}\sum_{i=1}^{k} M^I(U_i+w)l[V^I(U_i+w)-V_i^E], \quad (1)$$

where k denotes the length of the edgelet curve; (U_i+w) denotes the coordinate of images; $l[\cdot]\in[0,5]$ denotes the normalized orientation obtained by the definitions according to the difference of orientation $V^I(U_i+w)-V_i^E$, in which the region 0–180° (negative angles plus 180° to meet the region's limitation) is divided into six independent regions, for example 0–30° are normalized to 0, 31–60° are normalized to 1, and so on. The way to calculate the feature value is to quantize the orientation of the edgelet feature and the orientation at the same position in the image. It is obvious that the edgelet feature considers the magnitude as the weight for calculation. In many situations, the orientation is a stable feature for various lighting conditions since the texture of objects does not change frequently. Conversely, the magnitude is not robust against light change since it indirectly changes the contrast, and thus affects this feature. As a result, it makes the entire edgelet feature not robust against the light change. As the above analysis, the features which use the orientation and magnitude independently are better to resist the lighting problem.

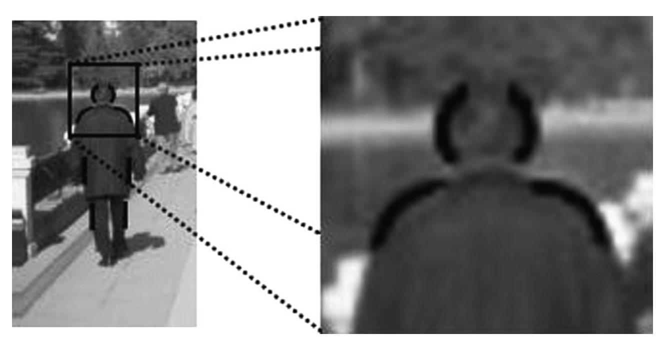

Fig. 2. Conceptual diagram of the edgelet feature [14] applied to pedestrians.

Fig. 1. Examples of pedestrians.

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