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Symmetrical Judgment and Improvement of CoHOG Feature Descriptor for Pedestrian Detection

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Abstract

Pedestrian detection method is the highest priority for "active safety" which prevents traffic accidents before happens. In previous studies, edge orientation based feature descriptors are proposed. Recently, high standard detection algorithm, Co-occurrence Histograms of Oriented Gradients (CoHOG) is proposed. However, this method has miss detection in complicated situation and processing cost is high. We propose symmetrical judgment algorithm and an extended version of CoHOG for high speed and high accuracy pedestrian detection. The effectiveness of the proposed method was proved on pedestrian detection performance test.

1. Introduction

Since the number of pedestrian deaths was the highest (1,721 casualties) among the traffic accident classifications in 2008 in Japan, pedestrian protection is the highest priority in traffic measures. One of the effective ways to reduce the number of pedestrian deaths is the widespread use of active safety systems in which an alarm or automatic braking would be activated before a vehicle-to-pedestrian collision. The system must detect the presence of a pedestrian on a road or street by camera or by radar equipped in a vehicle. Passenger cars hitting pedestrians crossing a road is reported to be the typical accident situation involving pedestrians.

The purpose of the present study is to develop an algorithm to recognize pedestrians crossing the street with the use of a single camera. Detecting pedestrians in images is a problem of late years [1]-[4]. Accurate pedestrian detection for traffic safety is a matter of urgency.

Edge based features is proposed, such as HOG (Histograms of Oriented Gradients) [1]. This feature descriptor describes human shape roughly. HOG has been proved to be a practical way of solving pedestrian detection in a real world. Recently, Watanabe et al. proposed CoHOG (Co-occurrence HOG), expansion of HOG [5]. CoHOG builds histograms by a pair of gradient orientations. This descriptor extracts edge orientation between two difference pixels. So CoHOG can reduce miss detection. However, CoHOG has miss detection in complicated situation, such as on the road and processing cost is high.

In this paper, we propose symmetrical judgment algorithm and an extended version of CoHOG for high speed and high accuracy pedestrian detection. Symmetrical judgment evaluates pedestrian's shape roughly. Extended CoHOG (ECoHOG) implements edge magnitude accumulation and histogram feature normalization.

2. Proposed method

Fig.1 shows our proposed method. There are two steps, extraction of candidate regions and pedestrian detection.

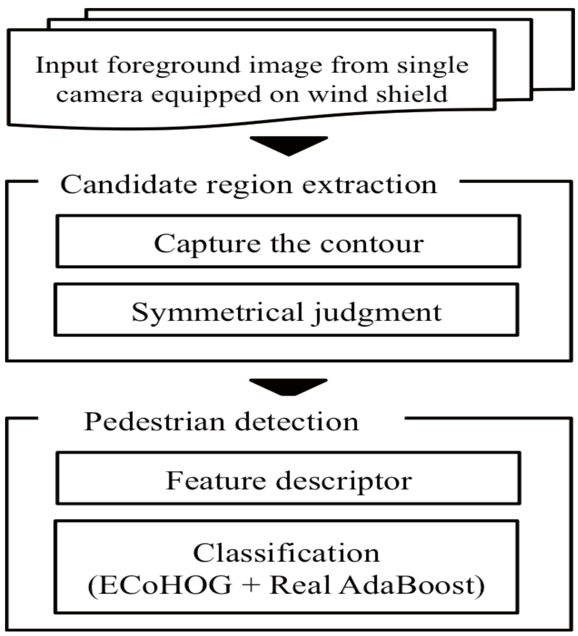

Fig.1 Proposed method flow

The first step selects pedestrian's candidate regions. In monocular camera, it is difficult to apply regions extraction algorithm like stereo matching. We detect candidate regions that include pedestrian by symmetrical judgment. Next, classification phase extracts pedestrian's feature in detail. We apply ECoHOG and Real AdaBoost classifier.

2.1 Symmetrical judgment

Fig.2 shows edge detection and binarization. Sobel edge detector and Otsu thresholding is applied in each part. We search a binarized image to evaluate human shape. When we search binarized image, scanning window is prepared and shift whole image. The window size is 50×60 pixels, scanning step is 5 (x direction) and 15 (y direction) pixels.

This is when scanning right and left images in window, the distance between window's centerline and pedestrian's edge is described as a histogram. We can calculate human's symmetry comparison these two histograms. Bhattacharyya coefficient calculates similarity between two histograms. Bhattacharyya coefficient calculates similarity after normalize histogram, so it is able to evaluate human shape regardless of distance edge and window's center. We decide threshold from database that pedestrian or not. Fig.3 shows candidate regions from image in a real road. Pedestrian's candidate regions are white circle in figure.

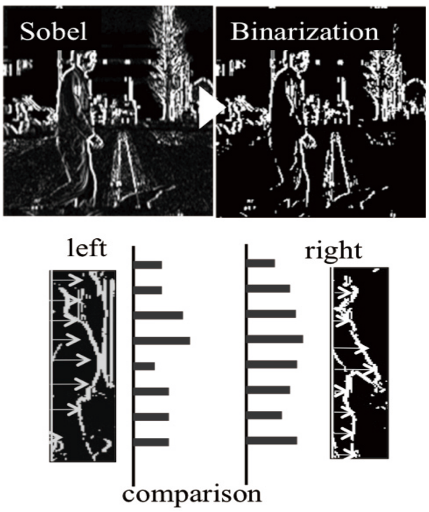

Fig.2 Symmetrical judgment

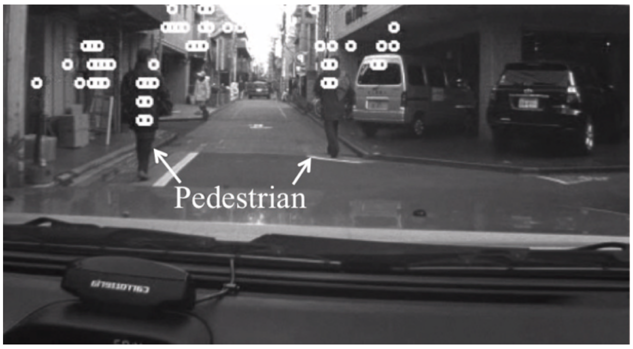

Fig.3 Candidate regions

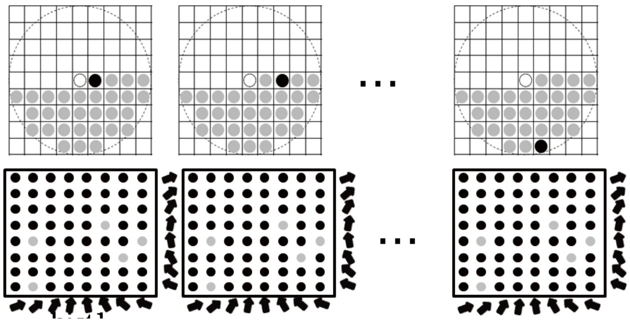

Fig.4 CoHOG histograms

2.2 Pedestrian detection

In this study, classification generation algorithm is AdaBoost. And more, we apply Real AdaBoost that expansion of AdaBoost. Real AdaBoost is known high accuracy detector because of generates many weak classifiers and combine into a strong classifier. Multi weak classifiers construct strong classifier as linear combination.

The feature descriptor is used ECoHOG (Extended Co-occurrence Histograms of Oriented Gradients), extended CoHOG (Co-occurrence Histograms of Oriented Gradients). CoHOG extracts gradient orientations from two different pixels. However, previous method was single pixel, such as HOG. CoHOG decreases miss detection by "Co-occurrence" feature description. In this paper, we accumulate edge magnitude from pixel pairs, not numeration orientation's pair.

Fig.4 shows CoHOG method to make feature histograms. CoHOG prepares window for feature extraction. The white circle and the gray circles are paired. We build co-occurrence matrix that expresses the distribution of gradient orientations at a given window over an image. Co-occurrence matrix describes sums of all pairs of gradient orientations. Orientation is divided 8 directions. Co-occurrence matrix is 64 dimensions, because this matrix composed different two pixels.

We accumulate edge magnitude from pixel pairs, shown as below:

$$m_1(x_1, y_1) = \sqrt{fx_1(x_1, y_1)^2 + fy_1(x_1, y_1)^2}$$
$$m_2(x_2, y_2) = \sqrt{fx_2(x_2, y_2)^2 + fy_2(x_2, y_2)^2}$$
$$C_{x,y}(i, j) = \sum_{p=1}^{n}\sum_{q=1}^{m}\sqrt{m_1(x_1, y_1) \times m_2(x_2, y_2)}$$
$$(\text{if } d(p,q) = i \text{ and } d(p+x, q+y) = j)$$

Co-occurrence matrix C is defined over two pixels edge magnitude m_1 and m_2. The x and y direction component is f_x, f_y. d is quantization number ($0 \leqq d \leqq 7$).

Additionally, we normalize feature histogram to accept brightness variation. Normalization range is a co-occurrence matrix. Normalization calculates as:

$$C'_{x,y}(i, j) = \frac{C_{x,y}(i, j)}{\sum_{p=1}^{8}\sum_{q=1}^{8} C_{x,y}(p, q)}$$

Table.1 shows ECoHOG settings about image size, block division and dimensions.

Table 1 Set for CoHOG

Pixels in window	18 pixels
Image size	60×120 pixels
Image division	2×2 blocks
Dimensions per co-matrix	64 dimensions
Dimensions	4608(dimensions)

Hierarchical clustering decides definitive pedestrian area. In statistics, each observations start in one cluster, and pairs of clusters are merged as one moves up the hierarchy. We integrate some windows to detect each pedestrian.

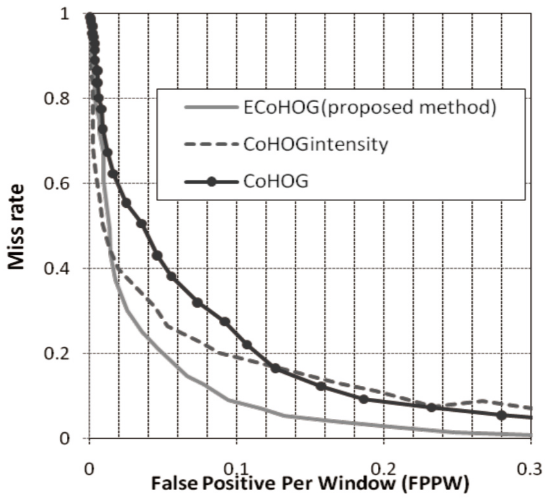

Fig.5 DET curve

3. Experiment

We verified the detection effectiveness of proposed method by applying real world images. The first experiment is comparison feature descriptor, CoHOG and ECoHOG. The second experiment shows detection effectiveness in a real road.

The first experiment, we used the INRIA dataset. The INRIA dataset contains positive images resized 64×128 pixels and negative images. There are training and test images. Training images are 2,716 positive and 1,218 negative images. Test images are 1,132 positive and 453 negative images. The second experiment, we used the video that captured in a real road.

We applied DET (Detection Error Tradeoff) curves on the INRIA dataset for evaluation. A DET curve plots error rates on both axes, the horizontal axis is False Positive Per Window (FPPW) and the vertical axis is Miss rate. This curve further towards the bottom-left of the diagram means better performance. Fig.5 shows the result of comparison previous method CoHOG and our proposed method ECoHOG. CoHOGintensity is non-normalization method of ECoHOG. The results show that our proposed method ECoHOG accomplished effective detection rate. Accumulated edge magnitude and normalization make ECoHOG excellent feature descriptor. Accumulated edge magnitude can classify human and non-human in the case of the same shape. And more, normalization accepts brightness variation. Table.2 shows comparison processing time.

Table 2 Processing time previous and proposed method

Feature	Processing time (ms / frame)
CoHOG	16.21
CoHOGintensity	17.87
ECoHOG	18.41

Though CoHOG is the quickest method of three feature descriptors, the processing cost of accumulated edge magnitude and normalization are computationally cheap.

The second experiment, we evaluated the availability of real-world conditions. We used darkened movie in this experiment. Fig.6 shows the result of three feature descriptors. CoHOGintensity expresses pedestrian's edge magnitude (Fig.6 (b)). ECoHOG also detects pedestrians accurately in the darkened image, because of normalization (Fig.6 (c)).

(a) CoHOG for pedestrian detection

(b) CoHOGintensity for pedestrian detection

(c) ECoHOG for pedestrian detection

Fig.6 Pedestrian detection by in-vehicle camera

4. Conclusion

In this paper, we proposed the method of pedestrian detection in a real road, candidate regions extraction and ECoHOG + Real AdaBoost classifier. We compared the detection performance of proposed method and previous method.

We are planning to track pedestrians for surveillance. Of primary importance is to track pedestrians after detection. Furthermore, we apply the proposed feature descriptor to put into practical use.

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