Night-time Pedestrian Detection Based on Temperature and HOGI Feature in Infra-red Images

Li Liu1, Hong Bao1,*, Weiguo Pan1, Cheng Xu2

1 Beijing Key Laboratory of Information Service Engineer Beijing Union University, Beijing 100101, China
2 Institute of Network Technology, Beijing University of Posts and Telecommunications, Beijing 100876, China

Abstract — **Pedestrian detection is very important and also has a big challenge in the Intelligent Transportation System. In this paper, our proposed method can detect pedestrians in infrared images robustly. Our method consists of two components. Firstly, the temperature matrix of infrared images is used to extract candidate pedestrians. For it performs robustly under different scenes without delicate parameter tuning. This is different from the traditional threshold or edge based region of interest (ROI) generation techniques. Secondly, the histogram of oriented gradient and intensity (HOGI)feature is extracted from infrared image combining the gradient and intensity feature. Finally, the HOGI features are employed to train classifier based on two kinds of machine learn-ing algorithms. Experimental results in various scenarios demonstrate the robustness and effectiveness of the proposed method.**

Keywords - Infrared image, HOGI, Temperature matrix, Pedestrian detection

I. INTRODUCTION

With the increase number of vehicles, traffic accidents frequent occur, Especially at cloudy and foggy night, with poor light conditions poor traffic accidents is serious. Therefore, obstacles detect under the condition of low illumination such as people in front of driving vehicles is particularly important[1][2]. In recent years, the majority of pedestrian detection re-search mainly focuses on the optical image, the method mainly including the shape, texture, body, movement and multiple features fusion aspects. Compared with visible light image, infrared image has significant advantages. For the thermal imag-ing is infrared images, it has the ability to through the darkness and smoke under the condition of dark light at night, and cannot affected by the visible light. It can reach the interest target all-weather observation over a long distance [3,4,5]. The technology based on infrared image can archieve better effect on pedestrian detection and recognition under the conditions of bad weather compared with mehods which is based on visual image.. Infrared image pedestrian detection is the key technology in the field of intelligent unmanned vehicle and vehicle auxiliary driving system. It can quickly detect the pedes-trian in front of the vehicle, give early warning and obstacle avoidance in time, to reduce or avoid collision accident of vehi-cles and pedestrians. It has potential economic value and broad application prospects [6,7,8,9], which can ensure the safe-ty of people's life and property.

While there exists much research in the pedestrian detection area, but it still exists some difficult problems. Due to tech-nical problems such as equipment, the poor quality of the infrared image itself (low resolution, low contrast, less distinguish-able feature points, scarcity of texture information, etc.). The problems of pedestrian appearance, posture, movement diver-sity, variety, variety of complex scenes, and keep out etc., all bring great difficulty to the test. In this paper, our study focus on the pedestrian detection at night environment, and proposes an infrared image pedestrian detection method based on the temperature information based on the histogram of oriented gradient and intensity (HOGI) features. The first step is to ex-tract the infrared camera to shoot video image corresponding to the temperature of the matrix, by a threshold. Then process interested pedestrian area by morphology. thefinal step is to extract the infrared images HOGI characteristics in each inter-ested area, and use the support vector machine (SVM) classification judgment for pedestrian detection results. The exper-imental results show that the proposed method didn't increase any feature dimension computational and improved the de-tection accuracy compared to the traditional infrared image pedestrian detection method based on HOG features.

The rest of this paper organized as follows: Section 2 reviews the previous works on pedestrian detection in infrared images. Section 3 introduces the proposed method which extracts the interested of region, fusion gradient direction, extract intensity histogram feature finding possible pedestrians, and the notification of final result. Section 4 is the experimental results. This paper is concluded in the final section 5.

II. RELATED WORK

The pedestrian detection algorithm can be roughly divided into model matching, shape information, motion information and statistical classification, etc.[3]. and the most often used method is based on the statistical detection. The method first extract samples feature , then use machine learning classifier, finally use the classifier to test[12,23,25,26,27]. The common used features include gray level statistics, contour, shape, texture and image algebra, etc.

Background estimation in literature [16] use pedestrians template on infrared image pedestrian detection, the method can detect pedestrians real-time, as for the complex dynamic scene environment need to set up a lot of template, and can't successfully applied in complex scenes. Brightness is an important characteristic in infrared images, while the human body's brightness is relatively stable. The difference is smaller between different parts. A. Miron [10] Proposed Intensity Self Similar-ity(ISS) to describe the relationship between local block features of human body, and combined pedestrian head highlighted area extracting ROI for pedestrian detection. The characteristics of the underlying computing is faster, but only describe the pedestrian characteristics, lack the discriminant ability. The literature [11] improved the traditional LBP feature, proposed a pyramid binary pattern real-time infrared pedestrian detection method.

Histogram of Oriented Gradient (HOG) is one of the characteristics that get more extensive application in the field of pedestrian detection [17]. HOG features calculated by local gradient magnitude and direction to describe the edge contour features of human body. Many other studies currently have shown that HOG is one of the best single feature to detect pedestrian , but its higher dimension, so computing speed is slower. In order to improve the computing speed of HOG, Zhu did im-prove on HOG, they use different size of block to make up IHOG (Integral Histograms of Orientated Gradients), then using integral histogram [21] technology to improve the calculation, use Adaboost algorithm cascade training again. Experiments show that this algorithm test nearly 70 times faster than the Dali [18]. HOG initially was applied in visible light images, de-script the shape characteristics of the local area, and shape characteristics in infrared image, so lots of pedestrian detection methods based on infrared image research use HOG features[6,15,19,20,21]. Inspired by HOG feature, D.S.Kim [22] use HLID (histogram of local intensity differences) on infrared image for character description, the mainly difference with HOG is the direction and gradient magnitude: the gradient direction of the pixel is determined by the direction of the maximum absolute intensity difference between the pixel and the surrounding pixel. The largest absolute intensity difference is used as the gradient magnitude.

III. PEDESTRIAN DETECTION VIA TEMPERATURE REPRESENTATION AND HISTOGRAM OF ORIENTED GRADI-ENT AND INTENSITY

A. Extract Interest Region Based on Temperature Matrix

Infrared sensor is used to induct surrounding thermal infrared radiation. The infrared image can be getting through a se-ries of transformation. What the device detected is the objects' temperature information. The higher the temperature of the object has the greater thermal infrared radiation in the infrared image grey value. Infrared thermal imager is shown in 2 dimensional image, reflecting the temperature distribution on the surface of the object. The object of infrared image surface temperature with high emissivity is close to its true temperature. The object surface's temperature of low emissivity in the infrared image is close to the ambient temperature. As the environment reflection, pedestrians clothing and equipment re-sulting low contrast gray image will be obtained. The conventional method based on ROI extraction in gray image for the leakage and error reason, cannot achieve good effect, and thus influence on the performance of the late classifier to detect [6,8,10,15,16,24]. For this reason, we present a kind of interested of the pedestrian area algorithm in infrared images based on the temperature information, as shown in fig.(1). The infrared thermal imager resolution used in this experiment is 640×480.

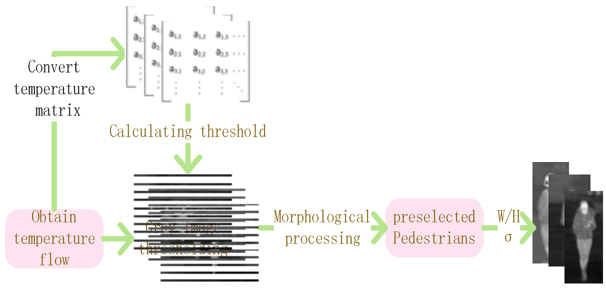


Fig.1 The Framework of Region of Interest Extraction

At the first step, we get the temperature of the stream of every frame image directly from the infrared camera, then convert it to a temperature of 640×480 matrix. The temperature matrix is expressed by the absolute temperature of the object, we convert the absolute temperature to the corresponding temperature, which does not affect the algorithm time . It can be seen that there is a big change in the target area and background area from the histogram. If the threshold of a certain temperature in the middle of the pedestrian area and the background area is used as the threshold , the target and the background can be separated well. In this paper, we calculate the threshold using the following equation(1).

$$T = \frac{5}{4}(\bar{I} + \delta_I) \qquad (1)$$

where $\bar{I}$ is the average temperature of the matrix,

δ_I is the standard deviation.

DOI 10.5013/IJSSST.a.17.28.14

ISSN: 1473-804x online, 1473-8031 print

By equation (2), the threshold temperature matrix can be converted into the corresponding gray image (0-255). And the morphological opening and closing operation processing is used to eliminate the isolated noise points and preserve the edge of the image. There might be some interference temperature close to the pedestrian objects in the resulting pedestrian areas of the primary, such as light bulbs, hot water cup larger heat source. According to the aspect ratio R pedestrians and primary area of standard deviation, we can get rid of the area that did not meet the requirements. R received by equation (3) in in-frared image, by calculating the ratio of R of 0.4. We can calculate their standard deviation for the high temperature region which is not satisfied with the requirement of the aspect ratio. Usually thermal radiation of infrared image in various parts of the body is different. The thermal radiation of the head and the thigh is greater than that of the other parts, while the light bulb and other heat sources are uniformly distributed. Therefore, the human body is generally higher than the non-pedestrian heat source. After calculation, the pedestrian primary area of the standard deviation is generally greater than 12. Finally, we conform to the conditions of the pedestrian preselected area unified adjust the size to get the original infrared images corre-sponding ROIs.

$$P_x = 256 * (x - MinValue)/(MaxValue - MinValue) \quad (2)$$

$$R = \frac{W}{H} \quad (3)$$

W is the region of interest width; *H* is the height of region of interest, as ratio of high to width of the region sof interest.

B. Histograms of Oriented Gradients

Based on machine learning, the basic idea of the pedestrian detection method is feature extraction, such as color, gradient, etc. Then need to obtain the characteristics of the vector, the objects divided into pedestrians and non-pedestrian. The ma-chine learning used to train two kinds of classifiers, which is used to decide the feature vector is a pedestrian model or the specific location of pedestrians. The core problem of this method is feature extraction, classification and location. There has many characteristics used to describe the pedestrian, but for infrared image pedestrian detection area is still not fully apply. Our algorithm is based on the brightness of the infrared image and contour information, using a blend of the HOG and the Histogram of Intensity (HOI) fusion HOGI feature extraction [12].

HOG features describe the edge contour of human body through the local gradient magnitude and direction in the image. It first divide the image into small unit cells, then collecting unit cells of each pixel in the gradient or edge direction histogram, the histogram finally combined constitute feature descriptor. To improve the performance of HOG and robustness, we transform the local histogram in the image of a block to normalization. The sample image segmentation for several pixel cell, with type (4) ~ (7) compute pixel gradient and direction.

$$G_x(x, y) = H(x+1, y) - H(x-1, y) \quad (4)$$

$$G_y(x, y) = H(x, y+1) - H(x, y-1) \quad (5)$$

$$G(x, y) = \sqrt{G_x(x, y)^2 + G_y(x, y)^2} \quad (6)$$

$$D(x, y) = \tan^{-1}\left(\frac{G_y(x, y)}{G_x(x, y)}\right) \quad (7)$$

Average gradient direction of each cell is divided into nine bin, in the face of all pixels in each cell of gradient direction his-togram statistics in all directions interval, a nine dimensional feature vector and the gradient direction histogram feature coding of the cell can be get.

$$M(k) = \sum_{x=1}^{n}\sum_{y=1}^{m} \delta[D(x, y) - k] \quad (8)$$

Due to the infrared image, the pedestrian edge profile of the gradient intensity to significantly higher than the edge contour, gradient direction of the statistical is shape characteristics of the pedestrian. Using gradient amplitude as weights, therefore, the weighted gradient direction, highlight the edge contour features of the human body more, better express the pedestrian targets. Weights are as follows:

$$W(x, y) = \frac{G(x, y)}{MAX(G)} \quad (9)$$

$$M(k) = \sum_{x=1}^{n}\sum_{y=1}^{m} \delta[D(x, y) - k] \times W(x, y) \quad (10)$$

A block is formed in each of the 4 adjacent cells. Feature vectors in a block are combined to obtain 36 dimensional feature vectors. The sample images are scanned with a block of a unit. Finally all the characteristics of the block from the HOG features of the body.

C. Computation of Histogram of Intensity

Histogram of intensity graphical denote pixel values in different intensity of the different values, also different frequency and strength for grey image range of [0 ~ 255]. The RGB colour images can indicate the strength of the three kinds of colour histogram independent. Histogram of intensity is one of the effective means can be used to search for grey image binarization threshold, if a picture of a grey, image histogram is shown as two peaks, the binarization threshold should be a grey scale value between the two peaks. At the same time, the histogram of intensity is to adjust the important basis of image contrast. The specific calculation as follows:

1) build histogram of intensity for each cell

The cell is divided into multiple images of the same size and composes multiple cell big blocks, the strength value is divided into several bin. For example, each cell size is 8×8 pixels, nine bin of the histogram is used to statistics the 8×8 pixels intensity, and namely the intensity range [0-255] of the cell can be divided into nine intensity range.

2) block the normalized histogram of intensity

The large space connected block combined by each cell . In this way, all cells within a block vector together then get the HOI feature vector of the block, and normalized the feature vector in the block. the blocks overlap each other is to make each cell of different blocks contribute normalization.

3) HOI characteristics

Finally, each block feature vector constituted to HOI features for classification. Through the image of the local cell, HOI features better describes the local brightness of image, which is relatively stable can describes the pedestrians in the infrared. However, HOI characteristics is difficult to distinguish with tree trunks. Street lamp also has more stable in the local bright-ness of objects, it is not very suitable as a pedestrian detection features alone, but can be combined with a description on the edge of the characteristics of HOG to improve the detection performance.

D. Histogram of Oriented Gradient and Intensity Feature Extraction

Proposed in the literature [12] gradient direction and intensity histogram feature well describes the pedestrian contour edge, head, body, legs and other local luminance information. It is a kind of feature descriptor by using support vector machine (SVM) training. In this paper, the size of the pedestrian sample library is 64×128. Cell 8×8 was used to scan the samples, the features HOG and HOI were extracted respectively. Every 2×2 cell to form a block, and enter the linear kernel function to SVM training and through the linear discriminant function . After the first training dates and HOI characteristics of each dimension's contribution to the classification of weight is obtained. The greater the w value means that the more features of the dimensional vector to represent the characteristics of the pedestrian. The maximum positive SVM weight dis-tributions of HOG and HOI in each block are respectively calculated. Comparing their position in the same block are w value to determine the block is calculated HOG features or HOI. The result weight distribution feature extraction template is HOGI characteristics of infrared image descriptor. In the subsequent training need to calculate the sample HOGI characteristics (i.e., each block position need to calculate the HOG or HOI), input classifier was train to get HOGI classification detector. After the classifier training done, we need to extract HOGI features of the ROIs in every frame image, and then by trained HOGI classification detector and got the pedestrian detection results. As shown in fig. (2) for infrared image pedestrian detection process.

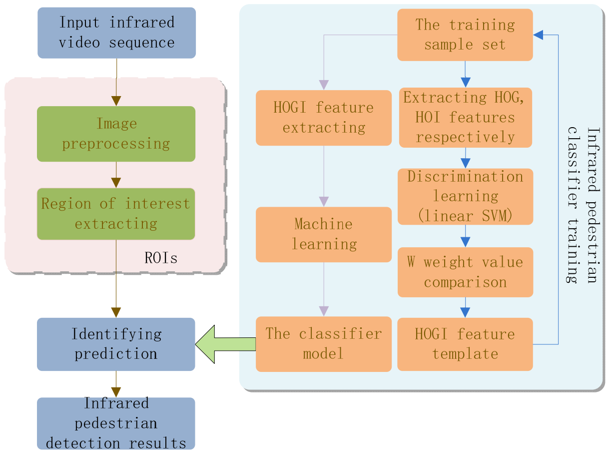


Fig.2 The Flow Chart of Infrared Image Pedestrian Detection

IV. EXPERIMENTS

A. Data Preparation

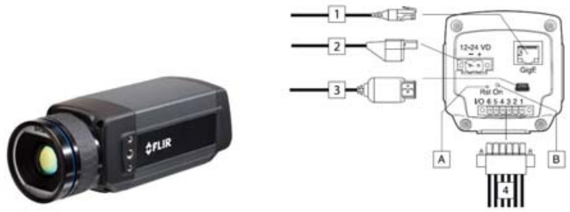
The dataset used in our experiments,is recorded in different scenes of campus environment, the park, the road pavement etc. It was acquired in 6 different sessions, each containing a varying number of images. Each session occurred at a different location and with different illumination and temperature conditions. The classification dataset comprises 40796 8-bit one-channel images with dimension 640×480 , divide into 8076 positives and 32720 negatives. The train set contains 5104 positives and 21695 negatives, while the test set contains 2972 positives and 11025 negatives. The detection dataset con-tains the full frames from which the classification dataset was extracted, along with manual annotations of the pedestrian's positions. It comprises 7612 8-bit one-channel images, with dimension 640×480. The train set contains 3079 images, and the test set contains 4533 images. Fig.(3) shows some cropped-image examples of positives and negatives of the classification dataset.

DOI 10.5013/IJSSST.a.17.28.14 ISSN: 1473-804x online, 1473-8031 print

Fig.3 Example Cropped Images of the Classification Dataset. The upper row contains examples of pedestrians acquired under different temperatures and illumination conditions. The lower row contains randomly selected windows from images containing no-pedestrians. For visualization purposes the contrast has been enhanced.

B. Experimental Environment

The computer used in our experiments with (R) Xeon (R) 3.00GHz (Inter) CPU (E5-1607), 8GB memory. The data acquisition equipment used is FLIR infrared thermal imaging instrument, the model is A615, the resolution is 640×480.As shown in figure (4), (a) is the infrared thermal imager, (b) for their backend interface diagram in detail. The specific parameters are shown in Table I.



a. b.

Fig.4 A615 Thermal Imager and Its Interface Diagram

TABLE I. A615 DETAILED PARAMETERS

Product model	FLIR A615
Viewing Angle（FOV）/The shortest distance	25×19 / 0.25m
The spatial resolution（IFOV）	0.68 mrad
The focal length	24.6nm
Image frequency	50Hz
The focal plane array detector（FPA)/Wavelength range	Uncooled bolometer / 7.5~14 um
Infrared resolution	640×480 pixel
Measurement object temperature range	-20 ~ +150℃ +100 ~ +650℃+300 ~ +2000℃
Working environment temperature range	–15℃ ~ +50℃

C. Results and Analysis

1) Evaluation on the classification dataset

Pedestrian classification is treated as a supervised pattern recognition problem. In this section two kinds of classification methods have been used, SVM and Adaboost. The train dataset is used to train the feature-classifier combinations. Likewise, testing is performed on the whole test dataset. Classification performance is evaluated by means of Detection-Error Trade-off (DET) curves, which quantify the trade-off between miss rate and false positive rate. The false positive rate and false negative rate is low, the better classification effect. HOG, LBP features combined with HOG and HOGI feature of three kinds of classification performance have been compared at the experiment.

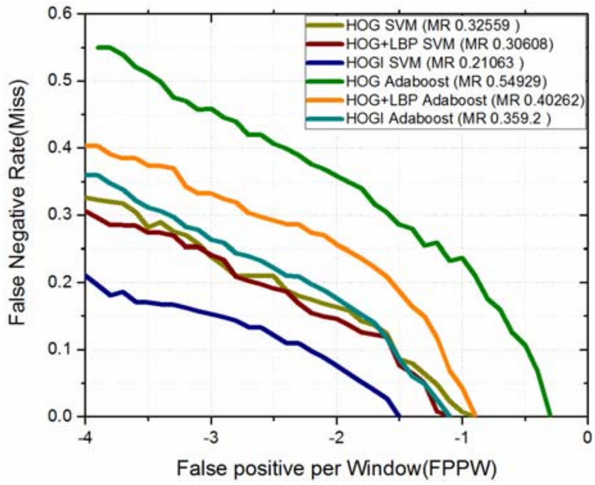


Fig.5 DET Curves for Each Feature Vector in the Classification Dataset. Horizontal axis represent the number of false positives per window analyzed. Vertical axis represent the miss rate. Legend states miss rate (MR) at10−4 FPPW.

The DET curves in Fig. (5) compare the performance of SVM and Adaboost detectors for the HOG, HOG+LBP and HOGI descriptors. From these curves it can be observed that the best performing feature seems to be HOGI with a miss rate of 0.21 at 10−4 false positives (FP) for the SVM-Lin classifier, followed by HOG+LBP with a miss rate of 0.30 at10−4 FP. LBP features combined with HOG significantly getting better results as an independent classifier than HOG reduced by 14% at 10−4FP for the Adaboost classifier. Concerning the classification methods, Linear SVM classifier performs better than Adaboost for the three kinds of descriptors.

2) Performance on the detection dataset under different illumination conditions

In order to verify the accuracy of pedestrian detection in low illumination environment, the detection performance of three feature descriptor classifier are compared on detection database collected in the sunny morning, cloudy evening and night three time. In Fig. 6, we plot DET curves of the three feature descriptor performing, i.e. miss rate versus false positives per image (FPPI), on our testing dataset under different illumination scene including sunny(2045Lux), cloudy(226Lux), dark night(0.024Lux). Best detection results were obtained with the HOGI descriptor, with a 30% miss rate at 0.1

False Positives per Image (FPPI), followed by the HOG+LBP, with a 38% miss rate at 0.1 FPPI. The HOG descriptor gets the slightly highest miss rate of 52% at 0.1 FPPI. Otherwise, there is little difference in the detection accuracy of different illumination for each feature descriptor. Pedestrian detection based on infrared image has good performance in low illumination environment such as night. Fig.(7) shows the examples of the detection results in different scenes.

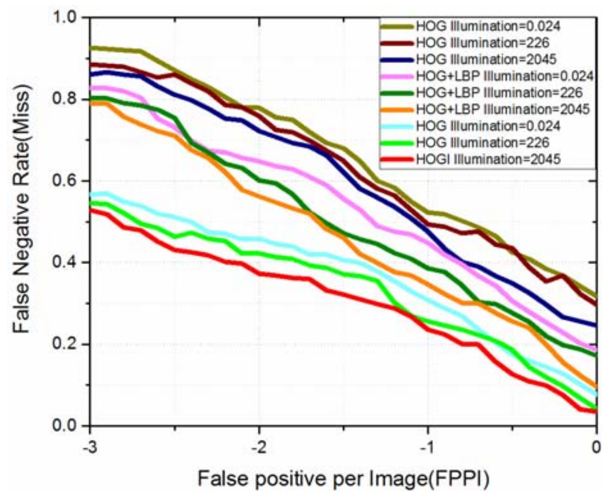


Fig.6 DET Curves on Our Testing Dataset for Large Pedestrian's Measure Report False Positives Per Image (FPPI) against Miss Rate. Legend states miss rate(MR) at 0.1 FPPI.

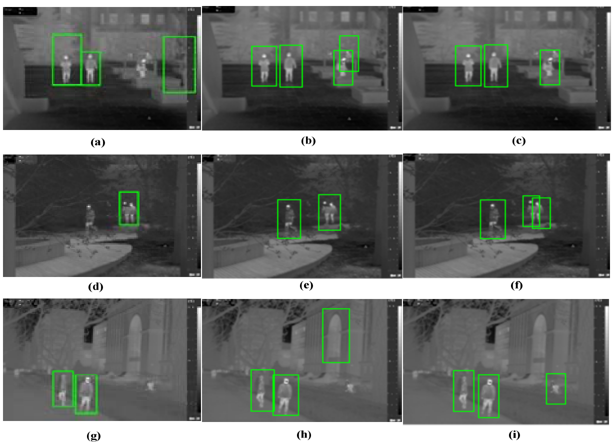


Fig.7 Pedestrian Detection Results from Different Scenes Including Campus, Park and Road.(a, d, g) HOG, (b, e, h) HOG-LBP, (c, f, i) HOGI.

V. CONCLUSION

This paper proposes a pedestrian ROI extraction method based on the temperature of the matrix. It can greatly overcome the low infrared image resolution, environment reflection and stability with the device itself interested in pedestrian area error caused by extracting or leakage problem. Combining the HOGI feature descriptor an effective infrared pedestrian detection method has been obtained .The experimental results show that our method under the condition of without any increase in feature dimension, obtain infrared image pedestrian contour features and brightness, better characterization of pedestrians, improve the computational efficiency of pedestrian detection and infrared image detection accuracy.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

ACKNOWLEDGMENTS

This project was supported by the project of the National Nature Science Foundation of China (Grant No. 61271370)., and the major program that is funded by National Nature Science Foundation of China (Grant No. 91420202). We thank Beijing Key Laboratory of Information Service Engineering for the vehicular. We also would like to thank friends' help to modify the English grammar of writing.

REFERENCES

[1] Geronimo D, Lopez A M, Sappa A D, et al. Survey of pedestrian detection for advanced driver assistance systems[J]. Pattern Analysis and Machine Intelligence, IEEE Transactions on, 32(7): 1239-1258.2010,

[2] Bertozzi M, Broggi A, Fascioli A, et al. Pedestrian detection for driver assistance using multiresolution infrared vision[J]. Vehicular Technology, IEEE Transactions on, 53(6): 1666-1678.2004

[3] Xu T,Huang T J and Tian Y H.Survey on pedestrian detection technology for on-board vision systems[J].Journal of Image and Graphics,18(4):359~367,2013

[4] Dollar P, Wojek C, Schiele B, et al. Pedestrian detection: An evaluation of the state of the art[J]. Pattern Analysis and Machine Intelligence, IEEE Transactions on, 34(4): 743-761. 2012

[5] Munder S, Gavrila D M. An experimental study on pedestrian classification[J]. Pattern Analysis and Machine Intelligence, IEEE Transactions on, 28(11): 1863-1868, 2006.

[6] Liu Q, Zhuang J, Ma J. Robust and fast pedestrian detection method for far-infrared automotive driving assistance systems[J]. Infrared Physics & Technology, 60: 288-299. 2013

[7] Wang J, Chen D, Chen H, et al. On pedestrian detection and tracking in infrared videos[J]. Pattern Recognition Letters, 33(6): 775-785,2012

[8] Zou H, Sun H, Ji K. Real-time infrared pedestrian detection via sparse representation[C]//Computer Vision in Remote Sensing (CVRS), 2012 International Conference on. IEEE, pp:195-198,2012

[9] Qi B, John V, Liu Z, et al. Use of sparse representation for pedestrian detection in thermal images[C]//Computer Vision and Pattern Recognition Workshops (CVPRW), 2014 IEEE Conference on. IEEE, 2014: 274-280.

[10] Miron A, Besbes B, Rogozan A, et al. Intensity self similarity features for pedestrian detection in far-infrared images[C]//Intelligent Vehicles Symposium (IV), 2012 IEEE. IEEE, pp: 1120-1125,2012

[11] Sun H, Wang C, Wang B, et al. Pyramid binary pattern features for real-time pedestrian detection from infrared videos[J]. Neurocompu-ting,74(5): 797-804, 2011

[12] Zhu Congcong,Xiang Zhiyu. Infrared Pedestrian Detection Based on Histograms of Oriented Gradients and Intensity[J] . Computer Engi-neering,40 (12) :195 - 198 ,2014

[13] Tan Y, Guo Y, Gao C, et al. Background subtraction based level sets for human segmentation in thermal infrared surveillance systems[J]. Infrared Physics & Technology, 61(5):230-240.2013

[14] Lei L, Huang Z. Infrared dim target detection technology based on background estimate[J]. Infrared Physics & Technology, 62(2):59–64.2014

[15] Li C C, Wu P C, Lin C H. Pedestrian detection using heuristic statistics and machine learning[C]// Information, Communications and Signal Processing (ICICS), 2013, 9th International Conference on. IEEE, pp:1-5,2013

[16] Erturk S. Region of Interest Extraction in Infrared Images Using One-Bit Transform[J]. Signal Processing Letters IEEE, 20(10):952-955.2013

[17] Dalal N, Triggs B. Histograms of Oriented Gradients for Human Detection[C]// IEEE Conference on Computer Vision & Pattern Recognition. pp:886-893,2005

[18] Zhu Q, Yeh M C, Cheng K T, et al. Fast human detection using a cascade of histograms of oriented gradients[J]. Cvpr, 2:1491-1498.2006

[19] Suard F, Rakotomamonjy A, Bensrhair A, et al. Pedestrian Detection using Infrared images and Histograms of Oriented Gradients[C]// Intelligent Vehicles Symposium, 2006 IEEE. IEEE, pp:206 - 212.2006

[20] Chang S L, Yang F T, Wu W P, et al. Nighttime pedestrian detection using thermal imaging based on HOG feature[C]// System Science and Engineering (ICSSE), 2011 International Conference on. IEEE, pp:694-698.2011

[21] Li W, Zheng D, Zhao T, et al. An effective approach to pedestrian detection in thermal imagery[C]// Natural Computation (ICNC), 2012 Eighth International Conference on. IEEE, pp:325-329.2012

[22] Olmeda D, Premebida C, Nunes U, et al. Pedestrian detection in far infrared images[J]. Integrated Computer-Aided Engineering, 20(4):347-360,2013

[23] Gao S, Kim I, Jhang S T. Sparse Representation based Target Detection in Infrared Imagee[J]. International Journal of Energy Information & Communications, 2013.

[24] Kim D S, Lee K H. Segment-based region of interest generation for pedestrian detection in far-infrared images[J]. Infrared Physics & Technology, 61(6):120–128.2013

[25] Li G, Zhao Y, Wei D, et al. Nighttime Pedestrian Detection Using Local Oriented Shape Context Descriptor[J]. ICCSEE-13, 2013.

[26] Olmeda D, De l E A, Armingol J M. Contrast Invariant Features for Human Detection in Far Infrared Images[C]// Intelligent Vehicles Sym-posium (IV), 2012 IEEE. IEEE, pp:117-122,2012

[27] Tian X, Bao H, Xu C, et al. Pedestrian Detection Algorithm based on Local Color Parallel Similarity Features[J]. International Journal on Smart Sensing and Intelligent Systems, 6(5): 1869-1890.2013