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Safety Helmet Wearing Detection Based on Image Processing and Machine Learning

Jie Li, Huanming Liu, Tianzheng Wang, and Min Jiang
Electric Power Research
Institute of Shanxi Province of State Grid Corporation
Taiyuan, 030001, China
Email: lijierson8@163.com; liuhuanming@sx.sgcc.com.cn; wangtianzheng@sx.sgcc.com.cn; jiangmin@sx.sgcc.com.cn

Kang Li and Xiaoguang Zhao
Institute of Automation of Chinese Academy of Sciences
Beijing, China
Email: likang2014@ia.ac.cn; xiaoguang.zhao@ia.ac.cn

Shuai Wang
State Grid Zhangjiakou Power Supply Company
Zhang Jiakou, 075000, China
Email: 13731320117@139.com

***Abstract*—Safety helmet wearing detection is very essential in power substation. This paper proposed a innovative and practical safety helmet wearing detection method based on image processing and machine learning. At first, the ViBe background modelling algorithm is exploited to detect motion object under a view of fix surveillant camera in power substation. After obtaining the motion region of interest, the Histogram of Oriented Gradient (HOG) feature is extracted to describe inner human. And then, based on the result of HOG feature extraction, the Support Vector Machine (SVM) is trained to classify pedestrians. Finally, the safety helmet detection will be implemented by color feature recognition. Compelling experimental results demonstrated the correctness and effectiveness of our proposed method.**

***Keywords*—vibe; histogram of oriented gradient; support vector machine; color feature recognition**

I. Introduction

Over the past decades, increasing accidents in power substation has raised many attention for safety monitor. In order to ensure the safe operation of power equipments, more and more intelligent surveillance systems had been developed based on computer vision or image processing [1]–[7]. This measure can not only address the problem of labour monitor, but also highlight the unsafe operation to avoid unexpected accidents.

Safety helmet wearing detection is a very common and crucial task for surveillance in power substation. Whereas there are few researches for studying this problem by using image processing techniques. Most researches focus on the approach investigating of motorcyclists whether wearing or not safety helmets. Waranusast *et al.* developed an automatically detect system for motorcycle riders and was able to ascertain whether they are wearing helmets or not. This system extracts the motion objects and trains a K-Nearest-Neighbor (KNN) classifier for detection [8]. Silva *et al.* exploited the Hough circular transformation to determine the shape of safety helmet and use the extracted Histogram of Oriented Gradients (HOG) features to train a Multi-layer perceptron classifier, which can effectively and simply detect wearing helmet of motorcyclists [9]. In [10], the Kalman filtering and Cam-shift algorithm are used to track pedestrians and determine motion objects. Meanwhile, the color information of safety helmets is used to detect safety helmets wearing.

The objective of this paper is to present a novel and practical safety helmet wearing detection method based on image processing and machine learning in power substation. In order to reduce detection range of surveillance video, the ViBe background modelling algorithm is adopted to segment motion objects in foreground frame. After that, we extract Histogram of Oriented Gradient (HOG) feature of pedestrians in corresponding range and use Support Vector Machine (SVM) to classify the human. Finally, the color feature is exploited to determine whether the human wearing safety helmet or not. Our proposed method includes machine learning like extracting HOG features and training SVM, meanwhile includes image processing like color feature recognition in RGB color space. Extensive experimental results in power substation illustrate the effectiveness and efficient of our proposed method.

The rest of this paper is organized as follows. The overall description of our method is provided in Section II. Section III gives the details of algorithms including ViBe background modelling, HOG feature extracting, SVM classifier training and safety helmet color feature recognition. Section IV presents the experiments and analysis in detail. Finally, conclusion is drawn in Section V.

II. Overall Framework of Safety Helmet Wearing Detection

As is shown in Fig. 1, This safety helmet wearing detection method consists of three phases: 1) background modelling 2) pedestrian classification 3) safety helmet detection.

In power substation, the surveillance camera is installed on the fixed location. So the view of camera is fixed which can make sure that the background can not change in frames. Consider this characteristic, we choose the ViBe background

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Fig. 1: Overall framework of safety helmet wearing detection.

modelling algorithm. Moreover, this method is fast and effective to determine the motion objects. In order to detect the people in power substation whether wearing or not safety helmet, the second step is that obtaining the human location and image information. Thus, we extract the HOG feature of people and train the SVM classifier for people to classify pedestrian in power substation. When we know the human information in frames, we can utilize the color feature to detect safety helmet wearing situations. The more details of our method are described as follow.

III. Principles of Our Method

A. ViBe Background Modelling

The ViBe background model was first put forward by Olivier Barnich and Marc Van Droogenbroeck [11]. It is a universal background subtraction algorithm for video sequences. This model mainly focuses on three parts: the background model establishment, pixel classification and the update strategy.

ViBe algorithm converts moving object segmentation as pixel classification problem. One pixel can be divided into moving foreground pixels or background pixels. A sample set $M(x)$ is established for each pixel x. There are n sample values $\{p_1, p_2, p_3, ..., p_n\}$ in each sample set $M(x)$. p is the pixel characteristic like gray values. $M(x)$ can be described as:

$$M(x) = \{p_1, p_2, p_3, ..., p_n\}. \tag{1}$$

Generally, ViBe algorithm uses the first frame to initialize the background model. Although each sample set has n sample values, the only certain value for each pixel exists in image. For obtaining the sample value, the neighborhood pixel values of each pixel is randomly parted to sample set.

Assume that $v_t(x)$ represents the characteristic value of pixel x in time t, $S_R(p_t(x))$ is denoted as a circular area with radius R and center $p_t(x)$, a threshold T_{th} is set. As the Eqs. (2) and (3), by calculating the intersection operator of $S_R(p_t(x))$ and $M(x)$ to obtain the number NUM_c of samples with same sample value. If the NUM_c is bigger than the T_{th}, $v_t(x)$ will be set as the background pixels, $v_t(x)$ will be described as moving foreground instead.

$$\{S_R(p_t(x)) \cap M(x)\} = NUM_c \tag{2}$$

$$\begin{cases} NUM_c > T_{th}, & background - pixel \\ NUM_c \leq T_{th}, & foreground - pixel. \end{cases} \tag{3}$$

The updating strategy of ViBe algorithm is conservative because the model updating needn't pixels detected as foreground in current frame. Each background pixel x can update a sample in sample set $M(x)$ with $1/\Phi$ probability. Furthermore, the neighborhood pixel also can update a sample in sample set $M(x)$ with $1/\Phi$ probability in same time. The probability of a sample both emerge at time t_0 and t_1 can be computed as

$$p(t_1 - t_0) = e^{-\ln[(n-1)/n]^{(t_1 - t_0)}}. \tag{4}$$

The use of this update method can improve the accuracy of background pixel estimation.

B. HOG Extracting and SVM Training

After obtaining the candidate motion objects range, we hope that machine learning technique can divide the moving foreground into two classes, one is pedestrians and the other is not. Thus we consider to use approach of Dalal and Triggs [12] to model local shape and appearance of the worker using dense histogram of oriented gradients (HOG). Meanwhile, using support vector machine (SVM) [13] to classify human or other moving objects.

The basic idea of HOG is calculating the histogram of oriented gradient in local image area. At first, we need to convert the color image into gray image, and then utilizing Gamma correction to normalize the origin image. Moreover, the edge extractor like Sobel is exploited to compute the gradient components of horizontal and vertical direction of image. This step can be written as:

$$G_x(x, y) = H(x + 1, y) - H(x - 1, y) \tag{5}$$

$$G_y(x, y) = H(x, y + 1) - H(x, y - 1) \tag{6}$$

where $H(x, y)$ is pixel value, $G_x(x, y)$ and $G_y(x, y)$ represent gradients at the vertical and horizontal direction of pixel (x, y) respectively. So the gradient magnitude $G(x, y)$ and gradient direction $\alpha(x, y)$ of pixel (x, y) can be denoted as:

$$G(x, y) = \sqrt{G_x(x, y)^2 + G_y(x, y)^2} \tag{7}$$

$$\alpha(x, y) = \tan^{-1}\left(\frac{G_y(x, y)}{G_x(x, y)}\right). \tag{8}$$

Finally, we divide image into a number of cells, calculate the histogram of oriented gradients of each pixel in cells, collect cells into blocks and convert those to a feature vector.

After acquiring the feature description of human, we will train a Support Vector Machine (SVM) to solve the binary classification. Suppose that a given training sample set S includes n training samples, which can be written as:

$$S = \{(x_i, y_i) | x_i \in R_d, y_i \in \{-1, 1\}\}_{i=1}^{n} \tag{9}$$

where x_i is the feature vector of training samples, y_i is the label of training samples, $y_i = 1$ and $y_i = -1$ are defined as two types of results. We can train a SVM classifier to find an optimal hyperplane $h(x)$. The hyperplane can achieve large margin of separated discrimination plane. If the data is linear separable, we can define the hyperplane by:

$$h(x) = sign(w^T x + b) \tag{10}$$

where w is weight of feature vector and b is the bias. For the pedestrian classification, the data is obvious non-linear seperable. Therefore, we can design a feature transform to map the input vector x into a high dimensional space $\Phi(x)$. By calculating the kernel function $K(x_i, x_j)$, which can be written as $K(x_i, x_j) = \langle \varphi(x_i), \varphi(x_j) \rangle$, we can replace the dot production operation in x space. Here, we select the radial basis function (RBF) kernel function to train SVM. The radial basis kernel function can be represented as:

$$K(x_i, x_j) = \exp(-\gamma \|x_i - x_j\|^2) \tag{11}$$

where γ denote the width of the kernel function. According to the given date (x, y), we can compute the SVM decision function as follow:

$$h(x) = sign(\sum_{i}^{N_s} a_i y_i K(s_i, x) + b) \tag{12}$$

where $a_i \geq 0$, the number of support vectors is N_s and the support vector is s_i.

C. Color Feature Recognition

Based on the results of pedestrian classification, we can acquire the more accurate human location and image information. As is shown in Fig. 3, considering the human body structure, the top region of on-fifth of human is set as the head location of human. We can only focus on this region of our interest. As is well known that the colors of safety helmets are finite, so the color feature will be chose to recognition whether wearing safety helmet or not for pedestrians. The color channels of image are set thresholds for variable colors like red or yellow. we can count the pixel numbers to determine safety helmets wearing situations.

IV. Experiment and Analysis

To evaluate the performance of proposed method, the experiments for safety helmets wearing detection are executed on real-time surveillance videos of power substation. The middle results can be described as follow.

Fig. 3 shows the background modelling results of one person walking in power substation. The white region is the motion objects and the black region is the static background. From the result, we can see that the noises are little but exist.

As is shown in Fig. 4, after the filter of background modelling procedure, the human region is reduced and classification becomes easy and accurate in some extent.

Finally, we detect safety helmet wearing situations and remind the human by our method. Figs. 5 and 6 show the safety helmets detection results, we can see that the result is satisfactory. Our methods can not only detect single person circumstance but also detect multi-persons circumstance.

Except for the qualitative analysis, the quantitative analysis is executed. We randomly sample ten videos data of

Fig. 2: Interest of head region.

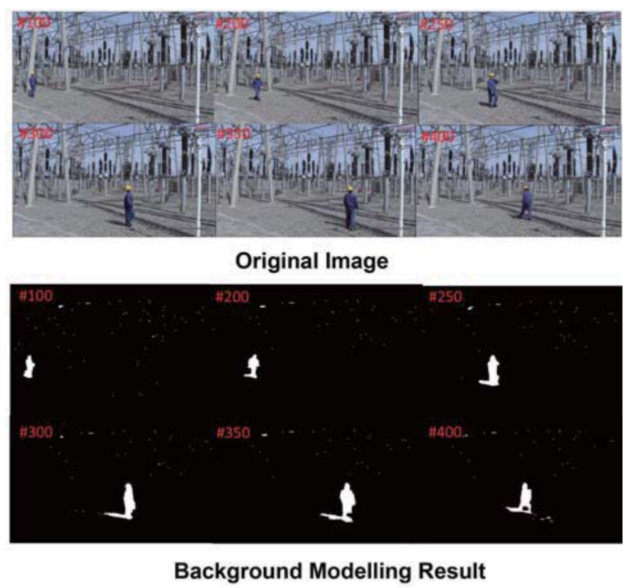

Fig. 3: Background modelling of single pedestrian.

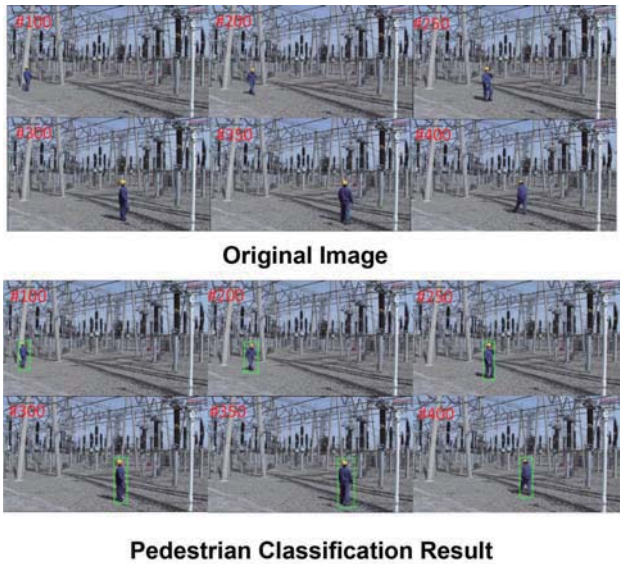

Fig. 4: Single pedestrian classification.

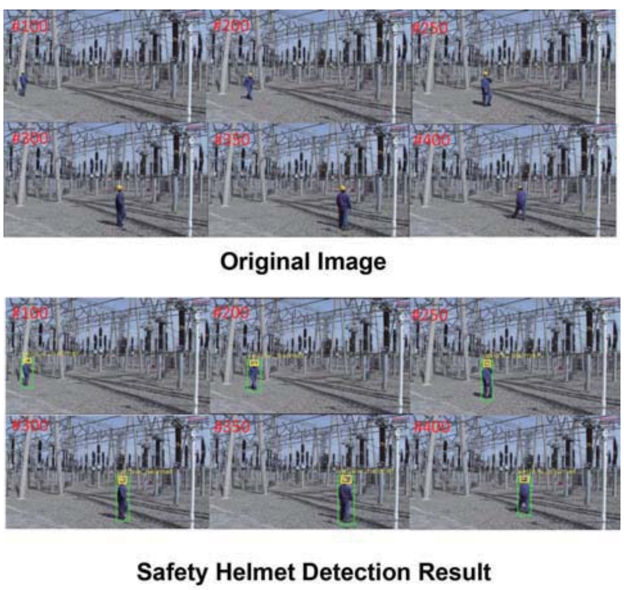

Fig. 5: Single pedestrian safety helmet detection.

Fig. 6: Three pedestrians safety helmet detection.

surveillance system in power substation and test our method. Here, we regard the detection result with red, yellow or blue color as the people with safety helmet, and the detection result with black or white color as the people without safety

TABLE I: The Execution Time and the Accuracy of Detection

Method	Accuracy of detection	Frame rate
Our method	80.7%	7 fps

helmet. By counting the number of detection results of people with or without safety helmet emerged in per frame of per video, we can obtain the average accuracy of detection. The method running speed is acquired by computing the detection number of frames per frame. The accurate rate of detection and speed are represented on the Table I. The performance of our method can meets the demand of real-time application in power substation.

V. Conclusion

In this paper, we have investigated a practical and novel method of safety helmets wearing detection in power substation which can real-time monitor the people whether wearing safety helmet or not. The image processing and machine learning techniques are employed in surveillance system of power substation. Firstly, ViBe background modelling algorithm was used to segment the moving objects under the view of monitoring camera. This trick could filter a lot of static objects. Moveover, the histogram of oriented gradient (HOG) feature extraction and support vector machine (SVM) classifier training were implemented to achieve human location per frame. Finally, we utilized color feature to recognize the safety helmet wearing situations. The overall method are verified by amount of experiments on the surveillance video of power substation.

The ongoing and future work will focus on the improving accuracy and speed of detection of safety helmet wearing. Sometimes, influenced by different light intensity, the classifier may give wrong results. There still exist many challenging problems, such as telegraph poles keeping safety helmet out of sight. So we will consider more kinds of features instead of single color feature. The more fast and excellent pedestrians detection algorithm and more accurate safety helmet detection strategy will be consider into our detection system frameworks.

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