Research on recognition of safety helmet wearing of electric power construction personnel based on artificial intelligence technology

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Abstract. The traditional safety helmet wearing recognition is only based on the color, shape, texture and other characteristics of the image, which is greatly affected by the external environment, and has the problem of unstable recognition accuracy. In view of the above problems, this paper studies the recognition method of power construction workers’ safety helmet based on artificial intelligence technology. After preprocessing the construction monitoring image, such as graying and denoising, the construction personnel in the detection image are located, that is, on the basis of detecting the construction personnel area, the head position of the construction personnel is located, and finally the safety helmet wearing recognition is realized by using YOLO algorithm. The simulation results show that the average recognition accuracy is 95.2%, the recognition effect is stable and has good robustness.

1. Introduction
In the process of electric power construction, electric power construction personnel must be equipped with a complete set of safety protection tools when carrying out relevant operations. Safety helmet is an important safety tool to effectively prevent the head injury of electric power construction personnel, but only by wearing the safety helmet correctly can the head safety protection function of construction personnel be realized [1]. The traditional recognition method based on HSV model can recognize the wearing of safety helmet by matching the color, shape and other features of the helmet [2]. However, this method is too dependent on the template, the actual recognition rate is not stable, and it is easy to be disturbed by the surrounding environment. Artificial intelligence technology is widely used in the field of image processing and analysis, which can effectively improve the efficiency and accuracy of image processing. Therefore, according to the above analysis, this paper will study the recognition method of safety helmet wear of electric power construction personnel based on artificial intelligence technology.

2. Method

2.1. Image preprocessing of construction personnel wearing safety helmet
When the artificial intelligence image recognition technology is used to identify the wearing condition of the safety helmet of the electric power construction personnel, the recognition basis is the monitoring video image of the monitoring camera on the construction site. Therefore, in order to improve the accuracy and efficiency of image processing by using artificial intelligence technology, it is necessary to preprocess the image of construction workers wearing safety helmets.

The weighted average method is used to gray the monitoring video image of the monitoring camera in the construction site [3]. According to the brightness component of pixels in the construction monitoring image, the conversion relationship between RGB and YUV color space is constructed as shown in equation (1).

\[
Y(i, j) = \alpha_1R(i, j) + \alpha_2G(i, j) + \alpha_3B(i, j)
\]  

(1)

Where \((i, j)\) is the position of pixel points in the image collected by construction monitoring; \(\alpha_1\), \(\alpha_2\), \(\alpha_3\) correspond to the weight of R, G, B three color components in RGB color space respectively; \(R(i, j)\), \(G(i, j)\) and \(B(i, j)\) are the brightness values of three components of the image; and \(Y(i, j)\) is the gray value of the image after gray conversion. The wavelet signal is used to denoise the image after the gray level conversion. The image is transformed from time domain space to wavelet domain space by multi-scale wavelet transform. The wavelet coefficients are extracted from the wavelet domain space, and the image wavelet coefficients are thresholded. Through the reconstruction of image reconstruction, the image denoising is completed [4].

In the monitoring video of the construction site, the image of personnel wearing safety helmet belongs to dynamic capture, and the background information in the image affects the recognition result. In order to simplify the image data, digital morphology is used to extract the important characteristics and shape information in the image region. According to equation (2), the image is etched to eliminate the edge minutiae of the object to be identified.

\[
A\Theta B = \left\{ x \mid \left(\hat{B}\right)_x \subseteq A \right\}
\]  

(2)

Where \(B\) is the structure element of the object to be identified in the image; \(\left(\hat{B}\right)_x\) is the pixel set of the structure element moving in the image; \(\Theta\) is the corrosion operator [5]. After the image preprocessing of the safety helmet worn by the construction personnel, the electric power construction personnel in the image are detected to facilitate the subsequent human head positioning.

2.2. Electric power construction personnel inspection

In this paper, we use the PHOG-LBP fusion feature extraction algorithm to detect the construction personnel in the preprocessed image. Firstly, the gradient of each pixel in the image is calculated by using one-dimensional discrete differential template [6]. The gradient vector calculation equation of a pixel in the image is as follows:

\[
\nabla I = \left( \frac{\partial I}{\partial x}, \frac{\partial I}{\partial y} \right) = \left( \frac{I(x+1,y) - I(x-1,y)}{2}, \frac{I(x,y+1) - I(x,y-1)}{2} \right)
\]  

(3)
Where $\nabla I$ is the gradient vector $I$ of the image pixel; $\frac{\partial I}{\partial x}$ is the partial derivative of the image pixel in the $x$ direction; $\frac{\partial I}{\partial y}$ is the partial derivative of the image pixel in the $y$ direction. The size and direction of pixels are obtained by gradient mapping. The image is divided into several square regions, each of which contains 8×8 pixels. According to the calculated image pixel gradient, each pixel is weighted with histogram [7]. After normalizing the weighted histogram, the HOG feature vector of the image is obtained [8]. PCA is used to reduce the dimension of HOG eigenvector to get PHOG eigenvector. Then LBP Operator is used to extract LBP features in 3×3 window. The threshold of feature extraction is set as the gray value of the center pixel of the window. The gray value of the pixels around the center pixel in the window is compared with the threshold value. If it is greater than the threshold value, it is taken as 1, otherwise it is taken as 0. If the binary number in 3×3 window is obtained in turn, the 8-bit binary number reflects the LBP eigenvalue of the image. The LBP eigenvalues obtained in the above steps are cascaded with the PHOG eigenvector to obtain the PHOG-LBP eigenvector. The feature vector is input and SVM classifier is used to detect the construction workers in the image.

2.3. Positioning of human head area

After the detection and determination of the presence of construction personnel in the video image of power construction monitoring, it is necessary to locate the head area of the human body, so as to detect whether the construction personnel wear safety helmets. Establishing the human contour area template is shown in Figure 1. The shadow part in the template area is marked as area A and the blank part is marked as area B [9].

![Figure 1. Human contour area template.](image)

Among them, area A is composed of head H and trunk T of electric power construction personnel. The area of area B is equal to area A, and the edge interval between area B and area A is consistent everywhere. Area B corresponds to the head and trunk of area A, respectively $H'$, $T'$.

The support vector machine is used to detect the construction personnel in the video image of power construction monitoring, and the image is transformed into a binary graph. If it is the pixel value $I(x, y)$ of the pixel on the position $(x, y)$, then the value range of the pixel in the binary image after transformation is [0, 1]. In this paper, the human head area is located by comparing the number of pixels with non-zero pixel values in template regions A and B [10]. The expression of the number of pixels with non-zero pixel values in regions A and B is as follows.

$$
\begin{align*}
\sum A &= \sum_{(x,y) \in A} I(x,y) \\
\sum B &= \sum_{(x,y) \in B} I(x,y)
\end{align*}
$$

(4)
The evaluation function $S$ is defined to evaluate the accuracy of human head region matching. The following is the definition of evaluation function:

$$S = \frac{1}{\text{Area}(A)} \left( \sum A - \sum B \right), \text{ if } S < 0, \text{ } S = 0$$

(5)

Where $\text{Area}(A)$ is the sum of the number of pixels in area $A$ and $S \in [0, 1]$. According to the above formula, the larger the function value of the evaluation function is, the more accurate the head positioning is. A square restricted area is set to simplify the calculation steps in the head positioning process. Suppose that the corresponding side lengths of the head and trunk in area $A$ and area $B$ are known, and according to the knowledge of human body structure proportion, the restriction relationship between the head positioning window and the side length of area $A$ and area $B$ is set as follows [11]:

\[
\frac{W_{H'}}{W} \in \{1.0, 0.95, 0.9, 0.85, 0.8, 0.75, 0.7\}
\]

\[
\frac{W_{H}}{W_T} = \frac{W_{H'}}{W_{T'}} \in \{0.55, 0.5, 0.45, 0.4, 0.35\}
\]

(6)

Where $W_{H'}, W_{H}, W_{T'}, W_{T}$ are the square side lengths corresponding to the restricted area $H, H', T', T$ respectively; and $W$ is the width of the head positioning detection window, and their values are known. According to the known value, the evaluation function value can be approximately obtained, and the head area can be roughly located. According to the above calculation process, the human head position coordinates can be obtained from the known coordinates of a head to complete the positioning of the human head area. After positioning the human head area, an artificial intelligence technology is used to identify the wearing situation of the safety helmet of the construction personnel.

2.4. Use artificial intelligence to realize safety helmet wearing recognition

In this paper, YOLO algorithm in convolution neural network is used to realize the recognition of safety helmet worn by construction personnel. Based on the structure of convolutional neural network, YOLO algorithm inputs the preprocessed image to be recognized into the network by the input nodes of the convolution neural network. The dimension of the image is reduced in the convolution layer, and the human body in the image is detected and the image head is located. After convolution operation, image features are extracted under the action of activation function sigmoid [12]. According to the extracted image features, the maximum likelihood probability of the category is calculated, and the soft Max classifier is used for image feature matching.

Due to the different convolution kernels in each convolution layer of the convolution neural network in YOLO algorithm, it is necessary to calculate the residual between the output value of each convolution layer node and the expected value. The residual value is determined according to the training results of neural network. When the residual value between the output value of neural network and the expected value is less than the residual value determined by training, the current network parameters are used to identify the wearing of safety helmet. The identification results of YOLO algorithm are marked to complete the identification of construction personnel wearing safety helmet. The above work completed the intelligent recognition of power construction workers' safety helmet.

3. Simulation experiment

The life safety of electric power personnel is an important basis for the stable development of the power industry. In the electric power construction, the safety helmet will be designed for the virtual simulation experiment of the intelligent recognition method for the safety helmet wearing of the electric power construction personnel in this section, and the effectiveness of the intelligent
recognition method of the safety helmet wearing of the electric power construction personnel studied above is verified through the experiment.

3.1. Experimental content
This simulation experiment adopts the form of comparing the recognition method studied in this paper with the traditional method, and verifies the effectiveness and reliability of the identification method of helmet wearing by using two simulation experimental platforms with identical configuration. The comparison index of the simulation experiment is the accuracy rate, recall rate and actual recognition effect of the two methods. In the process of the experiment, other experimental variables are controlled, and the final conclusion is obtained by processing and analyzing the experimental data.

3.2. Experimental process
Taking the monitoring video data of a power construction site as the experimental data source of this simulation experiment, the effective experimental images are intercepted from the video by using the editing software, and the resolution, size and other parameters of all experimental images are identical. By processing the experimental image such as scaling, rotation and offset, the deviation of simulation results caused by the imbalance of experimental images is avoided. In all experimental images, the situation of power construction personnel wearing safety helmet is recorded by manual statistics and calibration in the editing process, and the recorded data are used as the data basis for the analysis of the experimental results. In this paper, the artificial intelligence-based recognition method for safety helmet wearing of electric power construction workers is taken as the experimental item, and the traditional intelligent recognition method based on HSV model is taken as the contrast item. The experimental data corresponding to each experimental index is recorded, the experimental data is processed and analyzed, the performance of the two recognition methods is compared, and the final experimental conclusion is obtained.

3.3. Experimental results
Three representative images are selected from the recognition results of the effective experimental images. Figure 2 shows the comparison of the recognition effects of the two safety helmet wearing recognition methods on the experimental images. It is known that there is one person who does not wear the helmet correctly in figure (a), and there is no person wearing the helmet incorrectly in figure (b) and (c).

The recognition effect of the two wearing recognition methods is compared, and the actual recognition effect of the two wearing recognition methods is directly evaluated. In the figure, the black box indicates that the identification object is the human body of the electric power construction personnel; the red box indicates the wrong wearing of the safety helmet; the blue box indicates the identification result of the suspected wrong wearing of the safety helmet; and the green box indicates the correct identification result of wearing the safety helmet.

According to the known results of the recognition image, the recognition effect of the two methods in Figure 2 is analyzed. It can be seen that the recognition result of the method in this paper for figure (a) is incorrect, and the recognition result of the personnel wearing safety helmet in figure (b) and (c) is completely correct. The results of traditional recognition methods for the three images are wrong, and the recognition frame does not fully contain the range of the object, which further affects the recognition effect. Therefore, the recognition effect of the two safety helmet wearing recognition methods is intuitively compared, and the recognition effect of the safety helmet wearing recognition method studied in this paper is better.
Figure 2. Comparison of safety helmet wearing recognition effect. The upper row shows the recognition effect of the method of this paper; The bottom row shows the recognition effect of comparison method.

The recognition results of the two methods are statistically and calculated, and the comparison of the recognition results of the two methods is shown in Table 1. In the table, TP is the number of construction workers who are not correctly wearing safety helmets; FP is the number of construction workers who are wrongly identified as not wearing safety helmets correctly; FN is the number of construction personnel who are not correctly wearing safety helmets but are wrongly identified as correctly wearing them. The performance of the two methods is evaluated by analyzing the data in the table and combining the above conclusions.

| Image number | Recognition methods                  | Total sample | TP  | FP  | FN  | Accuracy /% | Recall rate /% |
|--------------|--------------------------------------|--------------|-----|-----|-----|-------------|----------------|
| 1            | The method of this paper             | 239          | 224 | 15  | 13  | 93.72       | 94.51          |
|              | Traditional method                   | 239          | 204 | 35  | 32  | 85.36       | 86.44          |
| 2            | The method of this paper             | 183          | 169 | 14  | 2   | 92.35       | 98.83          |
|              | Traditional method                   | 183          | 162 | 21  | 7   | 88.52       | 95.86          |
| 3            | The method of this paper             | 137          | 128 | 9   | 5   | 93.43       | 96.24          |
|              | Traditional method                   | 137          | 119 | 18  | 17  | 86.86       | 87.50          |
| 4            | The method of this paper             | 196          | 188 | 8   | 6   | 95.92       | 96.91          |
|              | Traditional method                   | 196          | 171 | 25  | 22  | 87.24       | 88.60          |
| 5            | The method of this paper             | 469          | 460 | 9   | 3   | 98.08       | 99.35          |
|              | Traditional method                   | 469          | 422 | 47  | 38  | 89.98       | 91.74          |
| 6            | The method of this paper             | 418          | 400 | 18  | 11  | 95.69       | 97.32          |
|              | Traditional method                   | 418          | 384 | 34  | 32  | 91.87       | 92.31          |
| 7            | The method of this paper             | 325          | 311 | 14  | 8   | 95.69       | 97.49          |
According to the above table, the recognition accuracy of this method is higher than that of the traditional method. In this experiment, the accuracy and recall rate of this method to identify the wearing of safety helmet of electric power construction personnel are maintained above 91%, which are higher than the recognition accuracy and recall rate of traditional method. It shows that the correct recognition effect of this method is better in the recognition process, and the above data are also matched with the corresponding experimental results in Figure 2. By further processing the data in table 1, the average accuracy rate and recall rate of our method are 95.2% and 97.4%, respectively; the average accuracy rate of the traditional method is 88.8%, and the average recall rate is 90.9%. According to the definition of robustness, the higher the accuracy and recall rate, the better the robustness of the identification method. In conclusion, the recognition accuracy of the safety helmet wearing identification method studied in this paper is better than the traditional method, and has high robustness, which can well meet the needs of identification personnel wearing safety helmet in the construction site.

4. Conclusion
The correct wearing of safety helmet is very important for the safety of electric power construction personnel. Therefore, this paper studies the intelligent recognition method of safety helmet wearing of power construction personnel based on artificial intelligence technology. Through comparative experiments, it is verified that the method in this paper has accuracy and robustness, and can effectively guarantee the safety of construction personnel.

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