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Face recognition technology based on CNN, XGBoost, model fusion and its application for safety management in power system

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Abstract. The safety maintenance of operating site is important for safety management in power system. With the development of artificial intelligence (AI) and popularization of monitoring camera, face recognition technology is widely utilized in operating site of power system. To improve the capability for safety management of operating site in power system, a face recognition model based on convolutional neural network (CNN), eXtreme gradient boosting (XGBoost) and model fusion is built. Firstly, pre-processed images are input into CNN to obtain the recognition probabilities of various face and the extracted face features. Secondly, the extracted features of CNN are input into XGBoost to obtain the recognition probabilities of various face recognized by XGBoost. Finally, above two groups of probabilities are weighted by model fusion technology to obtain the final recognition probabilities of various face, and the final face recognition results are output. Simulation results show that CNN has better capability of feature extraction, and the proposed face recognition model has the highest recognition accuracy among those advanced face recognition models. In addition, this paper describes the application based on the proposed face recognition model in non-working personnel recognition, trajectory tracking of operators, etc, so as to greatly improve the safety management of operating site in power system, which not only ensures safety, but also reduces unnecessary management expenses.

1. Introduction

Nowadays, people's security awareness is getting higher and higher, and the rapid development of artificial intelligence (AI) and scientific information technologies also provides stronger and stronger technical support for the security of all aspects. Among them, face recognition technology has been widely promoted and applied in judicial, financial and supervisory aspects. For the complex environment of operating site of power system, its safety management is particularly important. How to build a face recognition model with higher recognition accuracy and how to apply face recognition technology to improve its safety management capabilities for operating site of power system have received more and more attention and research from scholars.

In the aspect of face recognition, deep learning method is widely used, especially convolutional neural network (CNN). [1] presented a multi-task convolution deep network to build a face recognition model. [2] proposed a model based on multi-task learning and CNN for face recognition.

[3] presented a new approach for face recognition using CNN with hashing forest. In addition, CNN is considered to be the most powerful and effective feature extraction mechanism [4]. Therefore, [5] employed a deep CNN to extract facial features, and proposed a face recognition model based on bi-directional collaborative representation-based classification algorithm. [6] combined CNN and SVM to build a occluded face recognition model. In addition, eXtreme gradient boosting (XGBoost) is an excellent gradient boosting method and has been applied to feature recognition of urban road traffic accidents [7], network intrusion detection [8], multi-class disturbance Events recognition [9], etc. However, XGBoost is rarely utilized in face recognition modeling. Meanwhile, model fusion technology shines in field of face recognition. [10] presented a face recognition algorithm based on improved CNN and ensemble learning. [11] proposed a new face recognition method based on deep neural network and weighted fusion of face features.

For the application of face recognition technology in safety management in power system, [12] developed a comprehensive personnel security management platform using face recognition technology. [13] improved the face recognition algorithm based on Adaboost in substation remote monitoring system to further improve the safe operation of unattended substations. [14] designed a safety management system for construction site of power grid capital construction based on face recognition, which ensured the safety of power grid construction site.

On the basis of existing research, this paper gives full play to the powerful advantages of CNN for feature extraction, combines it with XGBoost, and utilizes model fusion technology to explore a novel face recognition model based on CNN, XGBoost and model fusion. At the same time, this paper describes the application based on the proposed face recognition model in non-working personnel recognition, trajectory tracking of operators, etc, so as to realize the scientific and intelligent safety supervision for operating site of power system, solve the problem of real identity verification and personnel safety behavior management.

2. Face recognition model based on CNN, XGBoost and model fusion

The proposed face recognition model based on CNN, XGBoost and model fusion is shown in Figure 1. Its process is as follows:

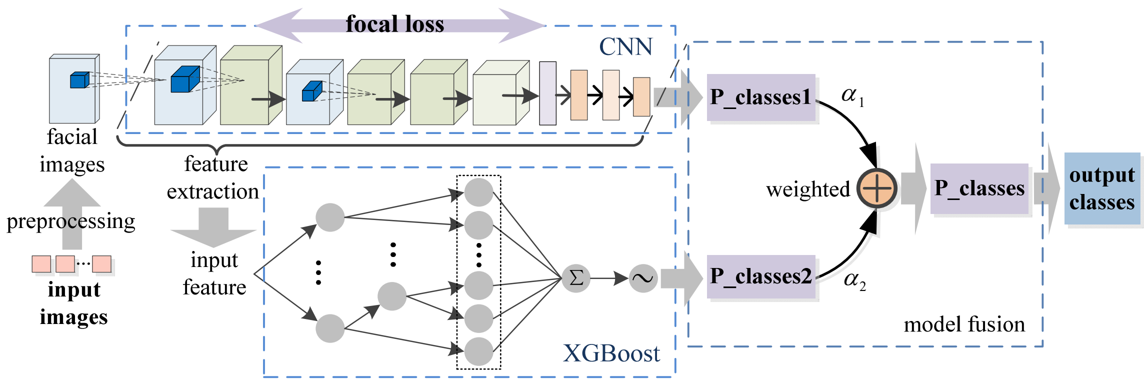

Figure 1. Proposed model.

1) Obtain the images and preprocess it into the required facial images;

2) Input facial images into CNN for training, so as to obtain the probability P_classes1 of tested face in each category recognized by CNN, and the effective face features extracted by CNN;

3) Input the face features extracted by 2) into XGBoost for training, so as to obtain the probability P_classes2 of tested face in each category recognized by XGBoost;

4) Weighted P_classes1 and P_classes2 to achieve the fusion of two models and obtain the final probability P_classes of tested face in each category;

5) Output each face recognition result utilizing P_classes obtained by 4).

2.1. CNN

The input of CNN is a two-dimensional image after simple regularization, in which the hidden layer is mainly composed of convolution layer and pooling layer alternately. The network structure of CNN in the proposed model is shown in Figure 2.

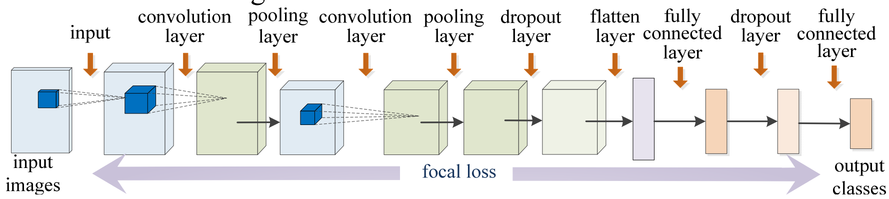

Figure 2. Network structure of CNN.

In the training process of CNN, loss function plays an important role. The common loss function for multi-classification tasks is cross entropy loss function. However, the model proposed adopts another loss function, i.e. focal loss [15]. This loss function can reduce the weight of easy samples and pay more attention to hard samples. It is defined as:

$$FL(p_t) = -\alpha_t (1-p_t)^\gamma \log(p_t) \tag{1}$$

where α_t and γ are hyper-parameters, p_t is the probability of recognition as a certain face class.

Through many experiments, it is finally determined that CNN is composed of one input layer, two convolution layers, two dropout layers, two pooling layers, one flatten layer, two fully connected layers and one softmax output layer. The number of convolution kernel in each layer is 5 and 10 respectively, and the size of each convolution kernel is 3×3. The size of each pooling kernel is 2×2. The dropout values are both 0.2, and the activation function is relu.

2.2. XGBoost

XGBoost is an ensemble tree model improved by boosting. Compared with the traditional boosting algorithm, XGBoost can make full use of multi-core CPU for parallel computing and improve the running speed. The basic principle of XGBoost is to combine multiple tree models with lower accuracy into one model with higher accuracy [16]. Its objective function is

$$F(x) = \sum_{i=1}^{n} l(y_i, \hat{y}_i) + \sum_{k=1}^{K} \Omega(f_k) \tag{2}$$

where n is the number of samples, K is the number of classification and regression trees (CART), $l(y_i, \hat{y}_i)$ is the loss function of model, $\Omega(f_k)$ is the regularization.

Then, the loss function is expanded by the second order Taylor expansion, and the optimal solution is obtained by adding a regularization to the objective function to avoid overfitting. Finally, the importance of each feature is calculated according to the number of times that tree node splits feature.

2.3. CNN-XGBoost

CNN is considered to be the most powerful and effective feature extraction mechanism. Therefore, the combination of CNN and XGBoost can give full play to the powerful advantages of CNN for feature extraction and further improve the recognition accuracy of XGBoost. The architecture of CNN-XGBoost model built in this paper is shown in Figure 3.

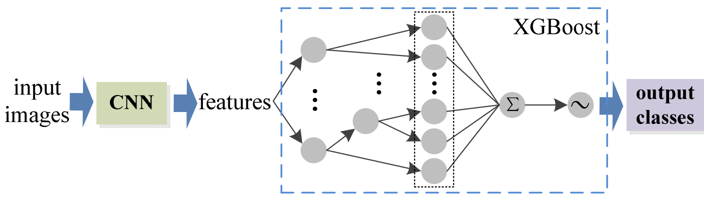

Figure 3. The architecture of CNN-XGBoost.

To optimize the XGBoost, the number of decision trees is set as 100, and several parameters are automatically optimized by cross validation with grid search. Finally, it is determined that the max depth of tree is 1, the penalty coefficient is 0, the feature sampling rate is 0.78, the L1 regularization term of weight is 0, and the learning rate is 0.1.

2.4. Model fusion

Model fusion technology can combine multiple learners, and generally can obtain better generalization performance than a single learner. It generally has two strategies: voting method and learning method. This paper adopts voting method. For the *j*th face, the recognition probability of various faces is:

$$y_i = \sum_{i=1}^{L} w_i d_{ij} \tag{3}$$

where ω_i is weight of the *i*th learner; d_{ij} is recognition probability of the *i*th learner to the *j*th face. According to the principle that category with the highest probability is the recognized face, the recognition result of each face can be obtained by y_j.

3. Simulation

3.1. Face database

Two representative benchmark face datasets, Georgia Tech (GT) face database [17] and Olivetti Research Laboratory (ORL) face database [18], are used in this simulation. Among them, the GT face database contains 15 color photos for each of 50 people, and each photo is 640×480 pixels. Each person was photographed twice or three times. Their faces are front or side, their facial expression and the illumination are also different, and the background is messy. The ORL face database contains 10 color photos for each of 40 people, and each photo is 92×112 pixels. It has various properties such as pose, expression and decorative face. Figure 4 and Figure 5 are some samples of two face databases respectively.

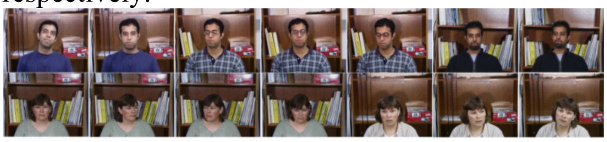

Figure 4. Some samples of GT face database.

Figure 5. Some samples of ORL face database.

3.2. Face detection and preprocessing

The GT face database contains messy backgrounds and the proportion of faces is too small, so that face detection and preprocessing should be carried out for these photos. This experiment uses the face detection classifier Haar of OpenCV to automatically detect faces of all photos in GT face database, and clip the detected facial images to a size of 47×57 automatically. To make the detail of the facial image clearer and reduce the influence of light, all clipped images do gray processing. Partial samples of processed samples are shown in Figure 6.

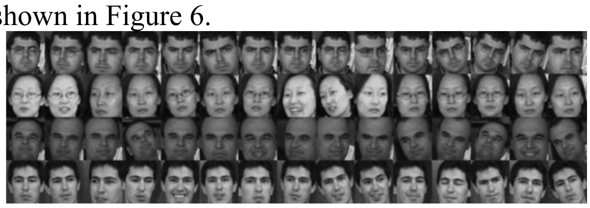

Figure 6. Partial samples of GT face database after graying.

3.3. Results

In order to verify the superiority of the proposed face recognition method, GT and ORL face databases are used to compare the proposed model with INNC model [19], DIBROS model [20], SVD fusion model [21], CNN model, XGBoost model and CNN-XGBoost model. The recognition accuracy of each face recognition model is shown in Table 1.

Table 1. Accuracy of different face recognition models for GT and ORL face databases.

	Recognition accuracy	
Model	GT	ORL
INNC	70.00%	93.75%
DIBROS	68.67%	90.00%
SVD fusion	70.67%	93.75%
CNN	66.67%	86.25%
XGBoost	84.00%	93.75%
CNN-XGBoost	84.67%	93.75%
Proposed	86.67%	95.00%

As can be seen from Table 1, whether GT or ORL face database is used, CNN-XGBoost model has higher recognition accuracy than XGBoost model, which shows that CNN has better ability of feature extraction and can further improve the face recognition performance of XGBoost.

In addition, the proposed model achieves recognition accuracy of 86.67% and 95.00% for GT and ORL face database respectively, which are higher than the recognition accuracy of two base learners. At the same time, compared with the three advanced face recognition models proposed in recent years, the recognition accuracy of the proposed model is still the highest. Simulation results show that the face recognition model based on CNN, XGBoost and model fusion has better face recognition performance and can improve the face recognition accuracy significantly.

4. Platform of safety management in power system based on face recognition

The face recognition technology based on CNN, XGBoost and model fusion can be used to build the platform for safety management in power system, and its basic architecture is shown in Figure 7. Through the identification of ID card, reliable information such as name, image, post and qualification of personnel can be obtained from the authoritative information sources of human resource. At the same time, combined with the monitoring camera collecting the personnel face of operating site, face recognition can be carried out, so as to realize the following functions for safety management in power system:

1) Non-working personnel recognition

The monitoring camera of operating site can monitor and recognize the personnel of site in real time. Once the non-working personnel is found, the sound and light alarm will be triggered immediately, and the relevant information will be uploaded to the safety management center, timely inform the relevant leaders in charge to leave the non-working personnel, so as to eliminate the potential safety hazards.

2) Qualification of special operators recognition

In the special operating site, real-time capture and recognition of personnel face is carried out by monitoring camera. At the same time, authoritative information sources of human resource is mobilized to obtain the qualification information of the personnel of operating site, and the qualification of special operators is ensured by comparison. Once the personnel without corresponding qualifications is found, the sound and light alarm will be triggered immediately, and relevant information will be uploaded to the safety management center, so as to ensure the safety of the operating site.

3) Alarm linkage

When there is an alarm signal on the operating site, the relevant leaders shall be informed immediately and the monitoring camera shall be linked to turn to the alarm site for recording. Meanwhile, face recognition is performed on the person who appears at the alarm site and the personnel information is recorded, which shall be stored in the local and server in real time for retention and verification.

4) Trajectory tracking of operators

Multiple monitoring cameras in the operating site can capture images of each operator at different times and sites. Through face recognition technology, each operator can be identified and its activity sites at different time can be recorded, so as to realize the trajectory tracking of each operator.

5) Personnel attendance

Through real-time video surveillance and capture of personnel images, face recognition technology is used to identify personnels, and the corresponding personnel information is uploaded and recorded, so as to realize the personnel clock in, and reduce the phenomenon of leaving the post without authorization.

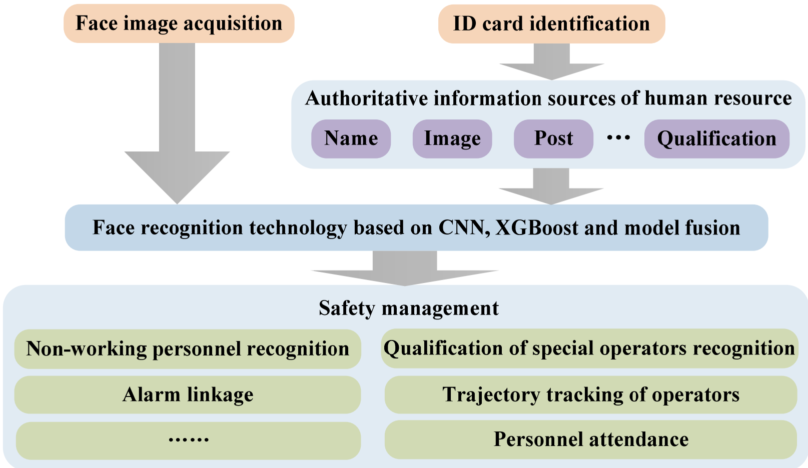

Figure 7. Basic architecture for platform of safety management in power system.

5. Conclusion

The improvement of safety management capability of operating site in power system focuses on the application of face recognition technology.

For face recognition technology, a face recognition model based on CNN, XGBoost and model fusion is proposed. The proposed model can take the advantage of CNN to fully dig the feature information of face, give full play to the classification advantage of XGBoost, and further improve the accuracy of face recognition by model fusion technology. Simulation results verify the highest accuracy of face recognition for the proposed model compared with other face recognition models. In addition, face recognition technology can be applied to the safety management of operating site in power system, such as qualification of special operators recognition and trajectory tracking of operators, so as to eliminate the potential safety hazards in operating site of power system and reduce management costs.

Acknowledgments

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