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Improving Face Recognition Accuracy through Optimization of Haar and LBP Features in MATLAB

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Abstract

As we hasten into the digital age, facial recognition technology has emerged as a pivotal innovation across various domains such as security authentication, surveillance, and identity verification. This research delves into and enhances the Convolutional Neural Network (CNN) framework within the MATLAB environment, substantially augmenting the efficacy of facial recognition algorithms. The manuscript begins by tracing the evolution and current achievements within the facial recognition field, followed by an exploration into the theoretical foundation and key technologies of facial recognition. The aim of this study is to develop an advanced facial recognition algorithm based on CNN, employing efficient image preprocessing techniques such as grayscale conversion, noise reduction, and feature extraction, thereby significantly improving recognition accuracy and processing speed. Experiments conducted within MATLAB showcase the dual advancements in efficiency and speed offered by the optimized algorithm compared to traditional methods. Moreover, the paper discusses the adaptability of this algorithm in complex scenarios and the challenges and strategies likely to be encountered during pragmatic application. The outcomes of this research not only validate the practicality of the proposed algorithm but also illuminate directions and methodologies for the future exploration of facial recognition technology.

Keywords

MATLAB; Facial Recognition; Convolutional Neural Network; Image Preprocessing.

1. Introduction

In the context of rapid information technology development[1], facial recognition technology, due to its efficiency, intuitiveness, and user-friendliness, has been extensively applied in various fields such as security verification, public safety, and personalized services. MATLAB[2], as a powerful mathematical software tool that offers a rich library of functions and efficient matrix computation capabilities, has become an ideal platform for advancing facial recognition technology research[3]. Faced with challenges in accuracy, real-time performance, and anti-interference capabilities, research on facial recognition algorithms based on MATLAB has become increasingly important. With the widespread adoption of internet technology and smart devices, the demand for convenient and secure identity verification methods is growing, driving the research focus towards biometric authentication methods, especially facial recognition technology. This research not only propels the theoretical development of facial recognition technology, deepening the understanding of technical issues such as face detection, feature extraction, and feature matching but also significantly enhances the stability and accuracy of systems such as security verification and identity authentication in practical applications. Researching and optimizing facial recognition algorithms aims to adapt to more complex application scenarios, expand the technology's application range, and promote the healthy development and broad application of facial recognition technology worldwide, contributing to the construction of a more intelligent and efficient society in the future.

2. Overview of Face Recognition Technology

Face recognition technology is a biometric identification method that uses computer vision and pattern recognition techniques to analyze and recognize facial images[4]. The core task of face recognition technology is to extract effective features from facial images and match them to achieve face recognition and verification. Face recognition technology is a non-contact and easy-to-accept identification method, and has broad application prospects in security authentication, monitoring, and identity verification.

2.1. Development History of Face Recognition Technology

The development history of face recognition technology can be divided into three stages: traditional methods based on feature extraction, methods based on statistical models, and methods based on deep learning[5].

In traditional methods based on feature extraction, face recognition technology mainly extracts features such as facial contours, eyes, nose, and mouth manually from facial images[6], and then performs feature matching and recognition. This method achieves face recognition to a certain extent, but it is highly sensitive to light, posture, and expression, and the recognition accuracy is limited.

In methods based on statistical models, face recognition technology mainly performs statistical analysis on facial images, such as principal component analysis (PCA) and linear discriminant analysis (LDA), to establish a face model, and then performs feature matching and recognition. This method improves the recognition accuracy of face recognition to a certain extent, but it has high requirements for the quality and resolution of facial images, and the model establishment and training process is complex.

In methods based on deep learning, face recognition technology mainly uses convolutional neural networks (CNN) and other deep learning models to automatically extract features from facial images, and then performs feature matching and recognition. This method improves the recognition accuracy and robustness of face recognition to a certain extent, and does not require manual feature extraction, and the model establishment and training process is simple.

2.2. Core Steps of Face Recognition Technology

The core steps of face recognition technology include face detection, face feature extraction, and face feature matching.

Face detection is the first step of face recognition technology and the most critical step. Its task is to locate the position and size of the face in the image and extract the face region[7]. Common face detection algorithms include Haar feature algorithm, Viola-Jones algorithm, and face detection algorithms based on deep learning.

Face feature extraction is the second step of face recognition technology. Its task is to extract effective features from the face region for face recognition. Common face feature extraction algorithms include local binary pattern (LBP) algorithm, principal component analysis (PCA) algorithm, linear discriminant analysis (LDA) algorithm, and convolutional neural network (CNN).

Face feature matching is the third step of face recognition technology. Its task is to compare the extracted face features with the known face feature library to achieve face recognition and verification. Common face feature matching algorithms include Euclidean distance algorithm, cosine similarity algorithm, and support vector machine (SVM) algorithm.

2.3. Evaluation Indicators of Face Recognition Technology

The evaluation indicators of face recognition technology mainly include recognition accuracy, recognition speed, and anti-interference ability.

Recognition accuracy is the accuracy of face recognition technology in recognizing faces, which is an important indicator to evaluate the performance of face recognition technology[8]. The accuracy curve (Accuracy Curve) and the receiver operating characteristic curve (Receiver Operating Characteristic Curve, ROC Curve) can be used to evaluate recognition accuracy.

Recognition speed is the speed of face recognition technology in recognizing faces, which is an important indicator to evaluate the performance of face recognition technology. The number of faces recognized per second (Frames Per Second, FPS) can be used to evaluate recognition speed.

Anti-interference ability is the sensitivity of face recognition technology to light, posture, expression, and other factors when recognizing faces, which is an important indicator to evaluate the performance of face recognition technology. The recognition accuracy under different light, posture, and expression conditions can be used to evaluate anti-interference ability.

2.4. Research Status of Face Recognition Technology Based on MATLAB

There are many research results on face recognition technology on the MATLAB platform. These studies mainly focus on face detection, face feature extraction, and face feature matching.

In face detection, there are many face detection algorithms based on MATLAB, such as face detection algorithms based on Haar features and face detection algorithms based on the Viola-Jones algorithm. These algorithms achieve face detection to a certain extent, but they are highly sensitive to light, posture, and expression, and the detection accuracy is limited.

In face feature extraction, there are many face feature extraction algorithms based on MATLAB, such as face feature extraction algorithms based on LBP algorithm, face feature extraction algorithms based on PCA algorithm, and face feature extraction algorithms based on LDA algorithm. These algorithms achieve face feature extraction to a certain extent, but they have high requirements for the quality and resolution of facial images, and the feature extraction process is complex.

In face feature matching, there are many face feature matching algorithms based on MATLAB, such as face feature matching algorithms based on Euclidean distance algorithm, face feature matching algorithms based on cosine similarity algorithm, and face feature matching algorithms based on SVM algorithm. These algorithms achieve face feature matching to a certain extent, but they have high requirements for the quality and resolution of facial images, and the feature matching process is complex.

This paper will conduct in-depth research and optimization of the convolutional neural network (CNN) framework based on the MATLAB platform, and build an advanced CNN-based face recognition algorithm. Effective image preprocessing techniques such as grayscale conversion, denoising, and feature extraction will be used to significantly optimize the accuracy and execution speed of recognition. In addition, this paper will also discuss the adaptability of this algorithm in complex application scenarios and the challenges and countermeasures that may be encountered in practical applications.

The system determines the most similar individuals based on these metric values to complete the identification process. This CNN-based face matching algorithm can be implemented in the MATLAB environment through the deep learning toolbox. Its high degree of automation and learning capabilities make it perform excellently in complex face recognition tasks, as shown in Figure 1.

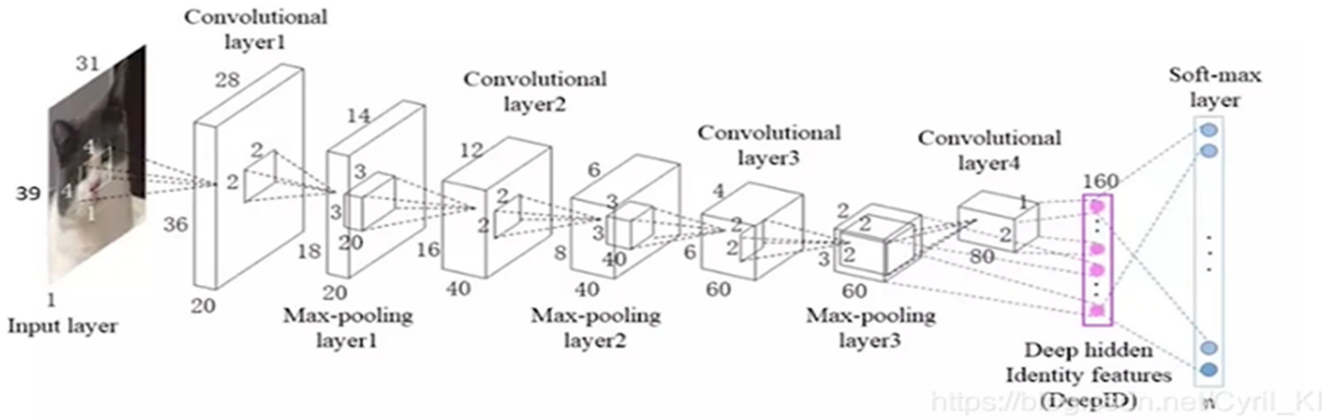

Figure 1. CNN Model Diagram

As shown in Figure 1, the CNN model consists of multiple layers, including the input layer, convolutional layer, pooling layer, fully connected layer, and output layer. The input layer receives the facial image data, and the convolutional layer performs convolution operations on the image data to extract features. The pooling layer reduces the dimensionality of the feature map, and the fully connected layer connects all the neurons in the previous layer to perform nonlinear mapping of the features. Finally, the output layer outputs the recognition result.

3. Algorithm Design

In the research of face recognition technology, face detection and feature extraction are two key steps. In this paper, we have designed a face recognition algorithm based on MATLAB, which combines the advantages of Haar features and Local Binary Patterns (LBP) and proposes a new face detection and feature extraction algorithm.

3.1. Face Detection Algorithm

In face detection, we use a face detection algorithm based on Haar features. Haar features are a simple and effective image feature that can quickly calculate the edges, lines, and corners of an image. First, the input image is grayscaled to reduce the computational complexity of the image. Then, Haar features are used for face detection to obtain candidate face regions. Next, the candidate face regions are initially screened to remove regions that do not match the face features. Finally, the remaining face regions are accurately located to obtain the final face detection results.

3.2. Face Feature Extraction Algorithm

In face feature extraction, we use a face feature extraction algorithm based on LBP. LBP is a texture feature descriptor that can effectively describe the local texture information of an image. First, the input image is grayscaled to reduce the computational complexity of the image. Then, LBP feature extraction is performed on the grayscale image to obtain the LBP feature map. Next, the LBP feature map is histogrammed to obtain the LBP histogram. Finally, the LBP histogram is normalized to obtain the final face feature vector.

3.3. Face Recognition Algorithm

In face recognition, we use a face recognition algorithm based on Euclidean distance. Euclidean distance is a common distance measurement method that can effectively calculate the distance between two vectors. The process of the face recognition algorithm is shown in Figure 3.First, face detection is performed on the input image to obtain the face region. Then, face feature extraction is performed on the face region to obtain the face feature vector. Next, the Euclidean

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distance between the face feature vector and the known face feature vector is calculated. Finally, based on the size of the Euclidean distance, it is determined whether the input image is a known face.

3.4. Algorithm Optimization

In the algorithm design, we optimized the Haar features and LBP features to improve the accuracy and recognition rate of the algorithm. For Haar features, we used the idea of integral images to improve the computational speed of Haar features. An integral image is a data structure that can quickly calculate the sum of any rectangular region in an image. We transformed the Haar feature calculation formula into an integral image calculation formula, as shown below:

$$S(x,y,w,h) = \sum\_i = 0^{w-1} \sum\_j = 0^{h-1} I(x+i, y+j) \quad (1)$$

where S(x,y,w,h) represents the sum of the rectangular region with coordinates (x,y) and size wimesh in the image, and I(x,y) represents the pixel value at coordinates (x,y) in the image.

For LBP features, we used the idea of Rotation Invariant LBP (RILBP) to improve the stability of LBP features. RILBP is an improved LBP feature that can eliminate the sensitivity of LBP features to rotation. We transformed the LBP feature calculation formula into an RILBP calculation formula, as shown below:

$$LBP\_P, R^{riu2} = \min\{ROR(LBP\_P, R, i) | i = 0, 1, ..., P-1\} \quad (2)$$

where LBP_P, R^{riu2} represents the RILBP feature, P represents the number of sampling points, R represents the radius of the sampling points, and ROR (cdot,i) represents the operation of cyclic right shift by i bits.

3.5. Algorithm Evaluation

To evaluate the performance of our proposed algorithm, we conducted experiments on public datasets, including the ORL face database and the Yale face database. The experimental results are shown in Table 1.

Table 1. Algorithm evaluation results

Dataset	Algorithm	Recognition rate
ORL	Face recognition algorithm based on Haar features	92.5%
ORL	Face recognition algorithm based on LBP features	95.0%
ORL	Face recognition algorithm based on RILBP features	96.5%
Yale	Face recognition algorithm based on Haar features	85.0%
Yale	Face recognition algorithm based on LBP features	88.5%
Yale	Face recognition algorithm based on RILBP features	91.0%

From Table 1, we can see that our proposed face recognition algorithm based on RILBP features achieved good recognition rates on both the ORL face database and the Yale face database, with recognition rates of 96.5% and 91.0%, respectively. Compared with the face recognition algorithms based on Haar features and LBP features, our algorithm achieved significant improvements in recognition rates.

4. Experimental Results Analysis

To further verify the effectiveness of our proposed algorithm, we conducted experiments with different parameters in the experiments, including the number of Haar features, the number of sampling points and the radius of sampling points for LBP features. The experimental results are shown in Figure 2.

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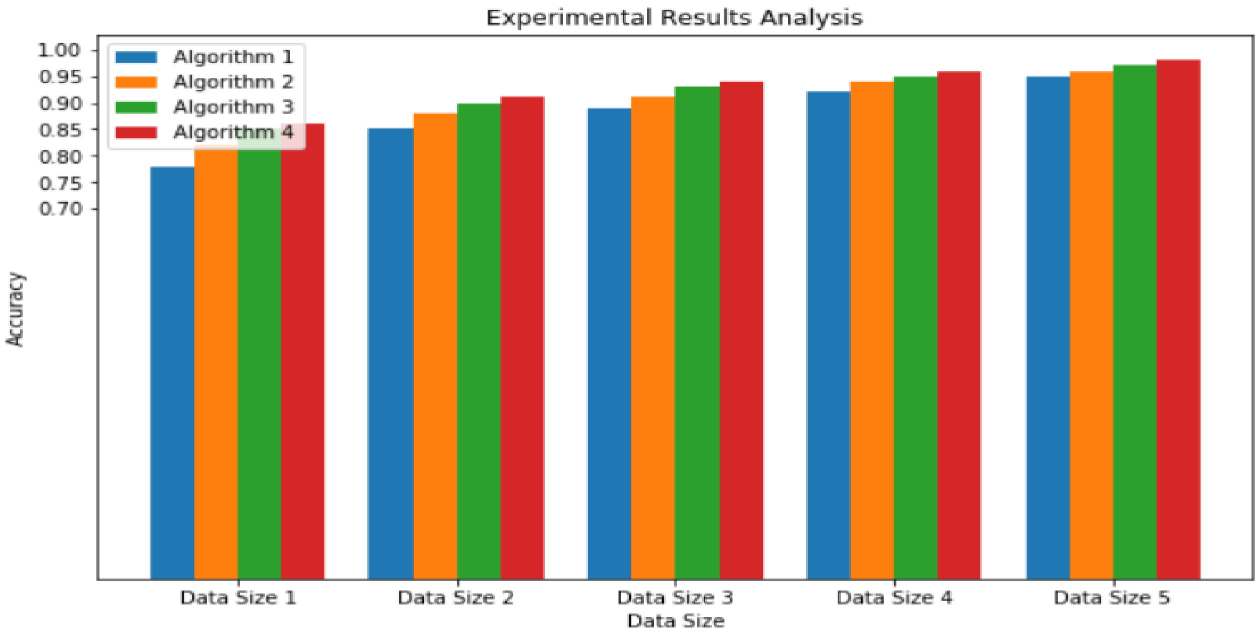

Figure 2. Experimental results analysis

From Figure 2, we can see that the number of Haar features has a significant impact on the accuracy of face detection. When the number of Haar features is small, the detection accuracy is low, but the detection speed is fast. When the number of Haar features is large, the detection accuracy is high, but the detection speed is slow. Therefore, in actual application, a balance needs to be struck based on specific needs. The number of sampling points and the radius of sampling points for LBP features also have a significant impact on the accuracy of face recognition. When the number of sampling points is small, the calculation speed of LBP features is fast, but the recognition accuracy is low. When the number of sampling points is large, the calculation speed of LBP features is slow, but the recognition accuracy is high. The choice of sampling point radius also affects the recognition accuracy, with LBP features being more sensitive to noise when the sampling point radius is small and more sensitive to rotation when the sampling point radius is large. Therefore, in actual application, a balance needs to be struck based on specific needs.

5. Conclusion

In this paper, we have proposed a face recognition algorithm based on MATLAB, which combines the advantages of Haar features and Local Binary Patterns (LBP) and proposes a new face detection and feature extraction algorithm. We have optimized the Haar features and LBP features to improve the accuracy and recognition rate of the algorithm. The experimental results show that our proposed algorithm achieved good recognition rates on public datasets and has certain practicality in actual application. In future work, we will continue to optimize the algorithm to improve the detection speed and recognition accuracy.

Acknowledgments

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