Eng Int Syst (2024) 5: 477–485

Engineering
Intelligent Systems

Face Recognition Image Processing Technology Based on SIFT Algorithm

Hao Zhao[1]* **and Panpan Li**[1]

Jinshan College, Fujian Agriculture and Forestry University, Fuzhou 350002, Fujian, China

With the development of image recognition technology, the processing of human face information can confirm human identity. Facial recognition technology has been widely used in many fields, effectively improving the efficiency of facial information entry and recognition. The core of the face recognition process is an analysis of the characteristics of face images. The traditional facial image recognition method involves a local binary pattern (LBP) algorithm, which has high recognition accuracy when facial images contain complete information. However, actual collected face images can be affected by various environmental factors, and traditional image recognition methods find it difficult to accurately determine facial characteristics. This paper applied a scale invariant feature transform (SIFT) algorithm to facial image recognition, and compared and analyzed the traditional LBP algorithm and SIFT algorithm in respect to four factors: illumination intensity, facial expression, image occlusion ratio, and face offset angle. Experimental results showed that for male facial images, the average face recognition accuracy rates of the LBP algorithm and the SIFT algorithm under different light intensities were 94.64% and 99.52%, respectively. For female facial images, the average face recognition accuracy rates of the LBP algorithm and the SIFT algorithm under different light intensities were 92.04% and 99.08%, respectively. Therefore, the application of SIFT algorithms can improve the accuracy of facial recognition under different light intensities.

Keywords: Image processing; facial recognition; scale invariant feature transform (SIFT); local binary patterns

1. INTRODUCTION

With the continuous deepening of social informatization, the development of society and people's lives cannot be separated from the use of information. Various information resources and information technologies have promoted social progress and provided people with a better quality of life. In the information age, personal information is an important prerequisite for participation in social activities. The human body has many individual and unique characteristics, which can be identified and authenticated by advanced technology These authentication methods include retina recognition, face recognition, fingerprint recognition, etc. The information recognition methods can greatly enhance people's lives and facilitate the exchange of social information. Compared to other recognition methods, facial recognition has the advantages of naturalness, greater user acceptance, and security. With the popularity of various high pixels, facial recognition is being used more extensively. Face recognition has applications in various fields, such as in identity authentication, where users are authenticated prior to using many network software. Facial recognition for identity authentication is a secure means of establishing identity. In intelligent access control, facial recognition can ensure the entry and security of access information. The core of facial recognition technology is the extraction of features from images. With the rapid development of image technology, it is possible to quickly obtain images of the human face in different environments. The processing of facial images can confirm facial information, offering

*Address for correspondence: Hao Zhao, Jinshan College, Fujian Agriculture and Forestry University, Fuzhou 350002, Fujian, China, Email: zhaoh@fafu.edu.cn

prospects for broad market applications. Therefore, this study has research significance.

Biometric features are inherent, and each person's facial features are unique. Various camera devices can be used to obtain facial images. Many researchers have studied and contributed to the feature recognition processing of facial images. Among them, Moussa optimized the genetic algorithm and compared the optimized genetic algorithm with the traditional genetic algorithm used for face recognition. Through multiple face recognition analyses, it was found that the optimized genetic algorithm had a better recognition accuracy [1]. Zhang introduced a new layer to embed the patch strategy into the convolutional structure to improve the effectiveness of facial representation. Due to end-to-end training, the patch strategy for deep facial recognition made better use of the interaction between global and local features in the model [2]. Godwill developed an automated student attendance management system that is less intrusive, more cost-effective, and used facial recognition, which used cameras installed in front of the classroom to capture images of the entire class. He improved the efficiency of attendance information entry by identifying and comparing facials with those registered in the database [3]. Rejeesh proposed a point-of-interest-based facial recognition method using an adaptive neuro-fuzzy inference system, which preprocessed facial images collected from a database, and used points of interest to improve detection rate [4]. The recognition of facial image features can establish a person's identity and can be used in the field of identity recognition. However, no recognition algorithm analysis has been conducted for possible illumination, expression, and posture situations in facial images.

There are many changing features in facial recognition images, among which the impact of light on feature recognition of facial images is quite significant. Researchers have applied SIFT algorithms to facial recognition image processing. Among them, Chater used a SIFT algorithm for feature recognition of open and unopened mouths, faces with glasses and without glasses, and open and closed eyes in facial images. The SIFT algorithm had a very high accuracy rate for facial change feature recognition [5]. Mahamdioua proposed a powerful method for extracting and describing local features called 'key points' in images. The extracted key points were invariant to scaling, translation, and rotation, and partially invariant to image illumination changes, which had significant recognition effects in facial recognition [6]. Bindu proposed a facial recognition system through feature extraction and classification, which could extract local and global features of images, and could be used to find a person's identity from the extracted feature vector database [7]. Yadav proposed a method for recognizing partially occluded faces using local general features by fusing feature SIFT and multiple LBPs. After conducting facial database recognition experiments, the proposed method was found to be superior to existing robust facial recognition methods [8]. SIFT algorithms can identify and process issues such as occlusion and light changes in facial images, improving the accuracy of facial recognition. However, SIFT algorithms have not been compared and analyzed with other feature recognition algorithms.

In actual face images, the process of feature extraction and recognition is hampered by factors such as illumination, posture, and occlusion. In this study, facial images were recognized and analyzed using scale invariant feature points. The method in this paper could improve the accuracy of face recognition in different facial expressions.

2. METHODS OF FACE RECOGNITION IMAGE PROCESSING

2.1 Principles of Face Recognition

The face is the main feature used to confirm a person's identity. The external appearance of a person's face is determined by genes, and the genes that determine the face are unique to each individual. Obtaining human identity information from faces accounts for more than 90% of the total information, and identifying facial features can accurately establish a person's identity.

There are many ways to recognize facial features, and the recognition process can be roughly divided into four categories based on the processing methods used for facial features. The first category is face knowledge recognition, mainly through the confirmation of the interrelationships among facial attributes. For example, a face can be recognized as it has two eyes, one nose, one mouth, and two ears; however, this method is limited to positive facial recognition. The second category is template matching recognition, which uses the template of the face to perform feature matching with the tested face. When the matching degree reaches a certain threshold, the adult face is recognized. The third category is appearance recognition, which uses a large amount of facial data to learn and train the system to identify the differences between facial features and non-facial features. The fourth category is feature processing, which processes the invariant features of the face, such as skin, eyes, nose, and other information, and then recognizes the face identity. However, the method of feature recognition is easily hampered by factors such as illumination, image occlusion, and image clarity.

The face recognition process is generally based on image recognition. The structure of facial recognition model is shown in Figure 1.

In Figure 1, the model structure of face recognition is described. First, the imaging device is utilized to obtain an original image of a human face. The face in the image is detected and located, facial feature extraction, and feature recognition analysis to achieve face recognition.

There are many characteristic factors in human faces, and human faces have rich information. The structure of a human face is very complex, and it is composed of skin, bones, and muscles. The expression elements displayed by a human face are very many. For example, the smile of a human face can be embodied as a smile, laughter, and so on. The rich micro-expressions of human faces make it extremely difficult to recognize the features of facial images.

The physiological structure of a human face is basically consistent, comprising features such as the face, eyes, nose, ears, and mouth. These obvious features can be used to

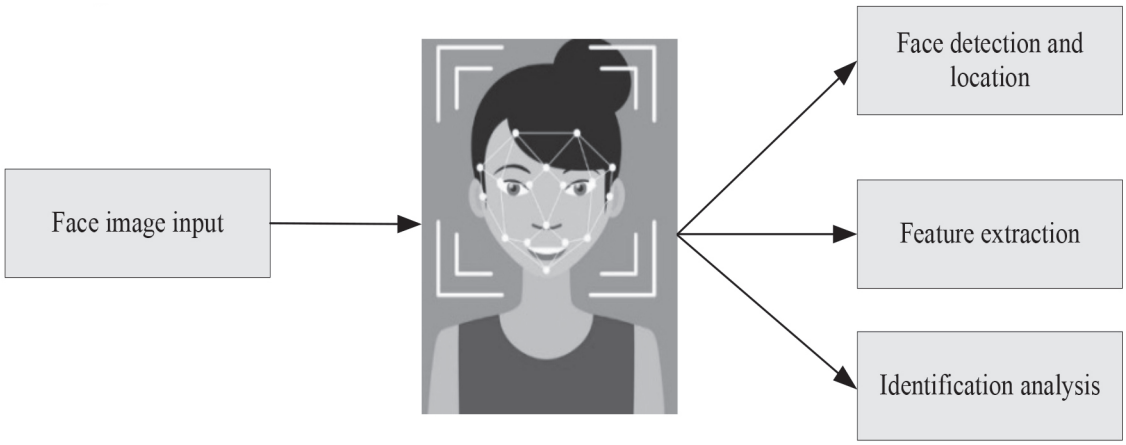


Figure 1 Model structure diagram of face recognition.

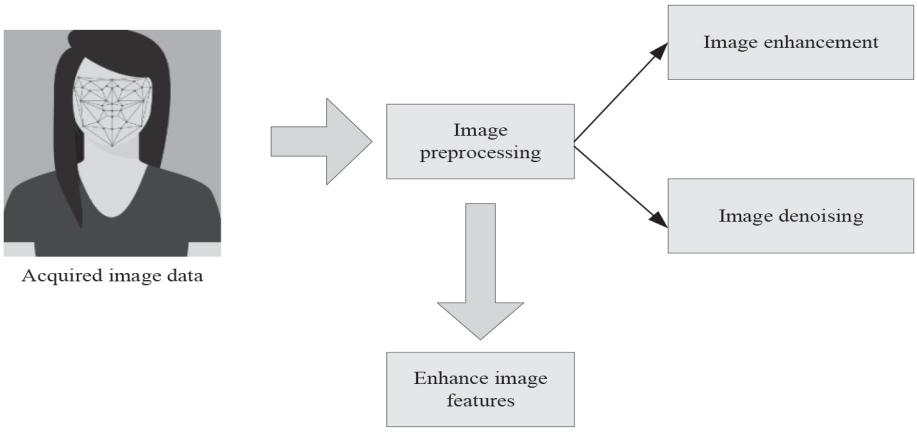


Figure 2 Diagram of face image preprocessing operation.

distinguish faces and other objects. There are many other features involved in facial recognition, but in actual face recognition systems, it is difficult to achieve satisfactory recognition results [9–10]. This is mainly due to the fact that the representation of features in actual face images can be subject to interference from other external factors, resulting in the blurring of facial features in the image, making it difficult to perform recognition analysis. The problems of actual face image recognition are mainly reflected in: unstable lighting, low image resolution, image faces generally being side faces, and serious object occlusion in face images. For example, in actual face images, the characters in the image often wear accessories such as hats, scarves, and glasses, which seriously hampers facial feature recognition.

2.2 Face Image Preprocessing

The core of facial recognition is the identification and analysis of the features of facial images, and achieve the purpose of face recognition by extracting, classifying, and recognizing image features [11–12]. However, the quality of face images collected in real life is very poor, and there is a large amount of noise data, which seriously affects the effectiveness of facial image feature analysis. Therefore, before face image recognition, it is necessary to preprocess the face image.

The steps for the preprocessing of a facial image are depicted in Figure 2.

Figure 2 shows the steps for the preprocessing of a facial image. The preprocessing operation comprises image enhancement and image noise reduction. The purpose of image preprocessing is to enhance image features.

There are many ways to enhance images. Histogram enhancement is used to improve image quality by correcting the histogram gray level. The grayscale histogram is the most basic statistical feature of an image. By applying the rule for grayscale transformation, the original face image can be converted into a balanced grayscale image, so that each grayscale level in the image contains the same number of pixel points. The formula for grayscale histogram transformation is expressed as:

$$h = \int_0^r K_r(t)dt \tag{1}$$

Formula (1) is applied to obtain:

$$\frac{dh}{dr} = K_r(r) \tag{2}$$

Using a discrete gray value c instead of a continuous gray value r, the gray scale in the histogram is represented as:

$$K_r(c) = {}^{n_c}\big/_{n} \tag{3}$$

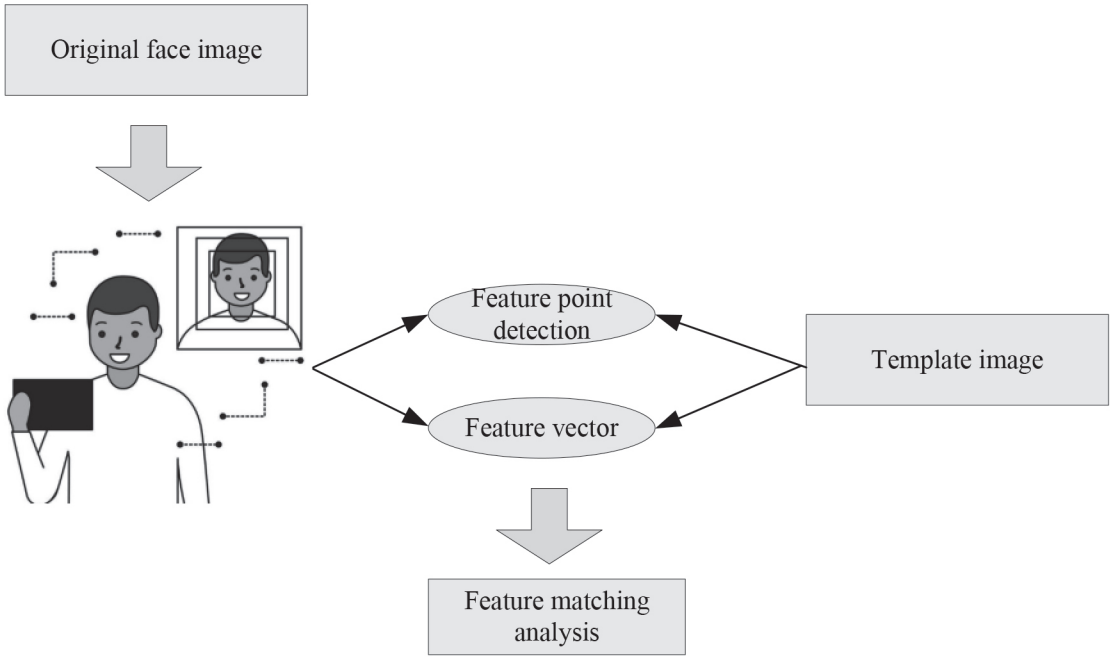


Figure 3 Diagram of SIFT algorithm for face recognition.

In Formula (3), n_c represents the number of grayscale pixels in class c, and n represents the total number of pixels in the face image.

The original face image is generally a color image, with pixels composed of three color components: red, green, and blue. However, color images are not conducive to the recognition and analysis of image features, so it is necessary to perform grayscale conversion on color images. The formula for image grayscale conversion is:

$$F(x, y) = 0.3R(x, y) + 0.59G(x, y) + 0.11B(x, y) \quad (4)$$

In Formula (4), $F(x, y)$ represents the grayscale value of pixel points (x, y).

After converting an image to a grayscale image, a grayscale transformation is required. The main purpose is to enhance the brightness of the image and improve the contrast of pixels. The formula for linear grayscale transformation is expressed as:

$$Y(x, y) = (u - v)/(i - j)[F(x, y) - j] + v \quad (5)$$

In Formula (5), $Y(x, y)$ represents the function after linear grayscale transformation. J and i represent the values before and after the grayscale value abscissa changes; v and u are the values before and after the grayscale value ordinate changes.

Image noise reduction is used to eliminate noisy data from facial images, and image noise is generally processed through filtering. Image filtering processing is to adjust the distribution of gray values in the face image, remove abnormal gray values in the image, and smooth out the distribution of gray pixels in the image.

The process of median filtering facial images is expressed as follows:

$$D(x, y) = M[F(x - w, y - e)] \quad (6)$$

In Formula (6), $D(x, y)$ represents the result of median filtering processing, and w and e determine the size of the filtering window.

2.3 SIFT Algorithm

SIFT is a computer vision algorithm that searches for extreme points in an image by analyzing local features in the image, and extracts feature information, including the location, size, and rotatability of features [13–14]. The SIFT algorithm is used to analyze key points in an image, which can effectively eliminate interference from external factors such as light and occlusion. The SIFT algorithm is well suited to facial recognition image processing.

The process of using the SIFT algorithm for feature point matching includes creating a dimensional space of the image, performing location analysis of feature points, determining the direction of feature points, and generating feature vectors [15]. The model for face recognition using the SIFT algorithm is shown in Figure 3.

In Figure 3, a model for facial recognition using a SIFT algorithm is described. Firstly, invariant point features of the original facial image and template image are obtained, and feature vectors are generated. Finally, feature points are matched and analyzed to achieve facial recognition.

To accurately analyze the features in a facial image, it is necessary to construct a scale space for the facial image in order to measure the position and direction information of the facial features. After constructing the spatial scale, it is necessary to detect the extreme points in the facial image, including the position and size of the human eyes in the image, as well as the skin color of the face.

It is necessary to filter the detected unstable extreme points. Generally, information such as the location and direction of

Table 1 Table of external factors affecting face image recognition.

Serial number	Influence factor	Number of participants	Percentage
1	Light intensity	56	28%
2	Facial expression	48	24%
3	Image occlusion	52	26%
4	Face offset angle	44	22%

Table 2 Statistical results of facial expressions.

Serial number	Expression	Number of participants	Percentage
1	Cry	70	14%
2	Laugh	80	16%
3	Smile	120	24%
4	Angry	100	20%
5	Calm	130	26%

key points is determined by apply a quadratic function to improve the stability of key point matching. The direction of key points is generally extracted through a direction histogram, which is mainly used to determine the direction characteristics of key points based on the peak value of the histogram. If the sampling point in the window is $H(x, y)$, the direction of the key point is expressed as:

$$b(x, y) = \text{acrtan}[(H(x+1, y) - H(x-1, y))/ (H(x, y+1) - H(x, y-1))] \quad (7)$$

In Formula (7), b represents the direction of the key points (x, y).

After describing the orientation and other attributes of feature points, it is necessary to perform matching analysis of the feature points in the original facial image and the feature points of the template image. Therefore, it is generally necessary to establish a feature description subset for reference and target images, extract facial feature information from complex and noisy backgrounds, and complete the detection of facial images through feature description, feature matching, and other means. SIFT algorithms [16–17] have many advantages in feature recognition. After rotating, scaling, and changing brightness of facial image features, they can still maintain feature invariance.

3. EXPERIMENTS FOR FACE RECOGNITION IMAGE PROCESSING

3.1 Data Sources for Face Recognition

With the advance of information technology, research on identity recognition is becoming more and more comprehensive. The collection and identification of humans is of great significance in fields such as information access. The human face contains important feature information, and the analysis of facial features can establish a person's identity. Facial images contain a large amount of noisy data, and facial features are often not fully captured in the image, resulting in poor recognition results for actual face images.

There are many factors that affect facial image recognition in real environments. In order to analyze the recognition of face images under different conditions, a questionnaire survey was conducted among 200 facial-recognition collectors. The results of the survey are shown in Table 1.

Table 1 shows the external factors that affect facial image recognition. A total of four influencing factors were identified, with the highest percentage (28%) being that of light intensity.

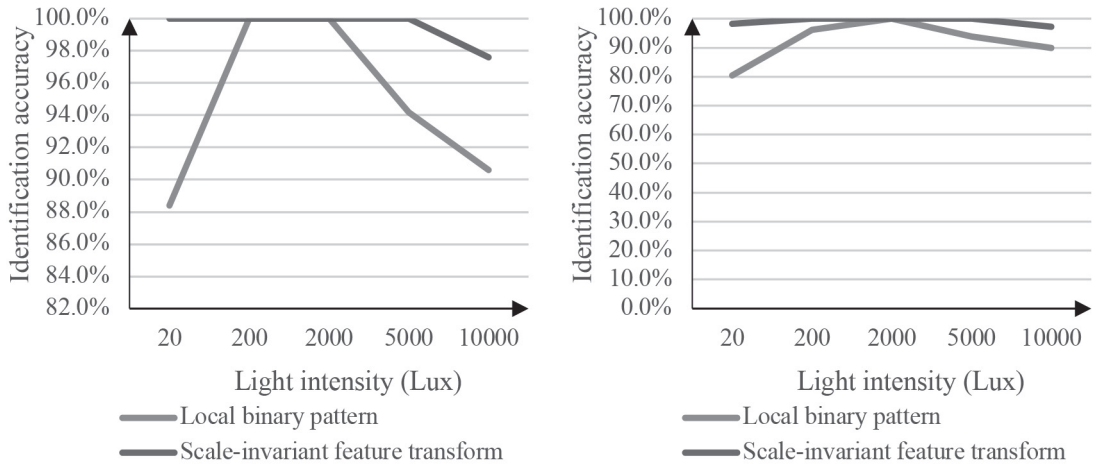
The main impact of external factors on facial image recognition is that the features in the original face image are not easily distinguished. For example, different lighting intensities can cause different levels of shadow in the face image, and human facial expressions can also interfere with the analysis of features. In this study, a camera was used to record the facial information of 512 participants; of these 500 images were valid, and 12 were invalid. The invalid images were mainly the result of the camera not recording or accidental damage done to the recorded images. The statistical results for facial expressions of the participants are shown in Table 2.

Table 2 presents the statistical results for facial expressions. A total of 5 facial expressions were identified. Among them, the maximum number of people with calm faces was 130, the number of people with smiling expressions was 120, and the lowest number (70) was for people with crying expressions.

3.2 Experimental Design of Face Recognition

Face recognition image processing is the main method used to analyze facial features. To improve the effectiveness of face recognition analysis, it is necessary to process the features of facial image. This study analyzed face recognition images by setting up a control group. Among them, the control group is a LBP algorithm, and the experimental group is a SIFT algorithm.

In this study, 2000 face images were selected for experimental analysis, and the experimental face images were subjected to interference from factors such as light intensity, facial expression, image occlusion, and face offset angle to construct a face image dataset. In this study, the LBP algorithm and the



(a) Male face images with different light intensities
(b) Female face images with different light intensities

Figure 4 Comparison results of light intensity.

SIFT algorithm were used to recognize and analyze facial images in data sets. Due to the significant differences in the contours and size of male and female faces, in order to avoid the influence of gender in the experiment, this study conducted experimental analyses of both male and female facial images.

4. RESULTS OF FACE RECOGNITION IMAGE PROCESSING

4.1 Light Intensity

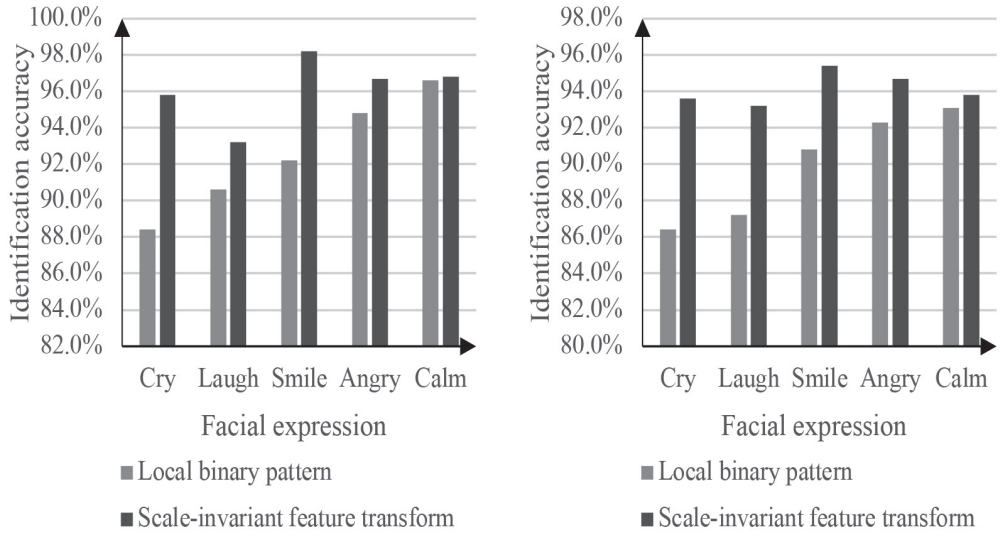
In actual face recognition situations, one of the most common influencing factors is that the light intensity of faces varied greatly from time to time, such as high light intensity at noon to low light intensity in the morning. In this study, five light intensity gradients were set, namely, 20Lux, 200Lux, 2000Lux, 5000Lux, and 10000Lux. The accuracy of two algorithms used for facial image recognition under different illumination intensities were compared. The comparison results are shown in Figure 4.

Figure 4 (a) shows a comparison of the recognition accuracy of two facial image recognition algorithms for images of male faces under different light intensities. The accuracy of the LBP algorithm for facial recognition reached a minimum of 88.4% when the illumination intensity was 20 Lux, and 100.0% when the illumination intensity was 200 Lux and 2000 Lux, with an average recognition accuracy of 94.64%. The average recognition accuracy of the SIFT algorithm was 99.52%. The accuracy of facial recognition based on SIFT algorithm was higher than the accuracy of LBP algorithm in all stages of the experiment under light intensity. Figure 4 (b) shows a comparison of the recognition accuracy of two facial image recognition algorithms for images of female faces under different light intensities. The accuracy of facial recognition based on LBP algorithm reached a minimum of 80.4% when the illumination intensity was 20 Lux, and reached a maximum of 100.0% when the illumination intensity was 2000 Lux, with an average recognition accuracy of 92.04%. The accuracy of facial recognition based on the SIFT algorithm reached a minimum of 97.2% when the illumination intensity was 10000 Lux, and the accuracy of facial recognition was 100.0% when the illumination intensity was 200 Lux, 2000 Lux, and 5000 Lux, with an average recognition accuracy of 99.08%. The recognition accuracy of the two facial image recognition algorithms was generally lower for female faces than for male faces. This is mainly due to the more pronounced facial contours of male faces, which are more conducive to facial feature recognition. Therefore, the proposed face image recognition algorithm can effectively improve the accuracy of face recognition.

4.2 Facial Expression

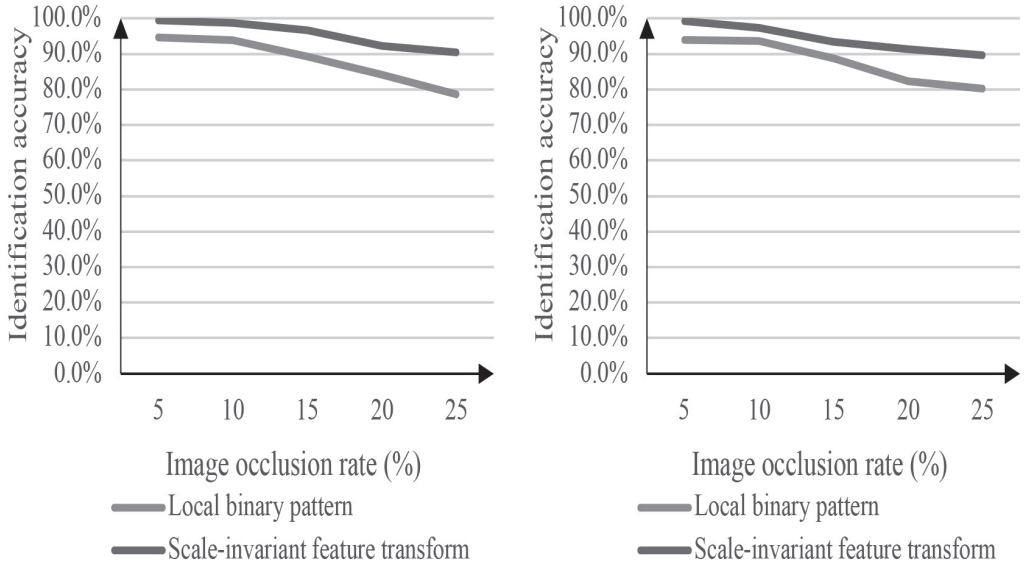
There is a great variety of facial expressions, and different facial expressions affect facial feature recognition. This is mainly because the form of facial expressions can change the normal shape of a person's facial muscles, making it difficult to perform feature recognition. This study compared the accuracy of LBP algorithm and SIFT algorithm for facial image recognition of different facial expressions. The comparison results are shown in Figure 5.

Figure 5 (a) shows a comparison of the recognition accuracy of two face image recognition algorithms for male face images with different facial expressions. The accuracy of facial recognition based on LBP algorithm achieved a minimum of 88.4% for crying expressions and a maximum of 96.6% for calm expressions. The facial recognition accuracy of the algorithm in this paper reached a minimum of 93.2% for laughing expressions and a maximum of 98.2% for smiling expressions. The overall accuracy of facial recognition based on SIFT algorithms was higher than that based on LBP algorithms, mainly because the algorithm in this paper was less affected by facial expressions. Figure 5 (b) shows a comparison of the recognition accuracy of two facial image recognition algorithms for female facial images with different facial expressions. The accuracy of facial recognition based on LBP algorithm reached a minimum of 86.4% for crying



(a) Male face images with different facial expressions
(b) Female face images with different facial expressions

Figure 5 Comparison results for facial expressions.



(a) Male face images with different image occlusion ratios
(b) Female face images with different image occlusion ratios

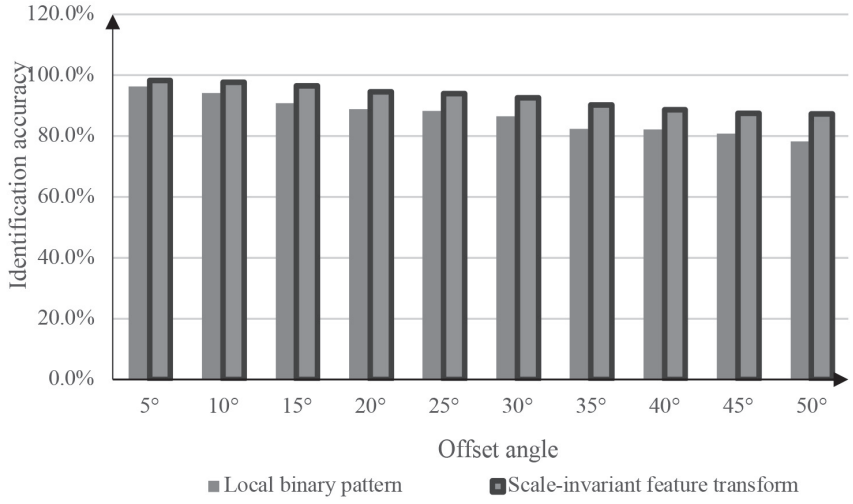
Figure 6 Comparison results for image occlusion.

expressions and a maximum of 93.1% for calm expressions, with an average recognition accuracy of 89.96%. The accuracy of facial recognition based on SIFT algorithm reached a minimum of 93.2% in laughter expressions and a maximum of 95.4% in smile expressions, with an average recognition accuracy of 94.14%. Therefore, the application of SIFT algorithms can improve the accuracy of facial recognition in the presence of different facial expressions.

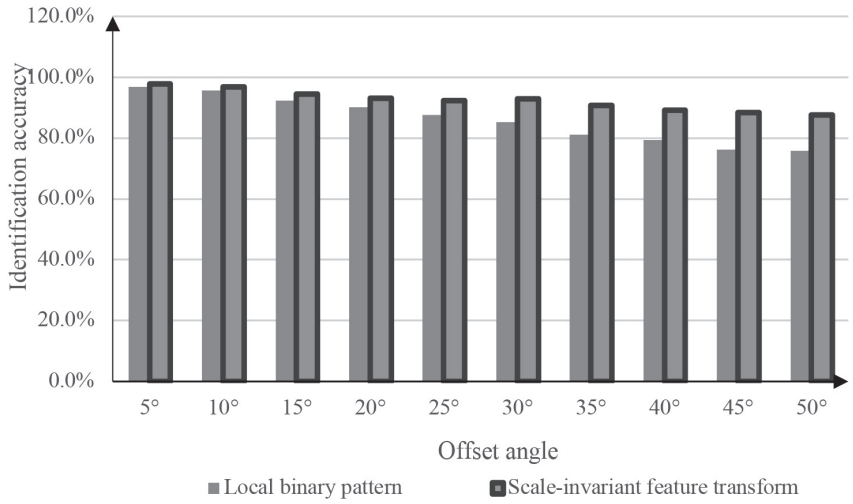
4.3 Image Occlusion

When a facial image is being captured, a person's face can be easily blocked by external objects hats, glasses, and so on. This paper compared the accuracy of two algorithms for face image recognition with different image occlusion rates. The comparison results are shown in Figure 6.

Figure 6 (a) shows a comparison of the recognition accuracy of two facial image recognition algorithms for male facial images with different image occlusion rates. The accuracy of facial recognition based on LBP algorithm decreased with the improvement of image occlusion rate. The recognition accuracy decreased from 94.6% when the occlusion rate was 5% to 78.6% when the occlusion rate was 25%, with an average facial recognition accuracy of 88.10%. The accuracy of both facial image recognition algorithms was continuously decreasing. In Figure 6 (b), a comparison of the recognition accuracy of two facial image recognition algorithms for female facial images with different image occlusion rates is described. The accuracy of facial recognition based on LBP algorithm reached a maximum of 93.9% when the occlusion rate was 5%, and reached a minimum of 80.2% when the occlusion rate was 25%. The average facial recognition



(a) Male face images with different face offset angles



(b) Female face images with different face offset angles

Figure 7 Comparison results for face offset angles.

accuracy was 87.76%. The accuracy of facial recognition based on SIFT algorithm reached a maximum of 99.2% when the occlusion rate was 5%, and reached a minimum of 89.6% when the occlusion rate was 25%. The average facial recognition accuracy was 94.16%. Therefore, facial recognition image processing based on SIFT algorithms has higher recognition accuracy in different image occlusion environments compared to LBP algorithms.

4.4 Face Offset Angle

Different face offset angles in face images affect the effectiveness of facial recognition. This study set different gradient face offset angles for analysis. The face offset angle is the angle between the front of the face and the camera. In this study, two algorithms were used to analyze the face offset angle. The comparison results are shown in Figure 7.

Figure 7 (a) shows a comparison of the recognition accuracy of two face image recognition algorithms for male face images with different face offset angles. The recognition accuracy of both facial image recognition algorithms was continuously decreasing. Among them, the accuracy of face recognition based on LBP algorithm reached a maximum of 96.4% when the offset angle was 5°, and reached a minimum of 78.2% when the offset angle was 50°, with an average recognition accuracy of 86.82%. The average recognition accuracy of this algorithm was 92.68%. Figure 7 (b) shows a comparison of the recognition accuracy of two facial image recognition algorithms for female facial images with different facial offset angles. The accuracy of facial recognition based on LBP algorithm decreased as the offset angle increased, from 96.8% at 5° to 75.8% at 50°, with an average recognition accuracy of 86.04%. The accuracy of facial recognition based on SIFT algorithm reached a maximum of 97.8% at an offset angle of 5°, and a minimum of 87.6% at an offset angle of 50°. Therefore, facial recognition image processing based on SIFT algorithms has greater recognition accuracy under different facial offset angles.

5. CONCLUSIONS

With the growth of Internet technology, information exchange is increasing, and personal identity is required prior to participating in social activities. Therefore, it is very important to establish a person's identity. Information related to human facial features is readily available, and the shape and position of facial features provide a good means of identification. Facial recognition has been achieved by collecting facial images and performing feature recognition. However, in practical facial recognition applications, it is difficult to accurately recognize facial images collected in image environments that contain too much noise or are impacted by factors such as light and obstructions. SIFT is a feature recognition method that can extract invariant features from images for analysis and achieve facial recognition through feature matching. Experimental results showed that the SIFT algorithm had high accuracy in facial recognition under different illumination intensities, different occlusion rates, and various facial expressions. Facial image recognition based on SIFT algorithms has a wide range of applications and can accurately identify faces. However, SIFT algorithms also have shortcomings. When performing feature recognition, the created feature descriptor dimensions are too large, which affects the speed of feature recognition. Therefore, the improvement of the SIFT algorithm and the use of sparse methods to calculate scale invariant features are the direction of future research.

ACKNOWLEDGEMENTS

This work was supported by the Education and Scientific Research Project for Young and Middle-Aged Teachers in Fujian Province (JAT201001), and Project of the 14th Five-Year Plan of Fujian Province's Education and Science (FJJKBK22-203).

REFERENCES

1. Moussa, Mourad, Maha Hmila, and Ali Douik. "A novel face recognition approach based on genetic algorithm optimization." Studies in Informatics and Control 27.1 (2018): 127–134.
2. Zhang, Yanhong. "Patch strategy for deep face recognition." IET Image Processing 12.5 (2018): 819–825.
3. Godswill, Ofualagba. "Automated student attendance management system using face recognition." International Journal of Educational Research and Information Science 5.4 (2018): 31–37.
4. Rejeesh, M. R. "Interest point based face recognition using adaptive neuro fuzzy inference system." Multimedia Tools and Applications 78.16 (2019): 22691–22710.
5. Chater, Ahmed, and Abdelali Lasfar. "New approach to the identification of the easy expression recognition system by robust techniques (SIFT, PCA-SIFT, ASIFT and SURF)." TELKOMNIKA (Telecommunication Computing Electronics and Control) 18.2 (2020): 695–704.
6. Mahamdioua, Meriama, and Mohamed Benmohammed. "Automatic adaptation of SIFT for robust facial recognition in uncontrolled lighting conditions." IET Computer Vision 12.5 (2018): 623–633.
7. Bindu, Hima. "Hybrid feature descriptor and probabilistic neuro-fuzzy system for face recognition." Sensor Review 38.3 (2018): 269–281.
8. Yadav, Amit Kumar. "Robust face recognition under partial occlusion based on local generic features." International Journal of Cognitive Informatics and Natural Intelligence (IJCINI) 15.3 (2021): 47–57.
9. Zeng, Dan, Raymond Veldhuis, and Luuk Spreeuwers. "A survey of face recognition techniques under occlusion." IET biometrics 10.6 (2021): 581–606.
10. Bate, Sarah. "Applied screening tests for the detection of superior face recognition." Cognitive research: principles and implications 3.1 (2018): 1–19.
11. Damer, Naser. "Extended evaluation of the effect of real and simulated masks on face recognition performance." IET Biometrics 10.5 (2021): 548–561.
12. Grm, Klemen. "Strengths and weaknesses of deep learning models for face recognition against image degradations." IET Biometrics 7.1 (2018): 81–89.
13. Bellavia, Fabio, and Carlo Colombo. "Is there anything new to say about SIFT matching?". International journal of computer vision 128.7 (2020): 1847–1866.
14. Hossein-Nejad, Zahra, Hamed Agahi, and Azar Mahmoodzadeh. "Detailed review of the scale invariant feature transform (sift) algorithm; concepts, indices and applications." Journal of Machine Vision and Image Processing 7.1 (2020): 165–190.
15. Taha, Mohammed A., Hanaa M. Ahmed, and Saif O. Husain. "Iris Features Extraction and Recognition based on the Scale Invariant Feature Transform (SIFT)." Webology 19.1 (2022): 171–184.
16. Tiexing He, Xueping Zhang, Limin Zhu. "Early Diagnosis of Alzheimer's Disease Based on Face Recognition Using M-Health Technology." International Journal of Engineering Intelligent Systems. 28.2 (2020): 99–108.
17. Jin Xu, Jianing Zhang, Long Ban, Guangbo Feng. "Multi-Feature Fusion Algorithm Based on AR-Based Panoramic Image Processing Technology Inside a Wind Turbine." International Journal of Engineering Intelligent Systems. 30.5 (2022): 377–385.