Research on Image Preprocessing Algorithm and Deep Learning of Iris Recognition

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Abstract. With the development of information society, biometrics technology has been paid more and more attention. Iris recognition is considered as the most promising biometric authentication technology in the 21st century because of its uniqueness, stability and non-creativity. However, due to the high cost of iris recognition equipment and some defects of the algorithm, iris recognition cannot be applied in real life on a large scale. In this paper, a fast localization iris recognition algorithm is proposed, which combines the iris segmentation algorithm with deep learning to quickly extract the iris region for recognition. Firstly, the pupil edge was extracted by dynamic threshold analysis and contour extraction, and then iris was located by edge detection and gray calculation. Finally, features of normalized images were learned by deep learning network. Experiments show that the method can guarantee the accuracy and efficiency of iris segmentation and has a high degree of recognition and matching.

keywords. Biometrics identification; iris segmentation; deep learning; image preprocessing.

1. Introduction
The boom in biometrics since the 1880s has been a boon. Biometrics can be used as a form of personal identification and access control. Physiological characteristics include fingerprints, palmprint, finger veins, iris, face, etc., while behavioral characteristics refer to individual pattern behaviors, such as voice, gait, etc [1].

Iris recognition technology is now recognized as one of the most accurate biometric technologies, the reason is that it has the characteristics of uniqueness, stability, can be collected and non-invasive, widely believed to be the most promising 21st world biological certification technology and the future in the defense, security, e-commerce and other fields of application, got the attention of the academia and the business. Genetic genes play a decisive role in the formation of iris. The shape of the general iris enters a stable period after eight months of development, the morphology of iris enters a stable period, and its surface appearance is immutable for 15-20 years [2]. Moreover, the uniqueness of iris pattern shows variation in everyone, and even individuals with the same gene also have completely independent iris texture [3].

A layer of cornea covers the iris pattern so that it is not exposed to the external environment, and the iris pattern does not change over time, and some eye diseases and operations will not affect it, is considered one of the biological characteristics of high height. As a result, the technology can be installed in a variety of places. For example, criminal investigation and citizenship agencies; financial services, health care and law enforcement; Travel and immigration sites, access to PC - and network-based systems, and more. However, under some non-ideal conditions, the iris pattern
acquisition will be affected by light source reflection, overexposure and hair occlusion [4]. How to overcome these problems effectively has become an extensive research topic in recent years.

The main iris recognition systems include Daugman system [5], Wildes system [6], Boles system [7] and iris system of Chinese academy of sciences.

The Daugman system is a widely used iris recognition algorithm in the world. The algorithm uses integro-differential operator to detect the inner and outer boundary of iris, and obtains the target parameters by integrating, normalizing and differentiating the gray value. In addition, Daugman also designed a two-dimensional Gabor filter for feature extraction, converted the extracted phase information into a total of 2048 bits of binary coding, and used the normalized hamming distance as a measure for iris image recognition.

The Wildes system adopts extended Hough transform to detect the inner and outer edges of iris, and overcomes the problems of image translation, rotation and scaling through image registration. The iris information data of 2048 digits is considered too little. He proposed the use of Gauss-Laplace filter to filter images of different resolutions, after 1/2 sampling to obtain a four-layer pyramid data structure. Finally, the Fisher classifier is used for classification.

The Boles system represents iris characteristics by the integral mean value of the zero crossing of wavelet transform and two consecutive zero crossing wavelet transform. Firstly, the iris mass is sampled with the iris center as the center, and the two-dimensional signal is changed into a one-dimensional signal. Then, the special wavelet function is used to transform it.

2. Iris Recognition

2.1. Iris Image Acquisition Principle

The iris image is acquired by taking a picture of the whole eye area of the human body with a special digital camera device and transferring the picture to the storage device through the collection card. The first step in iris recognition is the collection of iris images.

Due to the small area of the eye, the magnification is needed to meet the resolution of the iris recognition algorithm, but the depth of iris imaging is also small, so the existing iris recognition system requires the user to stand at the appropriate position when collecting image, and the eyes also need to gaze at the lens. In addition, compared with westerners, the iris color of easterners is darker, and the iris image collected by ordinary camera cannot meet the algorithm requirements, so the near-infrared light source is needed for iris collection. Therefore, iris image acquisition is different from biological features such as face and gait, which requires the configuration of required light source and electronic control unit.

In 1999, the institute of automation of the Chinese academy of sciences designed the country's first independent intellectual property iris image acquisition system, with small, flexible, low cost, clear image and other characteristics. After continuous improvement, the institute of automation of the Chinese academy of sciences has developed a collection device that can carry out voice prompt, automatic visual feedback and other technologies in the range of 20 ~ 30cm.

2.2. Technical Characteristics

(1) Iris recognition technology features: As one of the most developed biometric technologies, iris recognition technology mainly has the following characteristics.

(a) Biological activity: Under the protection of the cornea, iris has a strong biological activity. The iris tissue dilates when the body is brain dead or in a deep coma. Therefore, the biological activity of the pupil and the characteristics of human life exist at the same time.

(b) Non-contact: Iris image can be obtained from a certain distance, the user does not need to contact the device directly.

(c) Uniqueness: The iris tissue of different individuals contains information are not the same, its formation and embryonic development of physical and chemical conditions, with great randomness even if identical twins or even the same person's iris texture is different.
(d) Stability: Iris pattern in the life of people are stable and unchanged, general diseases or special occupation will not cause iris tissue damage.

e) Security: Iris information can’t be copied in the case of no impact on the vision, with photos, video or physical iris will be detected.

(2) Iris recognition system module: the current common iris recognition system includes the following four basic modules [8].

(a) Image acquisition: Iris image acquisition is the first step of iris recognition, because people have a small eye area, the subject needs to stand in the right position and stare at the lens. In addition, asians generally have darker irises, so it is necessary to use near-infrared cameras to collect images.

(b) Image preprocessing: Image preprocessing is a step to eliminate the noise in the image. The processing process generally includes image smoothing, edge detection, image classification and other operations.

(c) Iris segmentation: Iris segmentation is the process of locating the inner edge of the iris (i.e., the pupil edge) and the outer edge of the iris in iris images and extracting effective areas. The commonly used positioning methods can be roughly divided into two types: the method based on edge detection and Hough transform and the method based on edge search. However, the operation time of these two methods is long. Although improved algorithm has appeared later, iris segmentation is still one of the steps requiring the longest operation time in iris recognition algorithm.

(d) Feature extraction and recognition: It mainly includes image normalization and iris coding generation. The purpose of image normalization is to fix the size of the extracted iris area. Feature points are extracted and encoded by feature extraction algorithm, and compared and verified with iris image coding in database to achieve the purpose of recognition.

3. Iris Segmentation Algorithm

The performance of iris recognition system depends on the accuracy and efficiency of iris segmentation. Iris segmentation is the extraction of iris from the pupil, sclera, skin around the eye, eyelashes and eyebrows. According to the research, iris segmentation is the process that needs the most computing tasks in iris recognition system. In general, iris location methods can be divided into two categories. The first is based on the Hough transform and the second is based on histogram. In this chapter, a method combining threshold extraction and iris edge adaptive localization is proposed to locate iris region. The flow diagram is shown in figure 1.

![Figure 1. Flow chart of iris segmentation algorithm.](image-url)
3.1. Pretreatment and Pupil Localization

The purpose of image preprocessing is to eliminate noise in iris images, enhance information and simplify data. Processing process generally includes image smoothing, edge detection, image classification and other operations. In the process of iris image acquisition, different devices will cause great differences in image acquisition. As shown in figure 2, the iris image after bath pretreatment is obtained by extracting, locating and covering the light spots in the image with gray value, and then fusing the image with median filter.

![Figure 2. Iris image preprocessing.](image)

In the process of extracting pupil circle, the selection of threshold value is a key step. Reasonable threshold is an important guarantee to extract pupil circle. If the selected threshold is too small, the extracted pupil region is incomplete, that is, the pupil ring is in the pupil region. However, excessive selection threshold will introduce interference factors such as eyelashes, resulting in pupil displacement. In this paper, the threshold size of extraction pupil region is limited by calculating the average brightness of iris image. the appropriate threshold is extracted, the banalization image is located in the pupil area through shape screening, as shown in figure 3.

![Figure 3. Extraction process of pupil edge.](image)

3.2. Iris Segmentation and Image Normalization

In this part, the outer edge of the iris is positioned by the center and radius of the pupil circle, taking advantage of the approximately concentric nature of the pupil circle and the iris circle [9]. The ROI region of iris image was extracted by the center and radius of the pupil, and the pupil was covered. This method can reduce the interference of iris region eyelash and other noises on iris edge extraction. By combining edge detection with grayscale projection, it can be seen that the iris edge will peak in the projection curve, so two abscissa of the iris edge can be extracted to realize iris segmentation of the iris image, as shown in figure 4.

Each person’s eye size is different, in the same distance of the acquisition equipment, the external light will also lead to the pupil zooming effect. These changes in iris collection will affect the comparison results. Iris of different sizes is difficult to be used for matching and recognition. Iris normalization can effectively correct pupil dilation distortion. The graphic normalization method USES the Rubber - sheet model proposed by professor Daugman [5], which assumes that the iris is an elastic model with elasticity and isotropy. According to the fixed mode, the iris is converted into a fixed rectangular region, as shown in figure 5.

![Figure 4. Iris edge positioning process.](image)
4. Deep Learning

Deep learning is shown as the internal rule and presentation form of learning sample data. The information obtained during the learning process is of great value to the interpretation of data such as text, images and sounds. The ultimate goal of the process is to make machines as capable as humans when analyzing study materials, recognizing various data like text, images and sounds. As a complex machine learning algorithm, deep learning is equipped with much more speech and more efficient image recognition than previous techniques [10].

4.1. Deep Learning

Artificial Neural Networks (ANNs), also referred to as Neural Networks (NNs) or Connection Model, is a mathematical Model for distributed parallel information processing that imitates the characteristics of animal Neural Networks. Based on the research of modern neuroscience, the artificial neural network conducts information processing by simulating the neural network of the brain, which has four basic characteristics:

1) Nonlinearity: there are two states of stimulation or inhibition of artificial neurons, and their mathematical performance becomes a nonlinear relationship.

2) Very qualitative: the neural network can not only process various changing information, but also the nonlinear dynamic system itself is constantly changing.

3) Non-limitation: the overall behavior of a neural network is mainly determined by the connection and interaction between each unit, not by the characteristics of a single neuron

4) Non-convexity: non-convexity indicates the evolution direction of a system. In general, the system has multiple stable equilibrium values, which to some extent depends on a certain state function.

4.2. Convolutional Neural Network

Convolutional Neural Networks (CNN) can be called a representative algorithm of deep learning, it contains a type of Feedforward neural network, which has convolutional calculation and deep structure [11]. Convolutional Neural network can input information according to hierarchical structure translation and Invariant classification and has representation learning capability, which is also known as “shift-invariant Artificial Neural Networks (SIANN)” [12]. In the neural network structure, the input layer, the hidden layer and the output layer constitute the convolution., one hidden layer containing convolution, pooling layer and the structure of the three kinds of common connection layer, and the more modern algorithm also contains Inception module and residual module (residual block), etc., the convolution and pooling layer are peculiar to the convolutional neural network module.

1) Convolution layer: The function of the convolution layer is to extract the characteristics of the input data. It contains multiple convolution kernels, and each element constituting the convolution kernel corresponds to a corresponding weight coefficient and deviation vector. Convolution layer of neurons and the former are connected to the multiple neurons in the vicinity of a layer, The size of the convolution kernel has a decisive effect on the size of the connection area, this area is also known as the “receptive field” [11].

2) Pooling layer: After feature extraction, feature graph is sent to pooling layer for information selection and filtering. The preset pooling function in the pooling layer, and the results of the points in the feature map are replaced with the statistical information of the adjacent regions. The pooling layer is divided into Lp pooling, random pooling and spectral pooling, the main classification is based on size, step length and filling control.
4.3. Deep Learning Model
The AlexNet model [13] is adopted in this paper, the network of this model is composed of 8 weight layers. Each of the first five layers is a convolutional layer, and the last three layers are fully connected layers. The last fully connected layer can output the distribution of 1000 class labels and become the input of the dimension softmax. The softmax function will generate a distributed network of 1000 class labels that contains 8 layers with weights. Each of the first five layers is a convolutional layer, and the last three layers are fully connected layers. The last fully connected layer can output the distribution of 1000 class labels and become the input of the 1000 dimension softmax.

5. Experimental Results
The experimental results are divided into the experimental comparison of iris segmentation algorithm and the demonstration of iris recognition based on deep learning.

5.1. Experimental Data
CASIA-Iris-Interval [14] uses an auto radiographic near-iris camera with a circular near-infrared LED array (with eight circular white dots in the pupil region), and its luminous flux is suitable for iris imaging.

CASIA-Iris-Thousand [14] contains 20,000 iris images from 1,000 subjects, collected using binocular iris cameras, with a wide age distribution of participants.

UBIRIS.v1 database [15] is composed of 1877 images collected from 241 persons in two distinct sessions.

5.2. Iris Segmentation Algorithm
Sardar, Mitra and Uma Shankar [16] propose a new soft calculation method for iris segmentation based on rough entropy, and uses cyclic sector analysis (CSA) for positioning; thereby minimizing uncertainty. Table 1 shows the performance comparison analysis by using CASIA v3.0 (Interval) and UBIIRIS v1. It compares these algorithms through experimentations. The results show that the time efficiency of the proposed algorithm is higher than other four algorithms. Even more remarkably, our proposed method reduces the iris location time by 1/10 without reducing accuracy. Accuracy (Acc) is calculated as the following equation:

\[
\text{Acc} = \frac{\text{Number of correctly located images}}{\text{Total number of images in experiment}} \times 100\%
\]

| Method     | Accuracy (%) | Time (s) |
|------------|--------------|----------|
|            | CASIA V3.0 (Interval) | UBIRIS V1 | CASIA V3.0 (Interval) | UBIRIS V1 |
| Daugman [5] | 92.7         | 58.92    | 1.96       | 2.12       |
| Sadar [16]  | 97.12        | 97.17    | 1.56       | 1.68       |
| Proposed    | 98.61        | 98.04    | 0.16       | 0.32       |

5.3. Training of Convolutional Neural Network
The experimental use of the Caffe framework relies on two core configuration files: train_val.prototxt and solver.prototxt. The train_val.prototxt file is primarily used to define the network structure of the model. The layer parameter in this file can define different types of layer structures. The main function
of Solver is to alternately call forward and backward algorithms to continuously update parameters of
the network model, so as to minimize loss.

In this section, 500 people were randomly selected from CASIA v4.0 database as test samples, and
the samples were divided into training sets and test sets in a ratio of 8:2. Since there are only 10 images
in each data set, this experiment expands the training set by slightly rotating and mirror flipping images.
The data was iterated 40,000 times in the experiment. In the experiment, the data was iterated for
40,000 times, and the accuracy gradually leveled off when the iteration reached 15,000 times, its
matching accuracy is about 98.6% on average, as shown in figure 6.

Figure 6. Accuracy and loss line charts.

6. Conclusion
In summary, iris segmentation lays the foundation for subsequent deep learning and feature learning.
The iris segmentation algorithm proposed in this paper has more advantages than other algorithms in
the efficiency and accuracy of iris recognition. The AlexNet model is used to extract and recognize the
features of segmentation images, and the recognition rate is high. This study shows that iris recognition
efficiency can be improved by improving iris segmentation algorithm, and the recognition rate of iris
research can be improved to a greater extent by combining with deep learning network training.

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