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Research on Iris Recognition Method Based on Quantum Algorithms

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Abstract

Traditional iris recognition method has low speed and searching rate in large-scale unstructured database. Three different quantum algorithms are proposed in iris recognition. Quantum filtering algorithm can get a better filtering result than classical algorithm in iris filtering process. Quantum Fourier transforms exhibits an exponential speed-up compared with discrete Fourier transform in feature extraction. Improved Grover algorithm can reduce the matching time in the step of iris matching. The experiment results show that matching numbers and matching time reduce greatly.

***Keywords**: iris recognition, quantum adaptive median filtering, quantum parallelism, quantum fourier transform, grover algorithm*

1. Introduction

Quantum computing and quantum information are combination of quantum mechanics theory and classical computing theory. So far, the most representative quantum algorithms is the quantum searching algorithms in database proposed by Grover in 1996 [1]. Grover algorithm is the kind of quantum searching method which can search a particular element in an unsorted database. This method can exponential speed-up the searching speed. Applying quantum algorithms to iris recognition is still in the stage of development. Study shows that it is feasible to use quantum information and quantum computation in image processing. In 2003, R. Schutzhold [2] pointed out that the specific mode could be identified and searched from the macro-structure images on quantum computer. In May 2006, C. Y. Pang [3] proposed an algorithm which can successfully check out the best matching pattern between input image and sample collection. Subsequently, C. Y. Pang [4, 5] proposed a series of quantum image compression algorithm. In this article, quantum algorithms are used in the recognition steps including filtering processing, feature extraction, and we improved the Grover algorithm and use it in iris matching step. According to the experiment results, applying quantum algorithm to iris recognition can decrease the numbers of repetition and raise the probability of success.

The layout of the article is as follows. Section 2 uses quantum adaptive median filtering algorithm to iris filtering processing. Section 3 extracts iris feature based on quantum Fourier transform. Section 4 presents the iris matching method based on improved Grover algorithm. Section 5 carries out the simulation experiments and give the evaluation results between our method and traditional method. Section 6 concludes the paper.

2. Iris Filtering Processing Based on Quantum Adaptive Median Filtering Algorithm

In median filtering operation, the size and shape of operation window is fixed. A large window has strong noise reduction capability but it's easy to lose the detail [6]. A small window has poor ability to reduce the noise but it can't reach the application requirement. In this section we propose a quantum filtering algorithm on Iris filtering processing.

Quantum adaptive median filtering (QAMF) algorithm improves the traditional median filtering algorithm by using quantum mechanics and quantum information processing principle [7]. For a normalized digital iris image $f(m,n)$Č$[0,1]$, $f(m,n)$ stands for the pixel gray of this iris at the position of (m,n), $f(m,n)$ and $1-f(m,n)$ respectively denote the probability when gray-scale

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value of *(m,n)* is 1 and 0. Iris gray value of 1 and 0 can be represented by $|0\rangle$ and $|1\rangle$, the quantum bit form of the image *f(m,n)* is:

$$|f(m,n)\rangle = \sqrt{1-f(m,n)}|0\rangle + \sqrt{f(m,n)}|1\rangle \quad (1)$$

We translate traditional filter window into quantum bit form which is showed in Equation (2).

$$\left|W_{f(i,j)}\right\rangle = \begin{bmatrix} |f_{i-n,j-n}\rangle & \cdots & |f_{i-n,j}\rangle & \cdots & |f_{i-n,j+n}\rangle \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & |f_{i,j}\rangle & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & |f_{i+n,j}\rangle & \cdots & |f_{i+n,j+n}\rangle \end{bmatrix} \quad (2)$$

f(m,n) is transformed as $f_{m,n}(|f(m,n)\rangle \geq |f_{m,n}\rangle)$. Quantum Hadamard operation is used in each pixel of the above equation:

$$\begin{aligned} H \cdot |f_{i,j}\rangle &= H \cdot (\mu^0_{i,j}|0\rangle + \mu^1_{i,j}|1\rangle) \\ &= \frac{1}{\sqrt{2}}(\mu^0_{i,j} + \mu^1_{i,j})|0\rangle + \frac{1}{\sqrt{2}}(\mu^0_{i,j} - \mu^1_{i,j})|1\rangle \end{aligned} \quad (3)$$

Where $\mu^0_{i,j}$ and $\mu^1_{i,j}$ are probability amplitude of $|0\rangle$ and $|1\rangle$. The overall effect of the equation (1) to Equation (3) is:

$$T_{W_f} : W_{f_{i,j}} \rightarrow \left|H \cdot W_{f_{i,j}}\right\rangle \quad (4)$$

In other words, the gray values which are 1 and 0 in the traditional iris window are converted to:

$$0 \rightarrow \frac{1}{\sqrt{2}}|0\rangle + \frac{1}{\sqrt{2}}|1\rangle \quad (5)$$

$$1 \rightarrow \frac{1}{\sqrt{2}}|0\rangle - \frac{1}{\sqrt{2}}|1\rangle \quad (6)$$

After all the operations, the distribution of gray range in the iris image is compressed. It is conducive to generate the median operator template.

Then we randomly build *n=NòN* numbers where *$r_{i,j}$Č[0.5,1]*, if $r_{i,j} > 1/\sqrt{2}(\mu^0_{i,j} + \mu^1_{i,j})^2$, then $H \cdot |f_{i,j}\rangle = 0$, else $H \cdot |f_{i,j}\rangle = 1$. Then we get the re-adjusted binary window $|i_b(i,j)\rangle$. Quantum adaptive median filter can be expressed as:

$$y(i,j) \Rightarrow Med\{f_{i+r,j+s}(r,s) \in |i_b(i,j)\rangle\} \quad (7)$$

By using QAMF algorithm, the iris image details can be better preserved and the filtering ability is improved. Next we apply the binarization processing and pixel flip operation to filtered iris in order to benefit the feature extraction.

3. Iris Feature Extraction Based on Quantum Fourier Transform

Traditional discrete Fourier transform is defined as [8]:

$$y_k = \frac{1}{\sqrt{N}} \sum_{i=0}^{N-1} x_j e^{2\text{®}ikj/N} \ (k = 0,1,..., N-1) \tag{8}$$

Quantum Fourier transform (QFT) algorithm can be obtained from the traditional discrete Fourier transform which is:

$$QFT: U_{QFT} \left| x \right\rangle = \frac{1}{\sqrt{2^m}} \sum_{i=0}^{2^m-1} e^{2\text{®}itx/2^m} \left| t \right\rangle \tag{9}$$

Where the quantum bit numbers of the quantum state $\left| x \right\rangle$ are *m*, U_{QFT} is a unitary operator and QFT is a 2^m-dimensional unitary transformation [9]. Equation (9) transforms a unit quantum state into a superposition state [10]. Then we use QFT method to extract the iris feature.

The dimension of the filtered iris is $M\text{ò}N(M=2^a,N=2^b)$, we need to build *a+b* numbers of quantum registers, the location of the whiter point can be expressed by the coordinates of *x* and *y*. Let *z=x+ny*, *n* are the numbers of white points in each line and $\left| z \right\rangle = \left| x \right\rangle \otimes \left| y \right\rangle$.

A quantum initial state is constructed which expresses the locations of all the white points in iris as:

$$\left| \text{¨} \right\rangle = 1/\sqrt{\text{°} MN} \sum_{k=1}^{\text{°} MN} \left| z_k \right\rangle \tag{10}$$

Where ° is the proportion of the white spot accounting for all pixels, then the quantum Fourier transform is applied to the Equation (10).

$$U_{QFT} \left| \text{¨} \right\rangle = \sum_{t=1}^{MN} \sum_{k=1}^{\text{°} MN} \frac{1}{MN\sqrt{\text{°}}} e^{2\text{®}izkt/MN} \left| t \right\rangle \tag{11}$$

Equation (11) includes *(MN)*ò*(°MN)* items after being expanded. After comparing with Equation (8) and Equation (11), we can find out the difference between traditional Fourier transform and QFT: traditional method is Unitary transformation on *N*-dimensional Euclidean space, QFT is unitary transformation on *M*ò*N*-dimensional space, computation method of traditional method is serial computation but QFT is parallel computing, complex vector $(x_0,x_1,\ldots,x_{N-1})$ has become one row of the quantum state matrix which makes facilitates high-speed processing. If we apply traditional feature extraction method on an iris image, the amount of computation will be *N* times. In this paper, we use the parallel computing features of the quantum algorithm. *(MN)*ò*(°MN)* numbers of calculations can be completed through one time of QFT operation. Compared with traditional algorithm, the calculation speed of our method shows exponential improvement. Finally, Equation (11) is measured and the probability state is selected as:

$$\left| t \right\rangle = \left| kMN/r \right\rangle (k = 0,1,..., r-1, t = kMN/r) \tag{12}$$

Where $\left| t \right\rangle$ represents the positions of all white points. We extract all the positions of white points of iris and reconstruct the normalization grayscale of iris. Then we can extract the characteristic parameters *t* and finish the feature extraction step.

4. Iris Matching Method Based on Grover Algorithm

Iris feature matching method matches between identifying iris characteristics and registered iris characteristics in signature database, this method makes the final identification decision on the basis of feature extraction. Finally we can determine the identity of a person

[11]. The quantum circuit of original Grover algorithm is shown in Figure 1 [12]. Structure database issue such as detecting the sending sequence in modern communication, the data in this kind of database is stored in the form of disorder but whole arrangement. Then people can use the classical Oracle operator to solve this kind of problem by constituting a corresponding relationship between the quantum registers and sending sequences. It can detect the minimum judgment value by using an effective algorithm and finally get the sending sequence [13]. But in this paper, identifying irises can't form a corresponding relationship with quantum registers. If we apply the classical Oracle operator to this study, it may detect an iris which is not included in the iris database and result in an error. So in this section, we improve the Oracle operator of Grover algorithm and apply it to the iris matching.

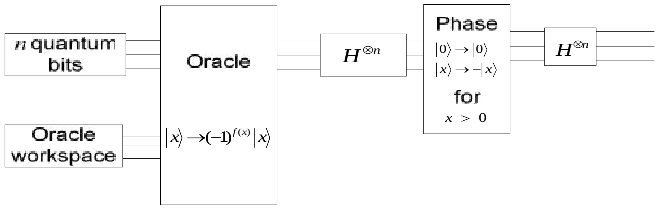

Figure 1. Quantum Circuit of Original Grover Quantum Algorithm

Assume that the identifying iris feature vectors is *A* and an iris feature vector in the database is *B*. The identifying iris after characteristics extraction has many feature vectors which are $A=\{a_0,a_1,\ldots,a_{N-1}\}$ and $N=2^n$. If $N\neq 2^n$, we add the feature vector number of the identifying iris and let the result is $N=2^n$. By the same way, we consume the feature vectors of iris image in database are $M=2^n$. The matching function in our method is defined as:

$$f_c(a_i,b_j)=\begin{cases}1, & a_i=b_j\\ 0, & else\end{cases} \tag{13}$$

We treat the identifying iris feature vector *A* as a database and store it in a memory. Each of the vectors a_i in the database corresponds to only one index *i*. The same method is used to deal with the iris vector *B*. Each of the vector b_j corresponds with only one index *j*. Then we structure five registers which are shown in Equation (14), five registers respectively save the index *i*, index *j*, vector a_i, vector b_j and matching function value f_c.

$$|i\rangle_1 |j\rangle_2 |a_i\rangle_3 |b_j\rangle_4 |f_c(a_i,b_j)\rangle_5 \tag{14}$$

All the five registers are initialized as:

$$|0\rangle_1 |0\rangle_2 |0\rangle_3 |0\rangle_4 |0\rangle_5 \tag{15}$$

Hadamard transform is applied to register 1 and register 2, and the effect is:

$$\frac{1}{\sqrt{MN}}\left(\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}|i\rangle|j\rangle|0\rangle|0\rangle|0\rangle\right) \tag{16}$$

Then U_L is used as a unitary operation, the feature vectors of identifying iris and the iris from database are loaded in the quantum entanglement state. That is to transform Equation (16) into the following quantum state:

$$\frac{1}{\sqrt{MN}}\left(\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}|i\rangle|j\rangle|a_i\rangle|b_j\rangle|0\rangle\right) \tag{17}$$

A unitary operation is used after computing the matching function f_c between the two irises which are shown by the following equation:

$$\frac{1}{\sqrt{MN}}\left(\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}|i\rangle|j\rangle|a_i\rangle|b_j\rangle|f_c(a_i,b_j)\rangle\right) \tag{18}$$

The next step is to apply the remaining three operations of Grover algorithm in Figure 1 which can search out the location of the matching iris. Then we measure the register 1 and the location of matching iris can be found out from iris database.

5. Experiment Results and Analysis

In this section, we compare our iris recognition method based on improved Grover algorithm with traditional iris recognition method.

In this paper, all algorithms are programmed in MATLAB. We use the CASIA V1.0 iris base to verify the effectiveness of our algorithm. We extract 256 iris images to create an iris template database. An iris is selected from the template iris database as the identifying one. Our experiment purpose is to find out the location of this iris in database. The experiment result is given bellow.

Table 1. Experimental Results of Traditional Algorithm and our Algorithm

Algorithm	*Traditional algorithm*	*Our algorithm*
Matching numbers	*256*	*16*
Matching time(s)	*0.31*	*0.17*

This table shows the different matching results between our algorithm and traditional method. We can see that our algorithm can largely reduce the matching numbers which are square root of the traditional algorithm. Moreover, our matching time has an obvious advantage on efficiency which needs almost half of traditional matching time.

6. Conclusion

We have applied three different quantum algorithms in iris recognition. In iris filtering process, we use QAMF algorithm to get a better filtering result than classical algorithm. Iris feature extraction, QFT can improve the extracting speed. Then we improve the Oracle operator of Grover algorithm and apply it to the iris matching step. Finally the location of target iris is recognized. Compared with traditional method, our improved Grover method can greatly enhance the iris recognition efficiency.

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