Iris Recognition Method Based on Ordinal Measure of Discrete Cosine Transform Coefficients

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***Abstract*—A recognition system based on irides has become important in the last decades due to its reliability and comfort. This paper proposed a method for iris recognition based on ordinal measure of Discrete Cosine Transform (DCT) coefficients. Ordinal measure was obtained by ordering the absolute value of AC coefficients of normalized iris image of both database and query image ascendantly. Distance between those image was measured by Minkowsky distance metrics. Five simulation sets, each with different of AC coefficient used, namely all, 63, 48, 32 and 16 coefficients were conducted, to find out recognition rate of the proposed method and the best trade-off between compression ratio and recognition rate. It turned out that 50% of querying task resulted in averaged recognition rate more than 60%, Moreover, the best trade-off between compression ratio and recognition rate was achieved when as many as 48 coefficients were used.**

I. Introduction

A recognition system based on irides has become important in the last decades and been applied in many applications. These are due to iris is found to be (1) more reliable because its structure is unique to an individual, stable with age, irides's pattern variability among different persons is enormous and iris image is relatively insensitive to angle of illumination and (2) comfort to use due to the irides can be captured in a less invasive manner [1], [2].

Many iris recognition techniques have been proposed recently. The author in [2] encoded local region of the iris onto quadrature 2-D Gabor Wavelets. The authors in [3] proposed a method that use phase components of 2D Discrete Fourier Transforms (DFTs) of the iris images. The experimental observation showed that the use of phase components of iris images makes possible to achieve highly accurate iris recognition even for low-quality iris images. The work in [4] presented an iris coding method based on differences of discrete cosine transform (DCT) coefficients of overlapped angular patches from normalized iris images.

Attempts to recognize iris based on ordinal measures/features have been proposed in [5], [6]. In [5], the ordinal measure is calculated by convolving iris with ordinal filters, namely Gaussian filters. Then SOBoost and Adaboost algorithms were used to select the most discriminative ordinal features. While the work in [6] compared three ordinal filters, namely Gabor, wavelet Haar and quadratic spline wavelet to determine the most discriminative ordinal features.

On the other hands, ordinal measure in DCT domain has been exploited maturely in content-based image and video copy detection application [7]–[9]. It was reported that ordinal measure were robust to alteration such as Gaussian noising, darkening and contrast changing [7]. These alterations are included in the most common alterations take place in iris recognition procedure. As a matter of fact, the DCT is transformation method employed in JPEG compression standard, which is the most popular and widely used standard in the world [10]. Considering the JPEG standard in a recognition system yielding the system's compatibility with many available hardwares and softwares. In addition, it can reduce processing time, due to complete decoding is not required to conduct a matching task.

This paper proposed an employment of ordinal measure of DCT coefficients for iris recognition. Our algorithm was implemented on normalized iris images, whose dimension was 20 by 240 pixels. Firstly, DCT coefficients of normalized iris images was computed (both database and query images). Then absolute value of AC coefficients were ordered ascendantly to obtain the ordinal measure. Distance between those image was measured by Minkowsky distance metrics. The proposed method was evaluated by conducting five classes of simulations (each class represents different number of AC coefficient incorporated, namely all, 63, 48, 32 and 16). Each of those classes were tested by ten query images that were randomly selected. Thus there were 50 querying tasks totally. Each of these task was run on a database of 750 iris images. It turned out that 50% of querying task resulted in averaged recognition rate more than 60%. Moreover, the best trade-off between the number of AC coefficients incorporated and recognition rate was achieved when as many as 48 coefficients were used.

II. Background

A. Iris and Iris Normalization

Figure 1 shows a front-view of the human eye which includes: eyelid, eyelashes, pupil, iris, sclera, collarette and specular reflection. The average diameter of the iris is 12 mm, and the pupil size can vary from 10% to 80% of the iris diameter. Iris is a circular region between pupil and sclera and can be localized using the circular Hough transform. In Figure

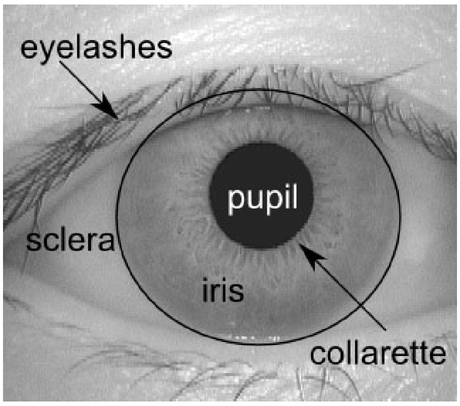

Fig. 1. Iris localization.

2 (a), the circular Hough transform is used to detect circular boundary between sclera and iris (showed by the bigg er circle) and a boundary between iris and pupil (showed by the smaller circle). A technique is also required to exclude eyelids, eyelashes and specular reflections [2], [6]. Normalization of iris regions was implemented based on Daugman's rubber sheet model. Figure 2 illustrates the normalization process. The centre of the pupil was considered as the reference point, and radial vectors pass through the iris region. A number of data points are selected along each radial line and this is defined as the radial resolution. The number of radial lines going around the iris region is defined as the angular resolution. For a non- concentric pupil, a remapping formula is needed to rescale points depending on the angle around the circle [2].

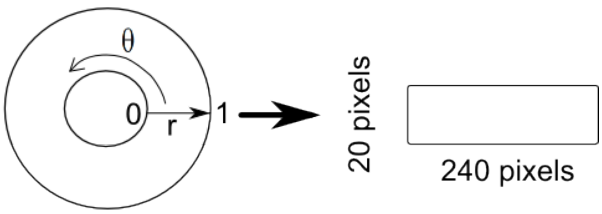

Fig. 2. Iris normalization.

B. Ordinal Measure of DCT Coefficient

In other references, ordinal measures is also referred to as ordinal features. In this paper these two terms will be used interchangeably. An approach to obtain ordinal measure of DCT coefficient can be summarized as follows [7].

- Let an image denoted by I.
- Let the DCT coefficients calculated from the whole image denoted by I_c.
- Figure 3 shows selection manner of AC part of DCT coefficients. In the figure, the number of rows was denoted as n_2, the number of column was denoted as n_1. The AC coefficient was selected similar to the zig-zag scanning used in JPEG standard. However, the size of the block under consideration was not specified as 8×8 as in JPEG standard. The zig-zag scanning was started at row 1, column 2 (first location of AC coefficient).
- Ordinal measure was obtained by ordering the absolute value of AC coefficient of I_c.

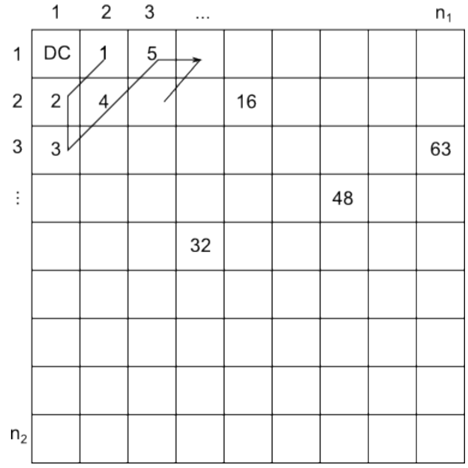

Fig. 3. Zig-zag scanning.

C. Frequency Selection in DCT Domain

The DCT has been famous for its energy compactness ability. Thus in DCT domain, most image information are available in low-medium frequency. In several cases, selection of suitable low-medium frequency resulted in better performance of the system [11], [12]. The work in [12] was a copy detection system, and the best performance of the system was achieved when 48 first AC coefficients were used in computing similarity between images.

Based on the above results, later in the experiment section, several evaluation sets is conducted to evaluate the performance of the proposed method. Each of them consist of different number of first AC coefficients.

D. Minkowsky Distance

The Minkowsky distance is defined as

$$\sum_{i=1}^{n} |x_i - y_i| \qquad (1)$$

here, x (and y) is a set of DCT coefficients in a form of column vector, and x_i (and y_i) is the i^{th} DCT coefficients of x (and y).

III. Proposed Method

The diagram of the proposed method is shown in Fig.4. It can be summarized as follows:

- Firstly, iris image of both database and query are localized and normalized according to an approach highlighted in Sect. II-A.
- The DCT coefficients of both images are calculated.
- The AC coefficients were ordered in ascendant manner to obtain ordinal features.

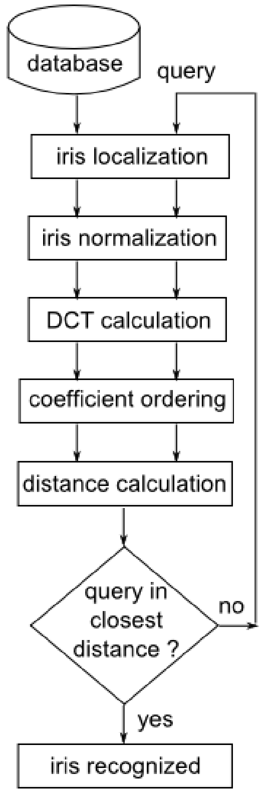

Fig. 4. Proposed Method

- The Minkowsky distance given by Eq.1, between those two ordered coefficients are calculated.
- If the distance of the query image is sufficiently close to the already available template in the database the iris was recognized and the process is stop. However, if if the distance is considerable far, the input query was considered as a version of different eyes, and the process were started all over again from the beginning.

IV. Experimental Results

A. Simulation Condition

Simulations were conducted using CASIA Iris Image Database Version 1.0 (CASIA-IrisV1) . CASIA-IrisV1 consisted of 756 iris images from 108 eyes. Each eye was captured seven times by two devices. For comfort and brevity, we renamed images in CASIA-IrisV1 as Casia-1 until Casia-756 (abbreviated C-1 until C-756). From these images ten images were selected as queries, in which the details are shown in Table I.

In the simulations, normalized iris whose dimension was 20 by 240 pixels (full size) obtained in a manner explained in section II-A were used. Five simulation strategies were planned, according to the number of DCT coefficients used, namely (1) all DCT coefficients, (2) 63 AC coefficients, (3) 48 AC coefficients, (4) 32 AC coefficients and (5) 16 AC coefficients. The coefficients were selected based on zig-zag scanning explained in Sect. III. The final location of zig-zag scanning of each of 63th, 48th, 32th and 16th coefficients were shown in Fig.3.

TABLE I
Query Images

No	No. of Query
1	Casia-2
2	Casia-64
3	Casia-207
4	Casia-273
5	Casia-343
6	Casia-420
7	Casia-484
8	Casia-556
9	Casia-625
10	Casia-691

Due to each eye in CASIA-IrisV1 database has seven versions, recognition rate of 100% means that all seven versions of an eye had the closest distance to the querying iris. While recognition rate of 0% occurred when there was no versions ranked at the closest distance from the query image. For information, Casia-2 (C-2) has seven other versions in the database, namely C-1 until C-7.

B. Results and Analysis

Table II shows recognition results of the proposed method (in percentage) using different number of AC coefficients. Each row corresponds to different AC coefficients used, namely: all, 63, 48, 32 and 16 AC coefficients. Column "Average I" consists of averaged recognition rate of each coefficient used. While "Average II" lists averaged recognition rate of all query images, regardless of the number of used coefficients.

From Table II, it can be seen that when 63, 48 and 32 coefficients were used, recognition rate of all image queries had been relatively stable, For example, querying C-2 with all those coefficients resulted in 71% recognition rate, while querying C-420 resulted in 57% recognition rate. When only 16 coefficients were used, several recognition rates decreases, such as when querying C-343 and C-420. This data indicated that using as many as 32 AC coefficient can be as good as using 63 AC coefficients.

From "Average I", the highest averaged recognition rate was achieved when as many as 48 AC coefficients were employed (with averaged recognition rate 60%). All the results indicated that it is not necessary to employ all AC coefficient to obtain the best result, as AC coefficients at higher frequencies serve as noises. Decreasing the number of coefficients used in the system can save the memory and cost required.

Furthermore, from "Average II", it can be noted that 50% of queries resulted in averaged recognition rate more than 60% (column C-2, C-64, C-343, C-625, C-691), while other 50% queries resulted in averaged recognition rate less than 60% (column C-207, C-273, C-420, C-484 and C-556). Amongst all, the lowest recognition rate was achieved when querying C-207 and C-484, that is 26% in average, and this value was

TABLE II
RECOGNITION RESULTS OF ORDINAL MEASURE OF DCT COEFFICIENTS; MEASURED IN PERCENTAGE

No.	Used AC Coefficients	No. of Query										Average I
		C-2	C64	C-207	C-273	C-343	C-420	C-484	C-556	C-625	C-691	
1	all	**86**	43	14	14	57	14	14	43	14	29	33
2	63	**71**	**71**	29	29	**71**	57	29	57	**71**	**71**	56
3	48	**71**	**86**	29	43	**71**	57	29	57	**71**	**86**	60
4	32	**71**	**71**	29	43	**71**	57	29	57	**71**	**71**	59
5	16	57	**71**	29	43	43	14	29	29	**71**	**86**	47
	Average II	71	69	26	34	63	40	26	49	60	71	

TABLE III
DISTANCE VALUE OF QUERY C-2, WITH ALL AC COEFFICIENTS USED

Rank	Recognized Iris	Distance Value
1	C-2	0.0000
2	C-1	0.3384
3	C-3	0.3542
4	C-5	0.3621
5	C-4	0.3639
6	C-396	0.3641
7	C-7	0.3654
8	C-121	0.3661
9	C-732	0.3807
10	C-397	0.3829

TABLE IV
DISTANCE VALUE OF QUERY C-2, WITH 63 AC COEFFICIENTS USED

Rank	Recognized Iris	Distance Value
1	C-2	0.0000
2	C-1	0.2089
3	C-3	0.2683
4	C-5	0.2832
5	C-396	0.3122
6	C-4	0.3190
7	C-391	0.3451
8	C-7	0.3454
9	C-6	0.3543
10	C-309	0.3742

TABLE VI
DISTANCE VALUE OF QUERY C-2, WITH 32 AC COEFFICIENTS USED

Rank	Recognized Iris	Distance Value
1	C-2	0.0000
2	C-1	0.1846
3	C-3	0.2192
4	C-223	0.2826
5	C-396	0.2851
6	C-5	0.2954
7	C-4	0.3114
8	C-391	0.3191
9	C-6	0.3413
10	C-7	0.3425

TABLE VII
DISTANCE VALUE OF QUERY C-2, WITH 16 AC COEFFICIENTS USED

Rank	Recognized Iris	Distance Value
1	C-2	0.0000
2	C-1	0.1283
3	C-3	0.1986
4	C-223	0.2303
5	C-5	0.2915
6	C-222	0.3011
7	C-467	0.3043
8	C-396	0.3047
9	C-268	0.3055
10	C-4	0.3155

not affected by setting different number of AC coefficients. The results motivate us to investigate the query images, and it turned out that those query images were not conveniently captured due to most of iris area were covered by eyelids.

C. Impact of Compression Rate on Distance Value

Operation of decreasing the number of AC coefficients used can be thought as a procedure to increase compression rates, as less coefficients were saved/stored to represent the same quantity. This section discussed the impact of increasing the compression rate on distance value. Simulation results when querying C-2 with full, 63, 48, 32 and 16 DCT coefficients respectively can be seen in Tables III, IV, V, VI and VII.

TABLE V
DISTANCE VALUE OF QUERY C-2, WITH 48 AC COEFFICIENTS USED

Rank	Recognized Iris	Distance Value
1	C-2	0.0000
2	C-1	0.2092
3	C-3	0.2453
4	C-5	0.2851
5	C-396	0.3046
6	C-4	0.3117
7	C-223	0.3282
8	C-391	0.3379
9	C-7	0.3558
10	C-6	0.3598

It turned out that reducing the number of coefficients used also reduced the distance. For example, in rank second in all those tables, the recognized iris was C-1. The distance value of C-1 and C-2 in Table III was 0.3384, while that in Table IV decreased to 0.2089. In Tables V, VI and VII the distances kept decreasing. The closest distance between C-1 and C-2 was achieved when as many as 16 AC coefficients were used, namely 0.1283. In words, the tables indicated that threshold selection depends heavily on the number of AC coefficients used.

Furthermore, there is a common assumption in a system implements a distance measure that "closer is better". However here, the best recognition performance was achieved when as many as 48 AC coefficients were used. This mean that when the proposed method is implemented, the thresholds listed in Tables VI and VII should not be considered.

V. Conclusion and Future Works

This paper proposed a method for iris recognition based on ordinal measure of DCT coefficients. Ordinal measure was obtained by ordered the absolute value of AC coefficients of normalized iris image of both database and query image ascendantly. Simulations were accomplished to find out (1) recognition rate of the proposed method and (2) the best trade-off between compression ratio and recognition rate. It turned out that 50% of querying task resulted in averaged recognition rate more than 60%. Moreover, the best trade-off between the number of AC coefficients incorporated and recognition rate was achieved when as many as 48 coefficients were used.

The proposed method was still in a preliminary stage. There are many aspects should be considered to enhance the performance of the method, namely (1) determination of threshold value should be more accurate, (2) usage of more iris images from several databases, especially the databases that include irides with non-ideal capturing condition such as darkening and contrast changing, and (3) selection of irides area more appropriately to obtain the most distinctive iris pattern.

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