Enhancement of Iris Recognition System Based on Phase Only Correlation

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Abstrak

　　Pengenalan iris mata adalah salah satu sistem pengenalan/identifikasi berbasis biometrik. Banyak teknik yang digunakan untuk menghasilkan tingkat pengenalan yang tinggi, salah satunya adalah metode korelasi berbasis fasa (KBF). Puncak korelasi yang tinggi dan signifikan mengandung arti bahwa sistem mengenali iris mata dari subjek (orang) yang sama, sedangkan puncak korelasi yang rendah dan tidak signifikan berarti sebaliknya. Metode KBF yang ada sekarang belum meneliti ukuran iris minimum yang bisa digunakan untuk tetap menghasilkan puncak korelasi yang tinggi. Paper ini mengusulkan penggunaan hanya seperempat dari ukuran iris penuh untuk mencapai tingkat pengenalan yang sama atau lebih baik dari penggunaan iris ukuran penuh (IUP) atau setengah ukuran penuh (SUP). Simulasi pada database citra iris CASIA-1, menunjukkan bahwa tingkat pengenalan rata-rata dari metode usulan mencapai nilai 67%, lebih tinggi daripada menggunakan SUP, dengan nilai rata-rata pengenalan 56%, atau IUP dengan nilai 53%. Selanjutnya, 100% nilai korelasi dari metode usulan lebih tinggi daripada nilai korelasi menggunakan IUP.

Kata kunci: *biometrik, Korelasi Berbasis Fasa (KBF), pengenalan iris, pencocokan citra, database citra*

Abstract

　　Iris recognition system is one of biometric based recognition/identification systems. Numerous techniques have been implemented to achieve a good recognition rate, including the ones based on Phase Only Correlation (POC). Significant and higher correlation peaks suggest that the system recognizes iris images of the same subject (person), while lower and unsignificant peaks correspond to recognition of those of difference subjects. Current POC methods have not investigated minimum iris point that can be used to achieve higher correlation peaks. This paper proposed a method that used only one-fourth of full normalized iris size to achieve higher (or at least the same) recognition rate. Simulation on CASIA version 1.0 iris image database showed that averaged recognition rate of the proposed method achieved 67%, higher than that of using one-half (56%) and full (53%) iris point. Furthermore, all (100%) POC peak values of the proposed method was higher than that of the method with full iris points.

Keywords*: biometrics, Phase Only Correlation (POC), iris recognition, image matching, image database*

1. Introduction

　　Biometric identification, which uses physiological characteristics of a person, has become an important research field in the last decades. It has been also prevalence due to its high reliability for personal identification. Several characteristics used for identification are fingerprints, footprints, palmprints, palm vein patterns, retinas, irises, facial characteristics, signatures, and vocal qualities [1] - [7]. Among those characteristics, iris is one that facilitates highly security system, in which misidentification rate is 1/1200000 (i.e.: among 1200000 identifications, one identification is false) [8]. Iris identification systems have been applied in access control, national ID card, border crossing, welfare distributions and missing children identification[9].

　　Previously, several iris identification methods have been proposed, which can be classified into two categories: feature based methods (methods need an encoding process) and a non-feature based methods. Featured based algorithms include: the method proposed by Daugman [10] that has become a most successful iris recognition system and the method proposed by Sun, et. al. that based on ordinal measures [9]. However, one problem encounter by feature-based iris recognition systems is that matching performance is highly affected by many parameters in feature extraction process such as spatial position, orientation and centre

frequencies and size parameters for 2D Gabor filter kernel [11]. To solve these problems, several authors proposed to compare transformed iris images in Fourier domain [11], [12], [13]. Specifically, the autors matched only the phase components in 2D DFTs (two-dimensional Discrete Fourier Transforms). The approach is known as phase only correlation (POC).

An extensive research of using POC for iris recognition has been conducted in [11]. Moreover, the authors expanded their research using band-limited phase only correlation (BLPOC), which was able to achieve higher correlation peak. Author in [12] developed a POC-based iris recognition system by proposing an elliptic limited phase-only correlation (EPOC) method. It was reported that the proposed method had better performances than BLPOC for the database used in the experiment. Anand et. al. proposed an iris recognition system based on hierarchical phase-based matching, in which matching processes are accomplished in sub-regions of iris images [13]. A recognition system based on POC should identifies/recognizes subjects/images of the same classes with higher correlation values, which is indicated by a present of a peak (POC peak). Conversely, it should recognize them of different classes with lower correlation values, without any POC peak.

In this paper, we propose an enhancement of an iris recognition system based on POC, by increasing POC peak values. Fortunately, we can achieve higher correlation by reducing iris points included in matching stage. Our contribution is twofold; increasing the POC peak and at the same time reducing iris points incorporated in matching stage. The former can increase matching score and the latter can reduce storage requirement. The method was evaluated using CASIA (Chinese Academy of Science – Institute of Automation) iris image database [14]. Simulation showed that averaged recognition rate of the proposed method achieved 67%, higher than that of using one-half (56%) and full (53%) iris point. Furthermore, all (100%) POC peak values of the proposed method was higher than that of the method with full iris points. The rest of the paper is organized as follows. Section 2 reviews fundamental processes in POC-based iris matching and highlights our approach to improve the work. Results and discussion are given in Section 3. Finally, section 4 provides a conclusion and future direction of the work.

2. Research Method

Figure 1 illustrates the processes accomplished in this research, which can be classified into two stages namely: pre-processing and matching. In pre-processing stage, firstly, iris of querying person is (1) localized and (2) normalized. Then (3) eyelid masking is accomplished on normalized iris. These steps are followed by (4) acquiring one-fourth of iris length. Previous methods either use all iris length [17] or one-half of iris length [11]. The images from the database also experience this pre-processing stage. In the matching stage, both images from the querying person and the database are compared by POC approach, and the POC peak is then calculated.
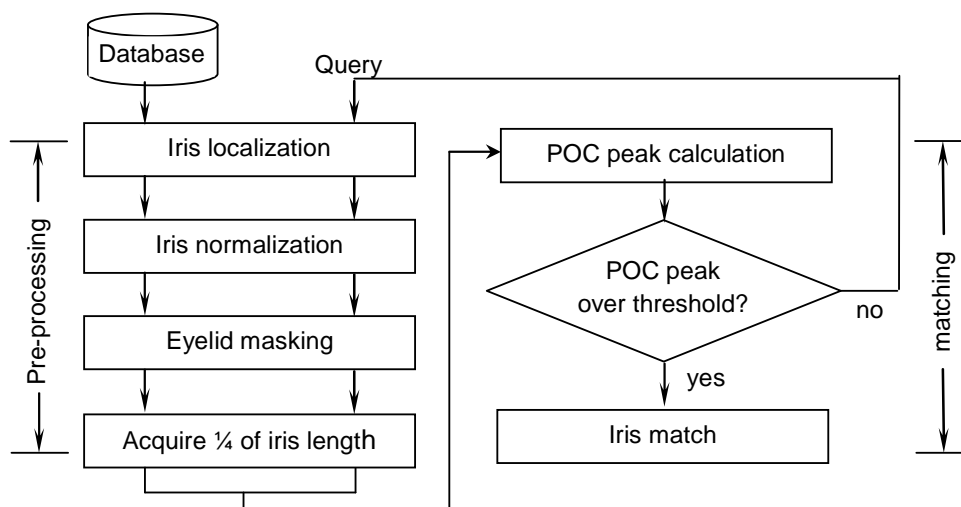

Figure 1. Flow diagram of POC-based iris recognition

If the POC peak is higher than a defined threshold, the querying person is recognized. Otherwise, the querying processes are started all over again.
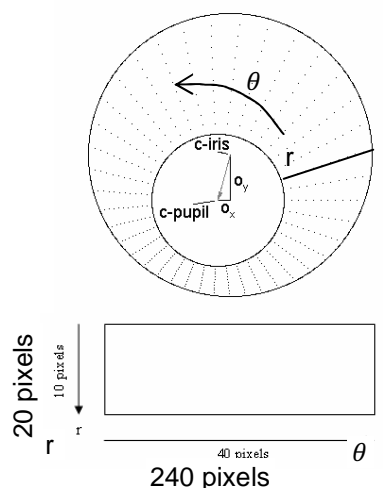
2.1. Pre-processing Stage

Figure 2 (a) 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 2 (a), the circular Hough transform is used to detect circular boundary between sclera and iris (showed by the bigger 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 [10], [15], [16], [17].

Normalisation of iris regions was implemented based on Daugman's rubber sheet model. Figure 2 (b) illustrates the normalisation 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 [17].
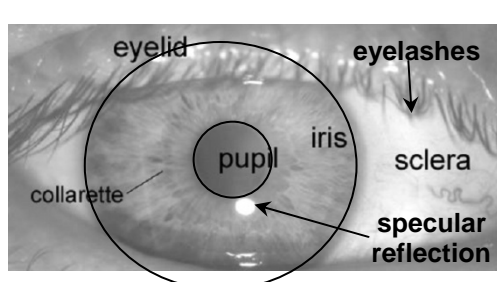
(a). A front-view of the human eye

(b). Iris normalization

Figure 2. Iris localization and iris normalization

2.2. Phase Only Correlation

The fundamental process in the matching stage is correlation of image phase, which is known as Phase Only Correlation (POC). In this section we briefly illustrate of how to use POC in recognition context and then we describe mathematical formula of the POC.

Figure 3 illustrates an interpretation of using the POC in recognition context. There are three possible conditions that are possibly observed, namely: (a) if POC peak value of two images is "1", the first images is a copy of the second one, indicating that the images are from the same person, (b) if POC value of two images is lower than "1", but the POC peak can be observed, the two images may be considered as originated from the same person, (c) if POC peak of two images is does not appear, the two images can be considered as originated from different persons.

Consider two images $f(n_1, n_2)$ and $g(n_1, n_2)$ with size of $N_1 \times N_2$. Index of the image ranges between $0 \leq n_1 \leq N_1$, and $0 \leq n_2 \leq N_2$. The 2D Discrete Fourier Transform (2D-DFT) of the images are denoted by $F_F(k_1, k_2)$ and $G_F(k_1, k_2)$ respectively, in which $0 \leq k_1 \leq N_1$ and

$0 \leq k_2 \leq N_2$. The cross-phase spectrum (or normalized spectrum) $R_F(k_1, k_2)$ of those two images are given by:
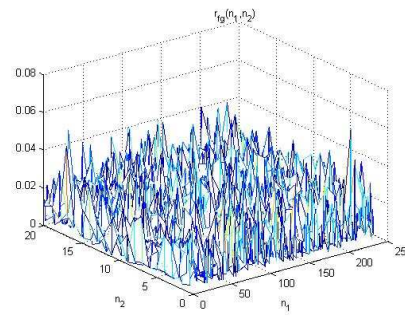
$$R_F(k_1, k_2) = \frac{F_F(k_1,k_2) \cdot \overline{G_F(k_1,k_2)}}{|F_F(k_1,k_2) \cdot \overline{G_F(k_1,k_2)}|} \tag{1}$$
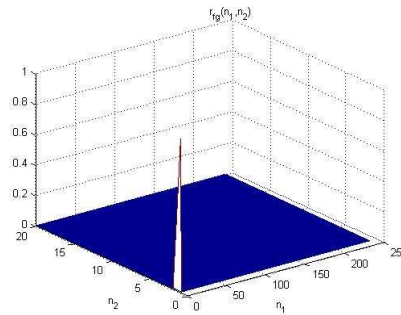
(a). POC peak of copy images
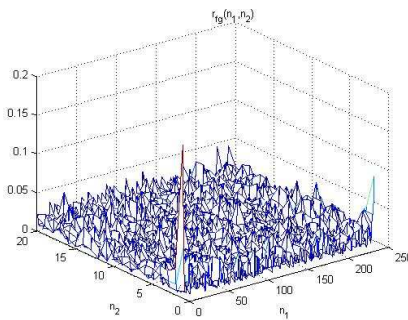
(b). POC peak of the same person   (c). POC peak of different persons

Figure 3. Interpretation of using POC in recognition context

Here, $\overline{X(k_1, k_2)}$ denotes the complex conjugate of $X(k_1, k_2)$.

The POC function $r_F(n_1, n_2)$ is the 2D IDFT of $R_F(k_1, k_2)$ and is given by:

$$r_F(n_1, n_2) = \frac{1}{N_1 \cdot N_2} \sum_{k_1} \sum_{k_2} R_F(k_1, k_2) W_{N_1}^{-k_1 n_1} W_{N_2}^{-k_2 n_2} \tag{2}$$

with

$$W_N = exp(-j2\pi/N) \tag{3}$$

3. Results and Analysis

Result and analysis will be focused on one-fourth circle normalization, half-circle and full circle normalization. The latter were accomplished for comparison purposes. The next sub-sections present simulation conditionss, which consist of: simulation preparation, simulation procedure and evaluation method.

3.1. Simulation Conditions
Simulation Preparation

The iris images were from the CASIA's database version 1.0 that contains 756 images of 108 Asian eyes (each person has 7 images, photographed at different times), each of 320 x 280 pixels. All images were then normalized according to [3] to 20 x 240 pixels.

From the database, 10 iris images from different persons were selected as query images. For convenience, the images from the CASIA's database are renamed: the query images are denoted as *query-1* until *query-10*, and the database images are denoted as *db-1,*

db-2,..., db-756. Furthermore: *query-1-a* correspons to the first query, photographed at time *a.* Query-1-a, query-1-b and query-1-c are called the versions of query-1. In words: if query-1 is an iris image of person "1", then query-1-a, query-1-b and query-1-c are the photographs of iris images of person "1", taken at three different times.

Simulation Procedure

We simulated with full, one-half and one-fourth of iris size that will be referred to as full circle normalization, one-half circle normalization and one-fourth circle normalization respectively. Figure 4(a) is an iris normalized at full scale (20 x 240 pixels). Figure 4 (b) – (g) show area of iris (highlighted by black box) that was used for comparison. We proposed to use only one-fourth of full iris size (20 x 60 pixels). For evaluation, images of full points (20 x 240 pixels) and one-half of full nomalized iris size (20 x 120 pixels) were also used. In subsequent sections, the simulation of querying with the area depicted in Figure 4 (c) is referred to as scheme second one-half. While simulation of querying with the area depicted in Figure 4 (g) is referred to as scheme fourth one-fourth. These terminologies are valid for other iris areas.

Evaluation Method

CASIA's database version 1.0 has 756 iris images from 108 person. It means one person's iris has six other versions in the database (totally seven irides), which are denoted as query-1-a, query-1-b,... and query-1-g. If all versions of an iris are recognized, recognition rate is 100%. At this condition, the POC peak value of all six other versions should be positioned on the highest ranks. Futhermore, POC peak of the proposed method should be higher than that of the previous ones.
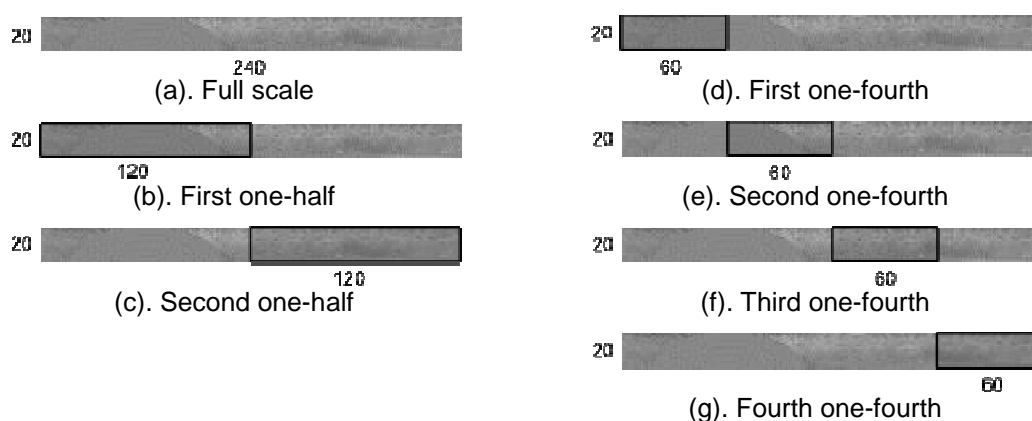

(a). Full scale	(d). First one-fourth
(b). First one-half	(e). Second one-fourth
(c). Second one-half	(f). Third one-fourth
	(g). Fourth one-fourth

Figure 4. Area of irides used for comparison in simulation

3.2. General Results

Table 1 shows results of all querying schemes. Average of recognition rate of full circle normalization, one-half circle normalization (presented by data of second one-half), and one-fourth circle normalization (presented by data of third one-fourth and fourth one-fourth) were the highest, with 53%, 56%, 57% and 51% respectively. To be fair, we will focus on those data in subsequent discussions.

For comfortness, we highlighted Table 1 in three grey-scale gradations, namely white, light-grey, and dark-grey. Lines highlighted by light-grey are querying results in which the proposed scheme was able to achieve the same or higher recognition rate as (than) other schemes. For example, at line nine, the proposed scheme can achieve a 100% recognition rate while scheme second one-half resulted in 86% and full normalization resulted in 86% too.

Furthermore, lines highlighted by dark-grey are querying results in which the proposed method achieved lower recognition rate as compared to other methods. For example, at line four, the proposed method can achieve as high as 43% and 57%, while when using scheme second one-half, recognition rate of 71% was achieved.

All querying results in line number three (highlighted in white) were less than 50%. It means that none of the scheme can achieve a reasonable recognition. Therefore, we inspected the iris image, and it turned out that the normalized iris image is mostly covered by eyelid. Extracted region becomes too small to perform image matching.

Averaging the data from scheme third one-fourth and scheme fourth one-fourth (a higher value between these two approach is selected as representative), resulted in 67% recognition rate. While averaged recognition rate of using one-half circle normalization was 56% and full circle normalization was 53%.

3.3. One-fourth Circle Normalization

Tables 2 (a) – (d) provide the POC peak values of 4 query images when correlated with the images in the database. The correlation values had been sorted from the highest to the lowest ones. There were 756 images in the database, yet for convenience, only POC results of 10 images are shown. POC values of a query's versions were printed in bold. Title of sub-tables are denoted similar to the scheme to partition iris images described in Section 3.1. The data shown in the Table 2 was the best one between scheme third one-fourth and fourth one-fourth from Table 1. For example, for query-1, the data shown were from scheme fourth one-fourth (Figure 4 (g)), while for query-8, the data shown was from scheme third one-fourth (Figure 4 (f)). In this and subsequent sections, the term one-fourth circle normalization refers to the best results between fourth one-fourth and third one-fourth.

In Table 2 (a), (c) and (d), all POC values of query's versions were positioned at the highest ranks (rank 1 to rank 7). While in Table 2 (b) POC values of five versions of query-2 were positioned at the highest ranks. Regardless that the data presented here are the best results from the simulation, it implies that based on one-fourth circle normalization, POC can be used to recognize irides of a person.

3.4. Comparison of One-fourth, One-half and Full Circle Normalization

Table 3 shows the POC results of one-fourth, one-half and full circle normalization. POC values of a query's versions were printed in bold. If the first seven entries are bold, it indicates that that the system can recognize the iris with 100% recognition rate. It is worth to note that for scheme one-half circle normalization the data was derived from the column 'second one-half' in Table 1.

Table 1. Percentage of recognition

No	Query Number	Full	One-half Normalization		One-fourth Normalization			
			First one-half	Second one-half	First one-fourth %	Second one-fourth	Third one-fourth	Fourth one-fourth
1	Query-1	100	57	100	29	71	**86**	**100**
2	Query-2	71	43	57	43	43	**86**	43
3	Query-3	14	14	43	14	14	29	14
4	Query-4	29	29	71	43	14	43	57
5	Query-5	43	43	57	29	14	**71**	57
6	Query-6	57	29	57	14	14	43	43
7	Query-7	29	29	29	14	29	14	14
8	Query-8	86	29	29	29	14	**100**	29
9	Query-9	86	29	86	14	29	**86**	100
10	Query-10	14	14	29	14	14	**14**	57
	Average	**53**	31	**56**	24	18	**57**	51

It can be seen that for query-1, all normalization approaches were able to achieve 100% recognition. For all other queries, one-fourth circle normalization achieve the best results, i.e., 100% recognition rate, except for query-2. Furthemore, all POC values (100%) of scheme one-fourth circle normalization (Table 3 (a)) are higher than those of scheme one-half and full circle normalization. This implies that a higher performance in terms of POC peak values was achieved, using only one-fourth circle normalization of iris images. Using smaller size of quantity for recognition can reduce the storage requirements and can accelarate the matching process.

Table 2. The POC Peak Values of Several Query Images of One-fourth of Normalized Irides

(a). Query-1; Scheme:fourth one-fourth			(b). Query-2; Scheme: third one-fourth		
Rank	Database Image	POC Values	Rank	Database Image	POC Values
1	query-1	**1**	1	Query-2	**1**
2	query-1-e	**0.5466**	2	query-2-c	**0.4360**
3	query-1-g	**0.3011**	3	query-2-e	**0.2682**
4	query-1-d	**0.2933**	4	query-2-b	**0.2676**
5	query-1-c	**0.2629**	5	query-2-d	**0.2404**
6	query-1-f	**0.2583**	6	query-2-f	**0.2142**
7	query-1-d	**0.2410**	7	db-80	0.2126
8	db-530	0.2305	8	db-713	0.2107
9	db-632	0.2027	9	db-588	0.2002
10	db-603	0.1986	10	db-117	0.1992

(c). Query-8; Scheme: third one-fourth			(d). Query-9; Scheme: fourth one-fourth		
Rank	Database Image	POC Values	Rank	Database Image	POC Values
1	query-8	**1**	1	query-9	**1**
2	query-8-g	**0.3063**	2	query-9-f	**0.3440**
3	query-8-e	**0.2763**	3	query-9-e	**0.3105**
4	query-8-b	**0.2544**	4	query-9-g	**0.2929**
5	query-8-d	**0.2407**	5	query-9-b	**0.2525**
6	query-8-e	**0.1963**	6	query-9-a	**0.2370**
7	query-8-c	**0.1949**	7	query-9-c	**0.2010**
8	db-420	0.1915	8	db-255	0.1957
9	db-499	0.1665	9	db-8	0.1889
10	db-368	0.1628	10	db-253	0.1834

Table 3. Comparison of One-fourth, One-half and Full Circle Normalization

(a). One-fourth Circle Normalization

	Query-1	Query-2	Query-8	Query-9
	1	**1**	**1**	**1**
	0.5466	**0.4360**	**0.3063**	**0.3440**
	0.3011	**0.2682**	**0.2763**	**0.3105**
POC Values	**0.2933**	**0.2676**	**0.2544**	**0.2929**
	0.2629	**0.2404**	**0.2407**	**0.2525**
	0.2583	**0.2142**	**0.1963**	**0.2370**
	0.2410	0.2126	**0.1949**	**0.2010**

(b). One-half Circle Normalization

	Query-1	Query-2	Query-8	Query-9
	1	**1**	**1**	**1**
	0.4019	**0.3718**	**0.3355**	**0.3131**
	0.3702	**0.2640**	0.2452	**0.2784**
POC Values	**0.3034**	0.1737	0.2207	**0.2648**
	0.2792	0.1552	0.2106	**0.2602**
	0.2680	**0.1540**	0.2026	**0.1811**
	0.2368	0.1527	0.2010	0.1684

(c). Full Circle Normalization

	Query-1	Query-2	Query-8	Query-9
	1	**1**	**1**	**1**
	0.2655	**0.1816**	**0.1220**	**0.1808**
	0.2519	**0.1394**	**0.1169**	**0.1795**
POC Values	**0.2503**	**0.1359**	**0.1102**	**0.1746**
	0.1937	**0.1075**	**0.1039**	**0.1459**
	0.1690	0.0946	0.0981	**0.1195**
	0.1649	0.0846	**0.0916**	0.1090

3.5. Discussion

Based on the diagram of the proposed method, to recognize an iris of a person, a threshold value is selected. If POC peak of a person under consideration is above the selected threshold, then the person is recognized, otherwise, he is dissapproved. With this assumption, the scheme one-fourth circle normalization outperformed both scheme one-half circle normalization and full normalization, due to its higher POC peak values. Due to the simulation data showed that querying with one-half or full circle normalization resulted in lower POC peak values and considering that when using one-fourth circle normalization the points are reduced

by a-half, we suggest to interchange those two areas (namely third one-fourth and fourth one-fourth) in implementation, to achieve a higher POC peak values.

4. Conclusion

We proposed an enhancement of an iris recognition system based on phase only correlation (POC). Enhancement is achieved by increasing the POC peak of iris images of the same persons. Our contribution is twofold; increasing the POC peak and at the same time reducing iris points incorporated in matching stage to one-fourth of original size. The former can increase matching score and the latter can reduce storage requirement. Simulation on CASIA iris image database showed that averaged recognition rate of the proposed method achieved 67%, higher than that of using one-half (56%) and full (53%) iris point. Furthermore, all (100%) POC peak values of the proposed method were higher than those of the method with full iris points.

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