International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-7 Issue-1, October 2017

Application of Polar Harmonic Transforms in Thumb Impression Recognition

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Abstract: Fingerprint recognition refers to the methods of matching or verifying a known and questioned fingerprint against another fingerprint to ascertain if the impressions are the same. Fingerprints are the most popular biometrics to authenticate a person as it is unique and permanent throughout a person's life. Polar Harmonic Transforms (PHTs) are orthogonal rotation invariant 2D transforms that provide various numerically stable features for fingerprint recognition. The kernel functions of PHTs are basic waves and harmonic in nature that consists sinusoidal functions that are inherently computation intensive that can be used to generate rotation invariant features. PHTs are characterized by low time complexity and numerical stability. In this paper, Polar Harmonic Transforms (PHTs) are introduced for rotation invariance in thumb impression recognition, namely, Polar Complex Exponential Transform (PCET), Polar Cosine Transform (PCT), and Polar Sine Transform (PST). Orthogonal kernels of PHTs are more effective in terms of information compactness and minimal information redundancy. A fast approach of computation of Polar Harmonic Transform for thumb impression recognition with low values of FAR and FRR have been implemented. The accuracy obtained is above 80 percent.

Index Terms: Fingerprint, PCET, PCT, PHT, PST, Rotation Invariant PHT,

I. INTRODUCTION

The increasing of society care to security threat has born new ways to protect software, hardware, building and even network system from outside party attacks. One of the security ways is by using biometric system. Such system use human body which always can be brought and not possible to leave it at home or loss during the trip. The technology becomes a popular identification and verification tool. Biometric fingerprint recognition systems are the most common used biometric technology due to their long tradition. Fingerprint identification systems have been developed for more than hundred years and the identification of person through their unique finger print. The pattern formed when the human still in obstetric.

Digital image or audio capturing such traits are submitted to image processing and pattern recognition techniques to extract computer recognizable features which are used to match them previously stored such information and hence identify or authenticate the persons concerned. Fingerprint recognition has advantages in that the images can be acquired relatively easily, quickly and using low cost equipment and the matching process can also be done efficiently as the images are of small dimensions. Fingerprints are today the most widely used biometric features for personal identification. Fingerprints can be found on practically any solid surface, including the human body. The basic premise of biometric authentication is that everyone is unique and an individual can be identified by his or her physical or behavioural traits. Other areas that are being explored in the quest to improve biometric authentication include brainwave signals, electronic tattoos, and a password pill that contains a microchip powered by the acid present in the stomach. Once swallowed, it creates a unique ID radio signal that can be sensed from outside the skin, turning the entire body into a password. There are number of desirable properties for any chosen biometric system. These include universality, uniqueness, performance, collectability and acceptability [1],[4]. The use of fingerprint recognition has existed as a means of identification for many years. With the advancement of computer technology the problem of automatic finger print identification has attracted wide attention among researchers since 1969 that results in a few state of the art automatic fingerprint identification system (AFIS) available today. Over the next few decades, NIST focused on and led developments in automatic methods of digitizing inked fingerprints and the effects of image compression on image quality, classification, extraction of minutiae and matching. The work at NIST led to the development of the M40 algorithm, the first operational matching algorithm used at the FBI for narrowing the human search [1]. The available fingerprint technology continued to improve and by 1981, five Automated Fingerprint Identification Systems (AFISs) has been deployed [2]. The skin on human fingertips contains ridges and valleys which together forms distinctive patterns. These patterns are fully developed under pregnancy and are permanent throughout a lifetime. Prints of those patterns are called fingerprints (Fig. 1). Each person has his own fingerprints with the permanent uniqueness. So fingerprints have being used for identification and forensic investigation for a long time. The global pattern of ridges and valleys and by the local pattern of bifurcations and endings which are called minutiae determines the uniqueness of a finger print. Finger prints have a long history of use as a means of reliably identifying individuals.

Manuscript published on 30 October 2017.
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Figure 1. A fingerprint image acquired by an Optical Sensor [3].

Fingerprints can be divided into three major patterns viz. arches, loops and whorls. These major pattern types can be dividing further into different subgroups as right, left or twin, plain or tended arches and spiral or concentric circles as whorls. Fig. 2 shows the different types of fingerprint with their images. In addition, when a fingerprint pattern is analysed at different scales, it exhibits different types of features. Normally the fingerprints are classified as Whorl, arch and loop.

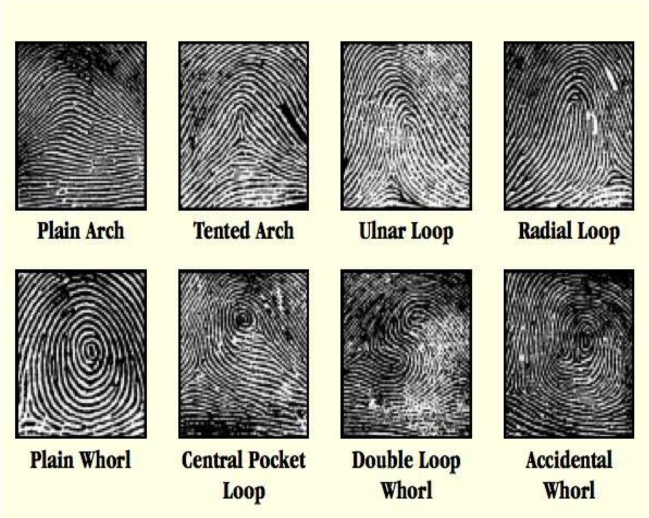

Figure 2. Different types of fingerprint patterns

Finger print recognition (referred to as dactyloscopy) is the process of verifying or matching a questioned and known fingerprint against another fingerprint to ascertain if the impressions are the same [5]. Based on fingerprint distinctiveness, persistence and ease of acquisition, it is one of the most important biometric technologies [7]. It is one of the most important biometric techniques based on fingerprints persistence, ease of acquisition and distinctiveness. It includes two sub-domains: fingerprint verification and fingerprint identification (Fig. 3).

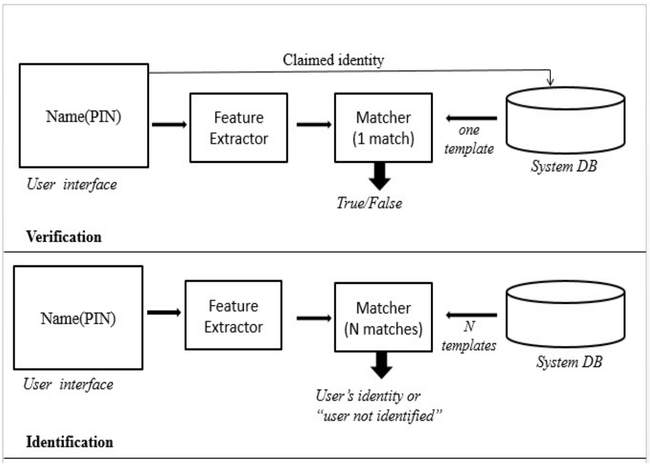

Figure 3. Verification vs Identification.

In the verification mode, an individual provides his/her biometric data and claims an identity, usually via a PIN (Personnel Identification Number), a user name, a smart card, etc. The system the verifies the individual's identity by comparing the acquired biometric data with the individual's own biometric template(s) stored in the system database. Such a system basically performs a one-to-one comparison to determine whether a claimed identity is true or not [5][7].

In the identification mode, the system compares the given biometric data with the templates of all the users in the database. Therefore, the system conducts a one to-many comparison to establish an individual's identity (or fails if the subject is not enrolled in the system database) without the subject having to claim an identity. However, the underlying principles of a fingerprint recognition and matching remain the same in all fingerprint recognition problems, either verification (one-to-one matching) or identification (one-to-many matching). Fingerprint identification is today the most widely used biometric identification among all biometric techniques [6].

Fingerprints have been found on ancient artefacts recovered from excavation sites of various civilizations [9]. However fingerprints have been used for identification only from nineteenth century onwards. A time-line of important events that has established the foundation of the modern fingerprint based biometric technology can be found in [10]. Henry Fauld [11] has first scientifically suggested the individuality and uniqueness of fingerprints. Sir Francis Galton has published the well-known book entitled Fingerprints [12], in which a statistical model of fingerprint analysis and identification has been discussed. An important advance in finger print identification has been made by Edward Henry, who has established a system known as 'Henry system' for fingerprint classification [13].

One of the main issue in fingerprint recognition that when the images are rotated at different angles the system is not able to match the fingerprint with the rotated fingerprint. Even when both the fingerprints are the same because when the image is rotated, the location of its features also get changed.

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This does not provide data authentication. So, the research objective of this paper is to propose an algorithm using Polar Harmonic Transforms (PHTs) which helps in recognizing the fingerprint at any of the angles rotated. Section 2 presents the proposed finger print recognition system based on the Polar Harmonic Transforms. Section 3 presents the results and evaluations of the proposed approach. Finally, we conclude the research work in section 4.

II. PROPOSED METHOD

The proposed scheme is based on the Polar Harmonic Transforms (PHT). Any one image from the database is taken as the training image. Then, it is cropped into a circle to reduce the number of pixels for a large image. The circle is generally formed to remove its edge so that we can move the image at any angle during the training session and during the testing session. On applying PHT algorithm, it extracts the features of the image. After this, a testing image is taken from the database. The image is rotated at desired angle and PHT algorithm is applied. Now, Euclidean distance is calculated between the training and the testing images. Then, the system shows if the fingerprint is matched. The False Acceptance Rate (FAR) and False Rejection Rate (FRR) is also calculated. Lower the FAR and FRR values, more accurate is the result.

In the proposed method, the input involves images both the training and the testing images from the database. These images are gray scale fingerprint images of a person, which has intensity values ranging from 0 to 255. The feature extracted from the trained image is the image itself as the method used is image based fingerprint matching system where the feature is the entire image considered. The image is trained using Polar Harmonic Transform so that it becomes rotation invariant i.e., the data does not get lost in rotation at different angles. The type of learning used is Unsupervised learning as there is not teacher signal or the desired output.

The first step in the development of an algorithm for fingerprint recognition is the selection of useful pixel or blockfeatures. Extracting a set of distinguishable features is critical for fingerprint identification. Many studies rely on more robust features representing the global or local ridge patterns in fingerprints [8]. The term feature is used to refer properties of individual pixels. However, for an image based fingerprint matching, a feature refers to properties of the entire (foreground) image. Here, the region of interest is the entire image. The proposed method uses Image based fingerprint matching scheme where the entire fingerprint gray scale image is enhanced using histogram equalization and then the enhanced image is taken as the feature i.e., the global feature of the image.

Polar Harmonic Transforms (PHTs) are a set of 2D transforms which are based on a set of orthogonal projection bases, to generate a set of features which are invariant to rotation [4]. It represent a set of transforms whose kernels are basic waves and harmonic in nature. PHTs consists of three different transforms, namely, Polar Complex Exponential Transform (PCET), Polar Cosine Transform (PCT) and Polar Sine Transform (PST). They have identical mathematical representation with a difference in the radial part of the kernel function. The PHTs are characterized by low-time complexity and numerical instability. The kernel functions of PHTs are orthogonal.

The block diagram of the proposed method is shown in Fig. 4. Firstly, in the training section, get a training image from the fingerprint database and crop it into a circle. Circle is formed for removing edges so that during the testing session and the training session, the image can be rotated at any angle. Then, extract features based on image based fingerprint matching system to extract features. In this method, the feature is the entire image so, it is a global feature. After this, apply PHT to the feature extracted to train the system. In the testing section, get a testing image from the database. Then, rotate the image at desired angle and apply PHT. Now calculate the Euclidean Distance between the two images. Then, show if the fingerprint is matched.

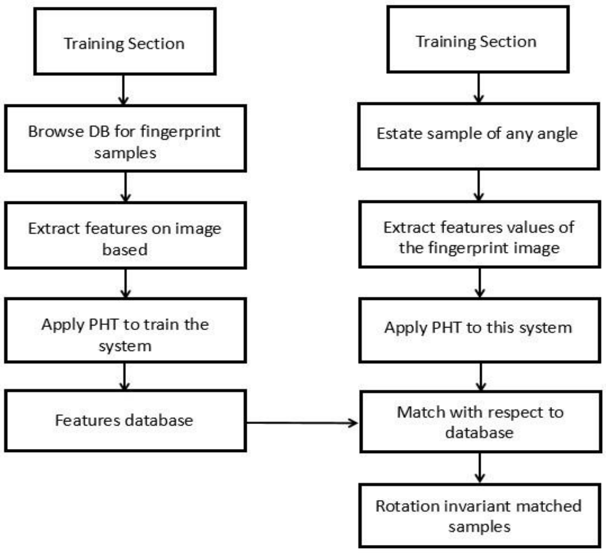

Figure 4. Block diagram of the proposed algorithm.

III. EXPERIMENTAL RESULTS

The evaluation and testing of the proposed approach has been done on CASIA database. This database consists of 100 different fingerprint images. The fingerprint samples are scanned with an optical sensor and have the actual region of interest i.e., the full fingerprint image. The sample images from this database are shown in Fig. 5.

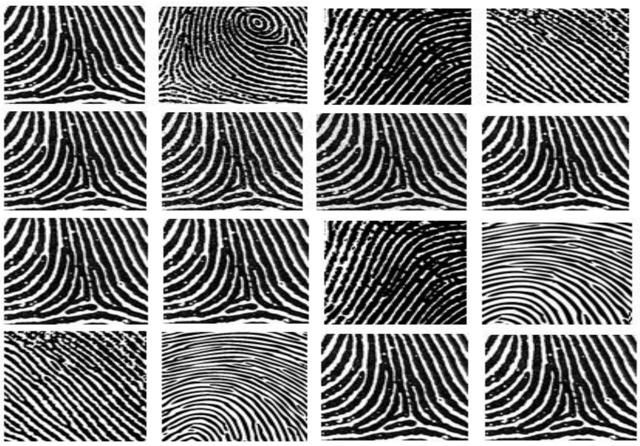

Figure 5. Image samples form database.

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Table 1. Parameter Results of PHT Applied on Test Images with Training Image 4.

Angels of rotation	Parameters									
	Euclidean Distance (ED)								FAR	FRR
	ED_1	ED_2	ED_3	ED_4	ED_5	ED_6	ED_7	ED_8		
10	50.46	0.35	337.64	0.44	51.79	49.49	54.80	52.67	1.6	0.4
20	49.05	1.32	336.93	1.14	51.35	49.40	53.82	50.02	2	0
30	51.61	2.12	330.13	1.14	52.50	50.64	55.41	53.38	2	0
40	51	1.23	333.66	6.36	52.23	50.91	56.74	51.97	2	0
50	51.97	0.17	338.96	3.35	52.76	50.55	55.77	52.94	1.9	0.1
60	48.61	1.32	339.41	2.38	51.61	48.34	53.38	51	2	0
70	49.67	1.85	341.17	2.82	51.97	49.05	53.65	51.88	2	0
80	48.79	1.50	339.85	3.182	50.55	47.99	53.56	50.02	2	0
90	50.82	0	340	0.53	51.70	50.29	55.68	53.20	1.6	0.4
100	50.11	0.35	341	3.62	51.79	48.96	54.88	50.73	1.9	0.1
110	49.05	0.70	343.12	5.65	50.64	48.87	54.35	49.67	1.9	0.1
120	50.46	1.06	338.96	0.26	52.41	50.11	54.62	52.76	1.7	0.3
130	51.26	2.38	341.09	0.70	52.50	51.88	56.12	51.97	1.7	0.3
140	52.59	0.44	339.32	1.50	52.32	52.41	57.54	53.20	1.9	0.1
150	50.38	0.61	337.55	2.47	53.32	47.99	53.65	52.32	1.9	0.1
160	50.64	1.32	340.03	0.44	52.50	49.32	54.71	51.79	1.7	0.3
170	51.17	3.09	338.43	1.94	52.76	51.53	55.06	52.59	2	0
180	50.29	1.50	344.62	1.67	52.41	48.26	54.27	51.53	2	0

From an image database, each test image is rotated by various angles and is matched against the original image to compute the False Rejection Rate [5], [7]. So, False Rejection Rate (FRR) is the ratio of the number of false rejections divided by the number of identification attempts. FRR is also known as False NonMatch Rate or Type I error. FRR is the fraction of genuine fingerprints which are rejected.

$$FRR = \frac{Number\ of\ genuine\ fingerprints\ rejected}{Total\ number\ of\ genuine\ tests}$$

Again from an image database, each test image is rotated by various angles and is matched against the original image to compute the False Acceptance Rate [5], [7]. So, False Acceptance Rate (FAR) is the ratio of the number of false acceptances divided by the number of identification attempts. FAR is also known as NonMatch Rate or Type II error. The FAR is the fraction of imposter fingerprints which are accepted.

$$FAR = \frac{Number\ of\ imposter\ fingerprints\ accepted}{Total\ number\ of\ imposter\ tests}$$

FAR and FRR are very much dependent on the biometric factor that is used and on the technical implementation of the biometric solution. Furthermore, the FRR is strongly person dependent, a personal FRR can be determined for each individual. Also, FRR might increase due to environmental conditions or incorrect use, for example when using dirty fingers on a finger print reader. Mostly the FRR lowers when a user gains more experience in how to use the biometric device or software. FAR and FRR are key metrics for biometric solutions for, some biometric devices or software even allow to tune them so that the system more quickly matches or rejects.

Three indexes are well accepted to determine the performance of a finger print recognition system. So, in the experiment, each sample in the database is matched against the remaining samples of the fingerprint images to compute the Euclidean distance, False Acceptance Rate(FAR) and False Rejection Rate(FRR).The main stage of the system is fingerprint identification from the database samples and the performance of this system is evaluated using the above-explained parameters.

From the database images, only one image is considered the training image with testing images being hundred. The training image is matched with the hundred testing images. Fig. 6 shows that, for a training image number 4, with the angle of rotation 100, the number of matched images are 19 and non-matched images are 81. Fig. 7 shows FAR and FRR for test images for training image 4 at rotation angle of 100. From the parameters calculated (Table 1) for the testing images at different angles of rotation, Table 2 shows the angle of rotation with the accuracy for some of the angles. The accuracy shown in Fig. 8 is high and different for different angles of rotation and the training image.

Table 2. Performance in presence of rotation for training image 4.

Angle of Rotation	Accuracy in %age
10	95
90	95
100	86.66
120	86.66

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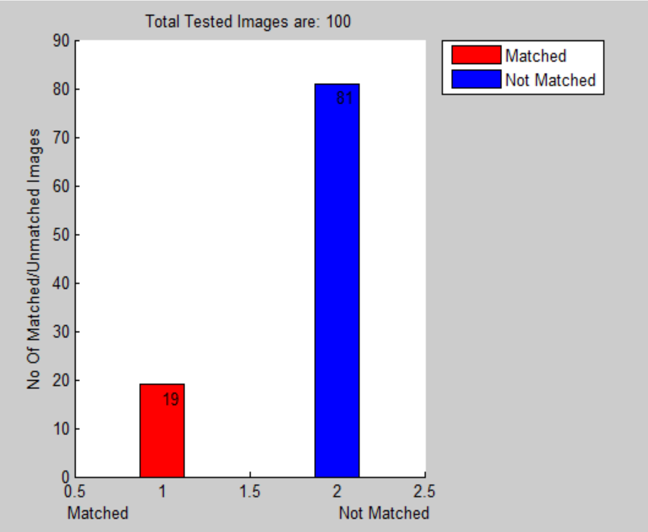

Figure 6. Matched and Unmatched Image score distribution for training image 4 at rotation angle of 100.

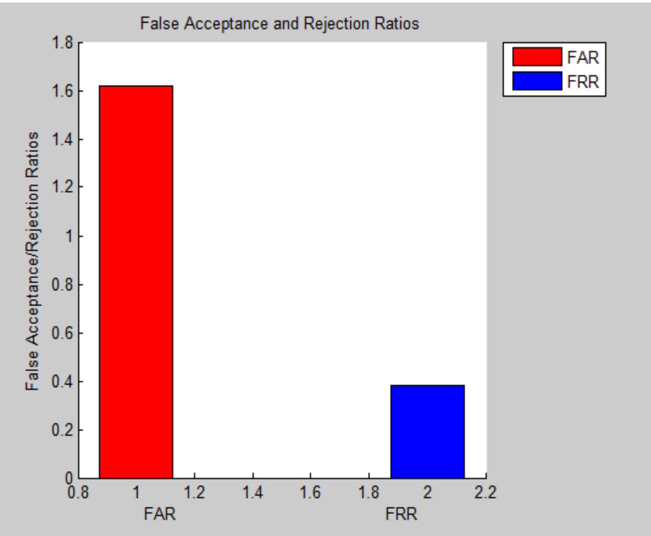

Figure 7. FAR and FRR for test images for training image 4 at rotation angle of 100.

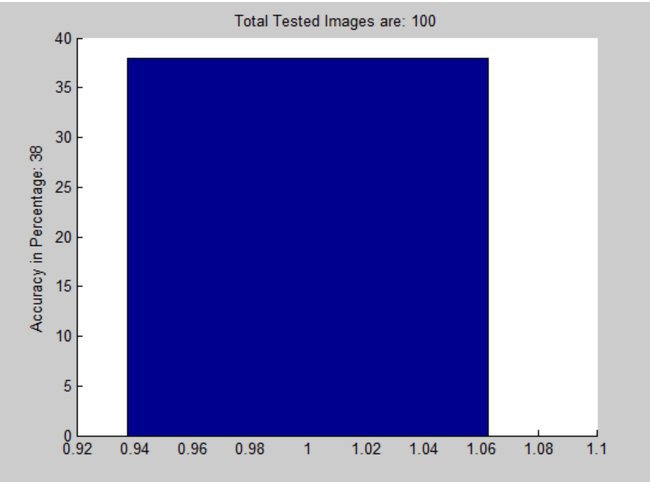

Figure 8. Graph shows the accuracy percentage of matched images for training image 4 at rotation angle 100.

IV. CONCLUSION

A new fingerprint recognition system which uses an image as the feature has been proposed in this paper. A set of Polar Harmonic Transforms (PHTs), namely, Polar Cosine Exponential Transform, Polar Cosine Transform, and Polar Sine Transform, have been proposed to generate rotation invariant features for fingerprint identification. The kernel function of PHTs consists of a sinusoidal function that is inherently computation intensive which is used to generate rotation invariant features. Polar Harmonic Transforms are very fast and efficient, providing high performance based on the number of finger prints present in the database. The result obtained shows both matched and unmatched images of the database system irrespective of the angle of rotation both with low values of FAR and FRR which shows that the probability of errors is the least. A large set of database images are tested with training images and at various angles of rotation and the images are matched based on the Euclidean distance. The accuracy of matched images for different images at different angle is above 80 percent.

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