Palmprint verification and identification using pyramidal HOG feature and fast tree based matching

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Abstract

In this paper, a palmprint identification and verification approach based on Pyramidal Histograms of Oriented Gradients (PHOG) and fast tree based matching is presented. In the feature extraction stage, proposed local histograms of oriented gradient are extracted in each level or scale of the Gaussian pyramid of the palmprint. This matter helps to extract high contrast and reliable lines. In the identification stage, features of the query palmprint are extracted and identified by matching against the training database palmprints or templates with tree based matching. The tree based matching makes verification and identification fast. The proposed method is evaluated by experiments on Hong Kong PolyU palmprint database. The experimental results show that the proposed method achieves a high performance according to identification and verification rate, over 99.85% accuracy, and high identification speed, which takes less than 2 seconds.

1. Introduction

The technology of human identification using biological features is known as biometrics. Biometric information is used in various applications in security systems. Hand based personal identification is one of the areas of biometric technology. Palmprint recognition is a distinct kind of hand based biometric technology for person verification and identification and has received interest in the area of research because of its several unique advantages such as low resolution imaging and low cost capture device, stability of the palmprint characteristics, namely lines and textures, fast operation, high accuracy and so forth. Extraction of reliable features and coding them are extremely challenging tasks for palmprint identification. The uniqueness of a palmprint can be inferred by proper features. There are many features in palmprint images used for personal identification. Principal lines of palmprint like life and heart lines are used in [1, 2]. Morphological operator in [1] and Radon transform in [2, 3] are used to extract principal lines. The principal lines are not sufficient enough features, since different people may have similar principal lines [4]. Texture features can be achieved by Gabor filter [4], wavelet [5, 6 and 7] and Fourier transform [8]. The texture feature expands the computation [2] and cannot extract local information of palmprints according to other palmprint lines. In some existing works, multiple features are used for hand based identification. Extremely small features are used for fingerprint identification tasks [9, 10, and 11]. This is not useful for palmprint identification because of the low resolution images of the palm. However, it is used with other features, referred to as multiple features for palmprint identification. In multiple features, minutiae and principal lines [12], a palmprint is coded by mixed features. Palmprint and middle finger [13], palmprint and finger knuckle print [14] are proposed for hand based identification.

In this paper, Pyramidal Histograms of Oriented Gradient (PHOG) is proposed as a reliable feature in palmprint recognition. The PHOG feature is based on HOG that is described in [15] for object detection tasks. This is a very robust feature in facing illumination changing and is useful to search local information about the object. Gaussian pyramid is mixed by HOG to extract information of the palmprint according to the strength and length of the lines. In verification tasks, a palmprint is identified by matching it against all others in the database. In the identification process, the identity of a query image is determined by searching the most similar sample from all the templates existing in the database. The identification process will be time consuming if the large numbers of templates (more than 10000) are collected as templates. For example, in a security system, the identification process with 5 templates in each class, takes more than 20 seconds. There are certain methods in the searching process such as reference subset [16], cover tree [17] and tree searching [18] that makes the identification process much faster.

The proposed searching process in this paper is similar to

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the presented method in [18]. In the proposed method, a query palmprint is identified by searching the most similar template in a database containing multiple templates per subject. The nearest palmprint template feature to the mean of the templates' features is selected as the root and others are selected as leafs. This tree increases the speed of the identification process.

The rest of the paper is organized as follows: In the second section, the proposed feature for palmprint verification and identification will be presented. Section 3 involves tree based matching method that makes the identification process faster. The proposed method will be evaluated by various experiments in section 4. Moreover, the proposed PHOG feature will be used in verification and identification processes along with the examination of the required time for identification using the proposed tree matching method which will be evaluated by two kinds of experiments. In section 5 conclusions will be presented.

2. Feature extraction

Palm contains many lines. They are found in principal or robust lines with high contrast or strength with great enough lengths and weak lines with low strength and short lengths. All kinds of the lines are located in palms with special orientations, lengths and strengths which are unique in each person. The state of the art features such as Gabor [4] and wavelet [6] extract the lines and code them without any respect to the kinds of lines. By principal line extraction [2] weak lines will be removed and some information of the palmprint cannot be extracted. Hence, in this paper pyramidal histograms of oriented gradient (PHOG) feature are proposed to extract rich information about the local strength of all kinds of lines according to their orientations in all the palmprint locations.

2.1. HOG feature

Histograms of Oriented Gradient (HOG) is represented in [15] for object detection tasks. HOG feature extracts textural properties of the object. The gradients magnitude and edges directions can describe the local object appearances. The HOG feature can be achieved by the processes mentioned below:

a. Gradient operator is implemented in two vertical and horizontal directions to extract gradient of the image. Furthermore, the edges in these two directions and the magnitude of the gradient and orientation in each pixel in the range of [0^o-180^o] of the image are extracted as well. The gradient operator on image *I*, gradient magnitude and orientation are formulated as below:

$$G_x = \frac{\partial I}{\partial x} \qquad G_y = \frac{\partial I}{\partial y} \tag{1}$$

$$Magnitude = \sqrt{G_x^2 + G_y^2} \tag{2}$$

$$Orientation = \frac{180}{\pi}\left(tan^{-1}\left(\frac{G_y}{G_x}\right) + \frac{\pi}{2}\right) \tag{3}$$

The image is divided in cells of size 6×6 pixels without any overlap. Gradient orientations in cells are settled in 9 bins of 20^o wide. The magnitudes of pixels in each orientation bin are collected. The amount of each bin indicates to the magnitude of the gradient in the orientation in the range of the bin.

b. To overcome illumination and contrast variations, the gradient magnitude must be locally normalized. For this reason every 9 cells, (3 cells × 3 cells), group together to create a block. Blocks have overlapped together. The amounts of bins in each block are measured and are used to normalize all cells values within the block. The HOG feature is extracted from every cell in a block.

The described feature is invariance to geometric and illumination transformation because it operates on local region by localized cells.

2.2. Gaussian pyramid

Gaussian Pyramid creates images in several levels of scales. The size or scale of the image in each level is half of the scale in the previous scale. The image in fine and coarse levels of the pyramid contains with the detailed and large information of the image respectively. The HOG operator was used in [19] in two levels of pyramid to capture whole object and object parts. The HOG feature at the coarse level of Gaussian pyramid captures tall and high strength lines with histograms over fairly large area of the coarse level gradient image and at the fine level captures short and low strength lines with histograms over small area of the fine level gradient image.

2.3. Pyramidal HOG

In this paper, the pyramidal HOG (PHOG) feature is presented in palmprint recognition task. All the feature extraction process is calculated on Region Of Interest (ROI) of palmprint. The ROI extraction will be presented in section 4. The PHOG feature is extracted by the process described below:

a. The Gaussian pyramid of the ROI image of the palmprint is created in 3 levels of scales 1, 0.5 and 0.25 in the sizes of 128×128, 64×64 and 32×32. The 128×128 image size is the original size of the ROI image and fine level of the pyramid. The gradient operator (equation 1) is used in each level to extract gradient of the image in two sides of x and y.
b. The gradient images are up sampled in to the fine level size. The Histograms of the oriented gradient are extracted from up sampled images. Therefore, three HOG features are extracted at the same sizes.
c. All 3 HOG features are added together. The resulting

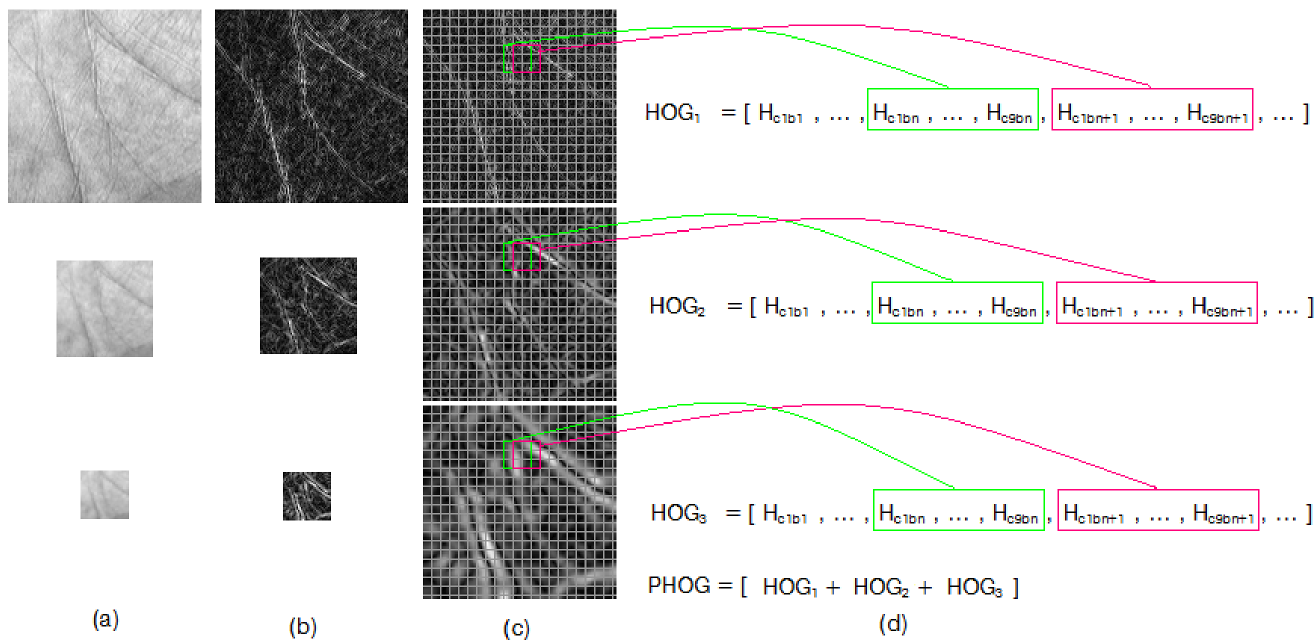


Figure 1: Feature extraction process. (a) 3 Level Gaussian pyramid of a palmprint ROI, (b) gradient magnitudes in each level, (c) cells and blocks in levels of the pyramid over gradient magnitude. Green and magenta squares are two blocks with 6/9 overlap, 9 cells are exist in each block, (d) Pyramidal Histograms of Oriented Gradient. Green and magenta rectangles include sequences of HOG features extracted from the green and magenta blocks in (c). PHOG is evaluated by adding PHOGs of 3 levels of the pyramid.

matrix is PHOG feature. By the manner that is mentioned, the values of the PHOG histograms are related carefully to the importance (strengths and lengths) of palmprint lines.

Figure 1 illustrates the process of the proposed PHOG feature extraction. The result PHOG matrix is reformed as a sequence. As the Figure 1 shows, at the coarse level of the pyramid, high contrast and tall length lines are extracted but at the fine level low contrast or weak lines can be found.

3. Fast tree based matching

A query palmprint is identified by searching within all the templates in training database. It is necessary to speed up the search process when a moderate or large identification system is applied [18].

A tree based algorithm is proposed in this paper for searching the nearest template in the database to the query image. Suppose that 5 images in each class of database are selected for training. The PHOG features of them are extracted. The tree is created by the algorithm described below:

a. The mean of the 5 features values is evaluated in each class.
b. The distances of 5 features values from the mean are computed by Euclidian distance. The Euclidian distance is formulated as below:

$$d = \sqrt{\sum_{i=1}^{N} (F_{q_i} - F_{t_i})^2} \quad (4)$$

In the above equation, N is the total number of bins of PHOG feature, F_{q_i} and F_{t_i} is the i^{th} value of the query and training image features respectively. Minimum and maximum distances are achieved. The image and correspondence feature with the minimum distance is selected as root. The other images in the class are selected as leafs.

c. The maximum distance is selected as $d_{\max}$ parameter of the class.
d. In matching process, the distances of the query image feature with root feature of all the classes (d_c) are evaluated using Euclidian distance and the current minimum distance is selected ($d_{\min}$).

$$d_{min} = \min\,(d_1, d_2, \dots, d_c, \dots) \quad (5)$$

e. The distances of query image feature from leafs features in a class are evaluated if the below condition is satisfied:

$$|d_c - d_{min}| \le d_{min} \quad (6)$$

In the above equation, d_c is the distance of the query feature to the root feature of the current class. During the

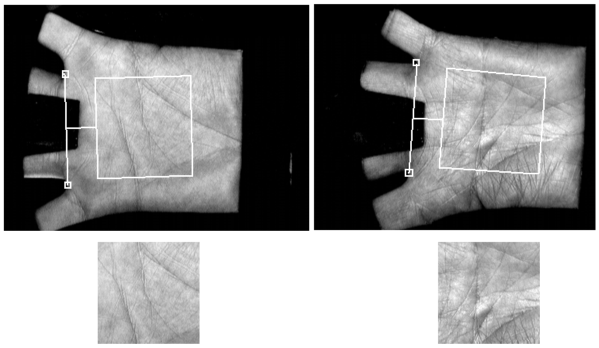


Figure 2: Two samples of PolyU palmprint database [20] and their ROI.

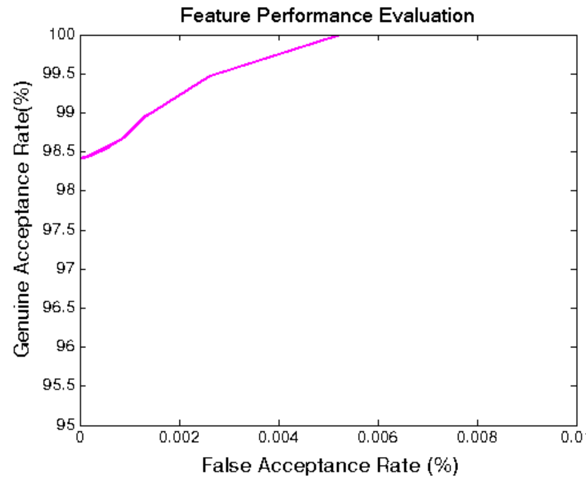


Figure 3: ROC curve of Feature Performance Evaluation. 100% Genuine Acceptance Rate was achieved in 0.005% False Acceptance Rate.

search process between leafs, the d_{min} will be updated if new minimum distance is obtained. The query image is recognized as the class with the d_{min}.

By the proposed process, if the condition is not satisfied none of the leaf features are compared to the query feature. Therefore, the query image is not compared against all of the images in database, and then the identification time is reduced.

4. Experimental results

The performance of the proposed method is evaluated by experiments on PolyU palmprint database [20]. This database is collected by Biometric Research Center at the Hong Kong Polytechnic University. The database contains 7752 images in 386 classes of palms. There are 19 to 21 samples in each class. Each class has two kinds of palmprints that are collected in two sessions of scan. Two kinds of palmprints are collected in about two month differences and are different in illumination. All the palmprints are 75 dpi and gray scale. The Region of interest (ROI) in 128×128 pixels size is extracted from palmprints and is used for experiments. Figure 2 shows two samples of two classes and their ROI. ROI is extracted by the procedure that is presented in [4]. The discussed procedure in [4] for ROI extraction is divided as below:

a. A Gaussian filter is applied to the original image and a binary image is extracted using a threshold.
b. The gaps boundaries between fingers are found using boundary tracking algorithm.
c. The tangent between two gaps (m) is obtained if two points (F_1x_j, F_1y_j) and (F_2x_j, F_2y_j) satisfy the quality $F_iy_j = m.F_ix_j + c$.
d. The line between two points is set as y axis. The line perpendicular to this line passing between two fingers determines the origin of the coordinate system. A sub image in size of 128×128 is extracted as ROI. Figure 2 shows two ROI of the palmprints.

The 3 experiments are done for evaluation the proposed feature and matching procedure in identification. A Score factor is defined to describe a better the performance. It is calculated as the equation below:

$$Score = \frac{1}{d} \times 1000 \quad (7)$$

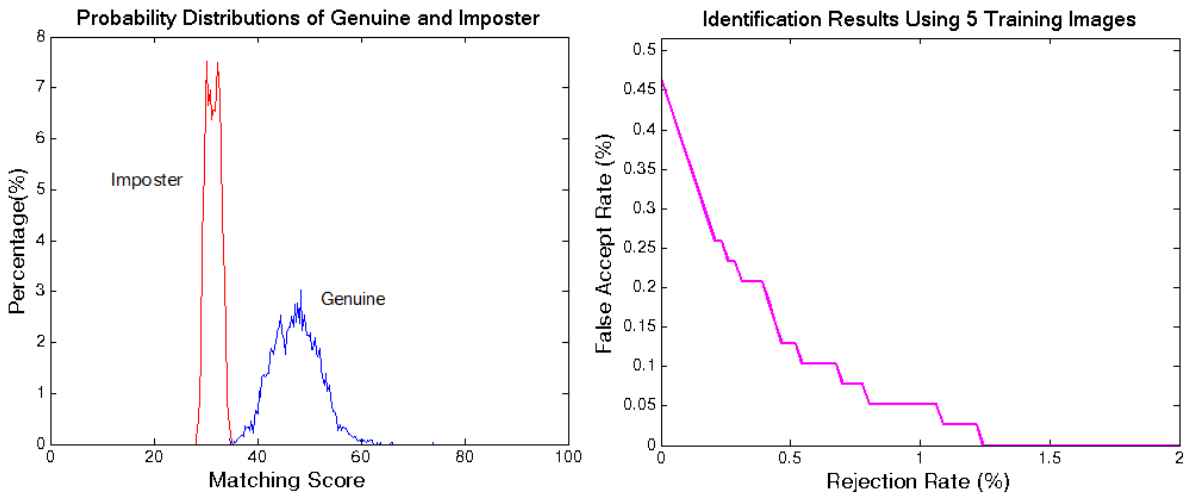
In the above equation, d is the Euclidean distance between two features sequences. The higher value for Score is accrued in the most similar feature sequences. The implemented system used MATLAB with non optimized programming code by a Pentium IV laptop with 2.5 GHz CPU. The feature extraction takes 1second.

4.1. Feature performance evaluation

One to one feature matching is used to evaluate the power of the proposed PHOG feature in palmprint verification. For this reason, each palmprint in the database is matched against the others at all of the classes. Therefore the total number of matching is 30,042,876. If a palmprint is matched against the others at the same class, it is counted as positive otherwise as negative. Figure 3 shows ROC curve, which is plots Genuine Acceptance Rate in percent against False Acceptance Rate in percent. As indicates in Figure 3, the proposed feature is very powerful for palmprint verification. The 100% Genuine Acceptance Rate is achieved in 0.005% False Acceptance Rate.

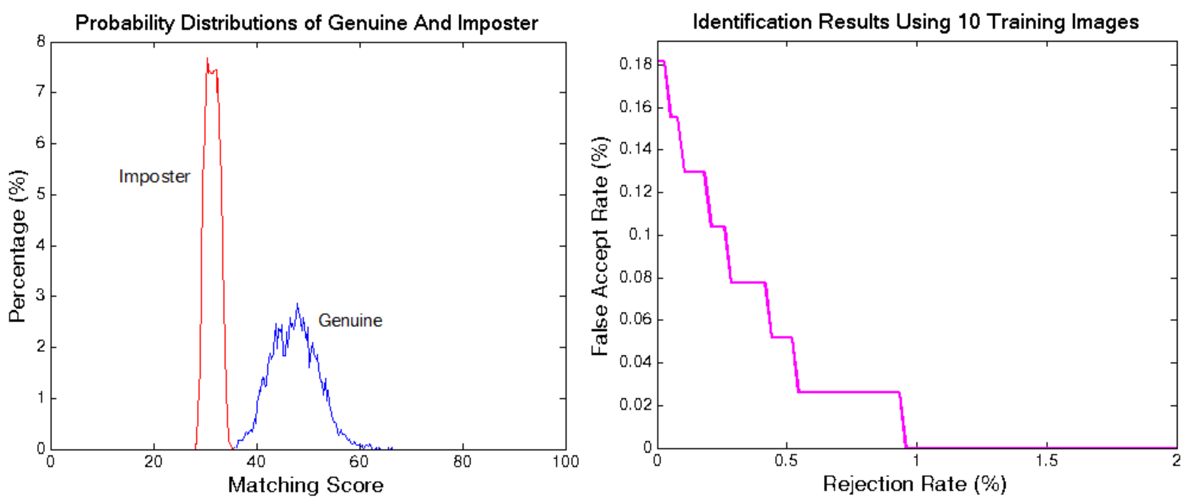
4.2. Identification using 5 training images

In this case, 5 images from the first session of palmprints in each class are selected as the training samples and the second session images are used as the test. The tree based matching and identification process takes only about 0.6 second and it further takes 1.6 second respectively for each



(a) (b)

Figure 4: (a) Genuine and Imposter distributions extracted and (b) ROC plot of experiments with 5 training images.



(a) (b)

Figure 5: (a) Genuine and Imposter distributions extracted and (b) ROC plot of experiments with 10 training images.

test palmprint. Figure 4(a) shows the Genuine and Imposter distributions of this type of the experiment. Figure 4(b) shows ROC plot, False Acceptance Rate in percent against Rejection Rate in percent. As the plot indicates, 100% accuracy will be achieved if the 1.25% of the test database images is rejected. In other words, the accuracy of 99.545% is achieved. Table 1 shows the accuracy rate and time of the identification process with 5 training images.

4.3. Identification using 10 training images

The performance of the proposed method is evaluated by selecting 10 training images from the first session. The second session in each class is used for testing. The identification process (feature extraction and tree based matching) for one test image takes less than 2 seconds. The Genuine and Imposter distributions are illustrated in Figure 5(a). Figure 5(b) shows the ROC plot, False Acceptance Rate in percent against Rejection Rate in percent.

It can be inferred from the plot that the accuracy of 100% will be achieved if 0.9% of the test images are rejected and the accuracy of the proposed system is 99.815. The accuracy rate and time of the identification process with 10 training images are shown in Table 1.

Table 1: Accuracy and time for identification experiment

Method	**5 Training Images**	**10 Training Images**
Accuracy Rate (%)	99.545%	99.815%
Time	1.6 s	2 s

5. Conclusion

In this paper, Pyramidal Histograms of the Oriented Gradient (PHOG) are proposed for palmprint verification and identification. This is a novel feature in palmprint verification and identification tasks that is composed of HOG and Gaussian pyramid. The proposed feature is very robust regarding illumination changes that are considered usual difficulties in palmprints and are very powerful to extract palmprint information by extracting weak and robust lines.

The need for a new matching process is unavoidable when a large database is used for identification. Consequently, in this paper a new tree based matching process was represented to speed up the identification process. To achieve a better accuracy, multiple features can be used for the future researches. Multiple features can help to compensate the weakness of a single feature in some situations.

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