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Comparative Performance Evaluation of FFT-PCA Human Palmprint Identification

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Abstract:

The paper aims towards development of FFT-PCA Human Palmprint Identification Application using MATLAB which is tested on three different databases available for palmprint recognition. Also the comparisons of the tested results are made for achieving accuracy and efficiency for its versatility of operation over a global population. The testing on CASIA Palmprint Database Dataset1 resulted in a % accuracy performance of 98.125%. The IIT Delhi Database results show a slightly lower % accuracy performance of 94.375%. The Hong Kong PolyU Database has testing shows slightly higher % accuracy performance of 96.25% than IITD Palmprint Database and slightly lower % accuracy than CASIA Palmprint Database. The FFT-PCA palmprint recognition application shows considerably better performance when tested on CASIA Palmprint Database (Dataset1) and PolyU Palmprint Database (Dataset3) than IITD Database (Dataset3) with %accuracy deficit rate of 3.75% and 1.875 respectively.

Keywords — **FFT, PCA, Palmprint, MATLAB, CASIA, IITD, PolyU**

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I. INTRODUCTION

This Palm lines are also known as “lines of fate”. The palm lines are formed in the budding or embryonic phase of the baby which is in the third month of fetal development inside mother’s womb. The baby folds the palm for long period. The skin is so sensitive at this stage the lines are formed. Palmprint has various main features like principal lines, wrinkles, and creases.

Palmprint image is mainly divided into three regions like finger-root region, an inner region and root region as shown in Fig. 1. Automatic palmprint identification systems can be classified into two categories: online and offline. An online system captures palmprint images using a palmprint capture sensor that is directly connected to a computer for real-time processing. An offline palmprint identification system usually processes previously captured palmprint images, which are often obtained from inked palmprints that were digitized by a digital scanner. In the past few years, some researchers have worked on offline palmprint images and have obtained useful results.

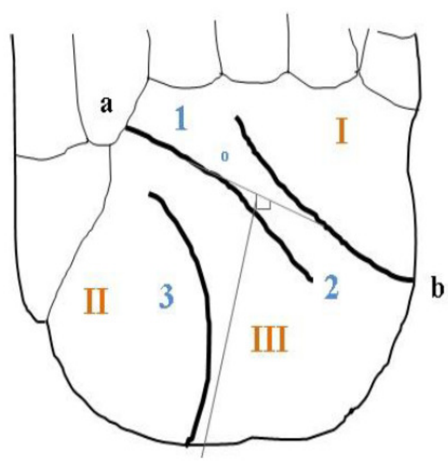

Fig. 1 Formation of Palmprint Regions and Lines [1]

The widespread use of information technology in our daily lives demands reliable, stable and user friendly mechanism to authenticate individuals. Personal authentication using palmprint has emerged as a promising biometric approach. However, most of the multi-biometrics approaches impose burden on capturing hardware, computation, and cost. Palmprint images with an abundance of features such as principal lines, wrinkles, ridges and minutiae provide good discriminating ability for accurate authentication. The palmprint provides large quantity of information and have many advantages. It deals with more~ stable physical characteristics and hence more stable biometric. It is mostly an acceptable biometric due to its permanence and uniqueness. Even identical twins have different principle lines, wrinkles, minutiae, datum point features and texture images. The basic advantages of using palmprint as a promising biometric are:

1. High distinctiveness
2. Permanence
3. High performance
4. Non-intrusiveness
5. Low-resolution imaging
6. User-friendliness
7. Low price palmprint devices
8. High stability

However, the palmprint has a serious disadvantage also. The palmprint may undergo changes depending on the type of work the person is doing over a long duration of time.

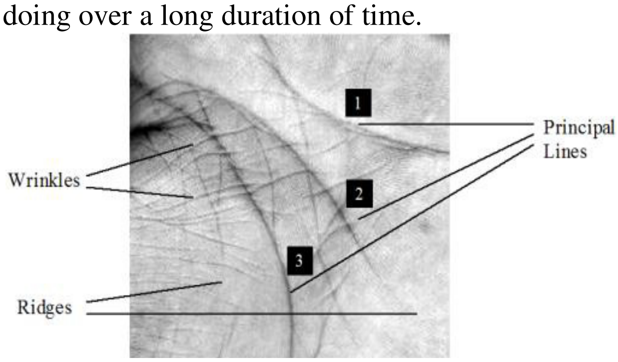

Fig. 2 Palmprint Principal Features [2]

A palmprint basically shows certain skin pattern of a palm, composed of many physical characteristics like lines, points, and texture of the skin. The palmprint epidermis may be as thick as 0.8 mm comparing to other part of our body which is 0.07 to 0.12 mm thick. In response to continuous pressure and friction after birth, the epidermis gradually becomes thicker. Palm in general contains three flexion creases which are genetically dependent (Fig. 2):

(i) Permanent creases (principal lines)
(ii) Secondary creases (wrinkles)
(iii) Ridges

Palmprint identification is divided into two categories: off-line and online. In online palmprint verification system, palm images are captured directly from the sensor/scanner or from database. The images are sent to the computer for real-time processing. Presently the focus is on off-line palmprint authentication system where palm images are inked and digitized through an image scanner. Palmprint authentication system is used in various fields of intelligence like forensic, banks, criminal, military applications, education institutions and attendance etc. Palmprint is a unique and reliable biometric characteristic with high usability. Palmprint images are distinctive for reliable human identification, which makes a competitive topic in biometric research. Relatively biometric feature has several advantages compared with other currently available features. Palmprint contains more information than a fingerprint, so they are more distinctive; palmprint capture devices are much cheaper than iris devices; palmprint can be extracted from low-resolution images. Highly accurate biometrics system can be built by combining all features of palm geometry, ridge, valley features and principle lines, etc. This makes palmprint recognition much more challenging than another traditional method of identification. Palm vein information can symbolize the liveliness of an object. It can be difficult to be modified as an internal feature. Similarly, it simulates using a fake palm. Because of these features, hand and palm vein seems a better biometric technique compared with other biometrics like fingerprint and face. Furthermore, palm vein is considered as the inner features of the body, it can't be fabricated, palm vein recognition is contactless and its characteristics are long-lasting. Palmprint, the inner surface of our palm normally contains three flexion creases, secondary creases and ridges. The flexion and secondary creases are also called principal lines and wrinkles, respectively. The flexion creases and the main creases are formed between the 3rd and 5th months after conception and superficial lines appear after birth. These creases are not genetically deterministic. Even identical twins who share the same DNA sequences have different palmprints. These non- genetically deterministic and complex patterns have rich information for personal identification. There are two types of palmprint recognition research, high resolution and low resolution approaches. High resolution approach employs high resolution images while low resolution approach employs low resolution images. High resolution approach is suitable for forensic applications such as criminal detection, while low resolution is more suitable for civil and commercial applications such as access control. Generally speaking, high resolution refers to 400 dpi or more and low resolution refers to 150 dpi or less. Figure below illustrates a part of a high resolution palmprint image and a low resolution palmprint image.

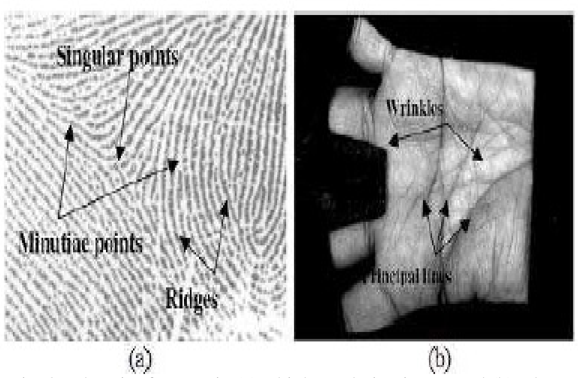

Fig. 3 Palmprint features in (a) a high resolution image and (b) a low resolution image [2]

In high resolution images, researchers can extract ridges, singular points and minutia points as features while in low resolution images, they generally use principal lines, wrinkles and texture. At the beginning of palmprint research, the high-resolution approach was the focus but almost all current research is focused on the low resolution approach because of the potential applications. A palmprint recognition system generally consists of five parts: palmprint scanner, preprocessing, feature extraction, matcher and a database. Palmprint scanner is to collect palmprint images. Preprocessing is to setup a coordinate system to align palmprint images and to segment a part of palmprint image for feature extraction. Feature extraction is to obtain effective features from the preprocessed palmprints. Finally, a matcher compares two palmprint features. All the images, templates generated are stored in a local or remote database [2].

II. LITERATURE REVIEW

Abdu Gumaei et al. proposed that multispectral palmprint recognition system (MPRS) is an essential technology for effective human identification and verification tasks. To improve the accuracy and performance of MPRS, a novel approach based on auto-encoder (AE) and regularized extreme learning machine (RELM) is proposed. The proposed approach is intended to make the recognition faster by reducing the number of palmprint features without degrading the accuracy of classifier [5].

Ali Mouad et al. published the methods to extract the Region of Interest (ROI) of palmprint image by using appropriate methods and to improve the accuracy of palmprint recognition system. This work illustrates Methods/Statistical Analysis which is primarily addressing the different mechanisms for extracting ROI area. The techniques like Competitive Hand Valley Detection (CHVD), and Euclidean Distance (ED) were applied as the part of pre-processing, while the Feature Extraction mechanism LBP was utilized to extract the texture feature from different type of ROIs of palmprint image [6].

I. Rida et al. proposed a simple and effective ensemble learning method for palmprint identification based on Random Subspace Sampling (RSS). To achieve it, system relies on 2D-PCA to build the random subspaces. As 2D-PCA is an unsupervised technique, features are extracted in each subspace using 2D-LDA. A simple 1-Nearest

Neighbor classifier is associated to each subspace, the final decision rule being obtained by majority voting rule [7].

Ashish Kumar Malviya publishes that main goal of edge detection algorithm is to produce a line and extract important features and reduce the amount of data in the image. Edge detection is one of the most important steps in image processing. There are some techniques for edge detection such as Sobel, Preweitt, Roberts, LOG, and Canny. But it has some limitations like fixed edge thickness and parameter like threshold is difficult to implement. The fuzzy rule based technique does not have such limitation, as we can change the edge thickness simply by the changing the rules and output parameters [8].

Khushi Diccar provides the basic idea about palm print recognition using OpenCV libraries, principal component analysis (PCA) algorithm and Beagleboard XM: DM3730 platform, OpenCV library is having rich functionality for image processing [9].

Dexing Zhong et al. present a comprehensive overview of recent research progress of palmprint recognition as well as the basic background knowledge for it. In addition, it mainly focuses on data acquisition, database, preprocessing, feature extraction, matching and fusion. Ultimately, they discuss the challenges and future perspectives in palmprint recognition for further works [10].

Deepali Koul uses PCA, Gabor Filter and KNN for the aim of classification and matching. The work show palm print authentication system operates in 2 ways in which first is enrolment and the second is verification [11].

III. METHODOLOGY

The processing level includes image acquisition level, feature extraction level, match score level and decision level. The basic level of processing is same for all the biometric system. The complexity lies in the implementation of processing using different approaches and methods. A biometric system which uses a palm print of a person for authentication/verification is shown in figure below.

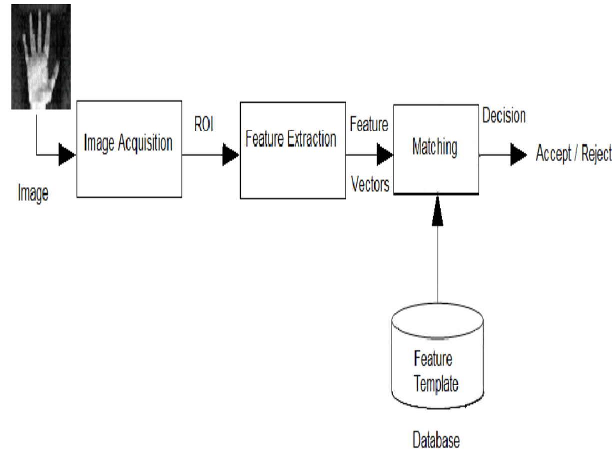

Fig. 4: Palmprint Recognition System: Processing Stages

Stage/Level 1: Palmprint Image Acquisition Level: It is the first step in any biometric system where the image of palm is captured for person identification. In this system the palmprint image source is from a readily available palmprint databases like CASIA Palmprint Database, PolyU Palmprint Database and IIT Delhi Palmprint Database.

Stage/Level 2: Palmprint Image Pre-processing Level: Palm images acquired are pre-processed to extract its features. The principal lines are significant and minutiae and textures are used as unique information in forensic .The pre-processing steps involve converting the image to binary, extracting the region of interest and segmenting, key point detection and establishing the coordinating system. Extracting the region of interest is carried out using many methods. Centre of palm is used as region of interest in many methods as it covers most of the palm features and has unique texture for each person. To extract the centre of palm image first it has to be aligned and oriented to crop the centre portion. In key point extraction the valley points from middle finger, ring finger, little finger and the line joining these are taken as orientation and a centre portion of palm image is found and a circular or a squared portion of defined size is cropped.

Stage/Level 3: Palmprint Image Feature Extraction using FFT-PCA: In image processing feature extraction is generally applied on two domains, namely spatial domain and frequency domain. For the spatial domain, features are directly extracted from the subject. However, for the frequency domain, the image should first be converted from spatial to frequency domain and then spectral features can be extracted The approaches used are of two types: one for verification and the other for identification. Line based, sub-space based and statistical based are used for verification of palm features from the stored templates. Some approaches are also combined and are used to extract palm features. Classifiers are used to make a final decision.

Algorithm for Palmprint Feature Extraction using Fourier Transform - Principal Component Analysis (FFT-PCA): Principle component analysis is a statistical method that is used in the field of pattern recognition and/or image compression. PCA is a good technique for converting high dimensional data to low dimensional representation that is useful for finding patterns within input data. PCA is also a powerful technique for data compression since; it can reduce the number of dimensions significantly, particularly for high dimensional images. Basic steps for feature extraction from 2D images are as follows:

Step 1: Select and Read the Images: In the first stage, palmprint images are taken from a dataset of L images. Each image has two dimensions which are N and M. Then the images are converted into a vector shape.

Step 2: Calculating Mean Center of Dataset: In this stage, the mean of the input dataset is calculated.

Step 3: Subtracting Mean from the Vectors: In this stage, the calculated mean is subtracted from each image in the dataset. The goal of this operation is to remove constant component and deal with the maximum directions of in variance in the database.

Step 4: Compute the Covariance Matrix: Following the mean-subtracted dataset, the covariance matrix C is calculated.

Step 5: Computation Eigenvalues and Eigenvectors of the Covariance Matrix Eigenvectors of the covariance matrix are computed to find the principal bases of variation. Since the covariance is typically square, eigenvectors and eigenvalues can be computed from $CV = \lambda V$, the solution of which can be obtained using the factorization of equation. The diagonal matrix λ keeps the eigenvalues and V is the matrix of corresponding eigenvectors. If the dimensions of C are PxP, this procedure computes P eigenvalues and the same number of eigenvectors, one for each eigenvalues.

Step 6: Sort the Eigenvectors in Decreasing Order of their Eigenvalues: Eigenvectors are sorted in decreasing order of their eigenvalues.

Step 7: Determining Principal Components: After sorting the eigenvalues, eigenvectors corresponding to the highest eigenvalues represent principal components of the dataset. Simply, a number, K, of eigenvectors corresponding to the largest eigenvalues are considered C to build the projection matrix of PCA.

Step 8: FFT- Principal Component Enhancement from Spatial to Frequency Domain: In this palmprint recognition, Fast Fourier Transform can be used in feature extraction as there exists few correspondences between palmprint features on a spatial domain image and those on a frequency domain image. In general, the stronger the creases are on a spatial domain image, the less compact the information is on a frequency domain image. And if a palmprint image in the spatial domain has a strong line, in the frequency domain there will be more information in the line perpendicular direction. In this palmprint recognition system, as feature extraction is conducted in the frequency domain, it is important that similar palmprints resemble each other when converted into frequency images.

Stage/Level 4: Matching and Decision Making: Features extracted are stored in the database as templates. Each template is unique and has salient features of the image under consideration. When the query image is processed for verification / authentication, the features are compared with the stored template using matching techniques. Match scores are estimated using a threshold and final decision is taken to accept /reject the query image. Euclidean Distance is used to compare the feature vectors.

IV. RESULTS AND DISCUSSIONS

The application tested on a total of 480 images combined from the three databases and results are recorded and compared for performance analysis of FFT-PCA technique for one-to-many (1: N) matching criteria and one-to-one (1:1) matching criteria.

TABLE I
PALMPRINT IMAGE DATASETS

Dataset	File Format	No. of Classes	Images per Class	Total Images per Dataset	Total Ear Images
Dataset1 CASIA Palmprint Database	.jpg (Grayscale)	10	16	160	480
Dataset2 IITD Palmprint Database	.jpg (Color)	16	10	160	
Dataset3 PolyU Palmprint Database	.bmp (Grayscale)	08	20	160	

The performance analysis is based on the parameters like %Accuracy, %Error, Accurate, In-accurate matches and Euclidean Distance. The feature extraction output from CASIA Palmprint Database, PolyU Segmented Database and IIT-Delhi (IITD) Palmprint Database are shown below.

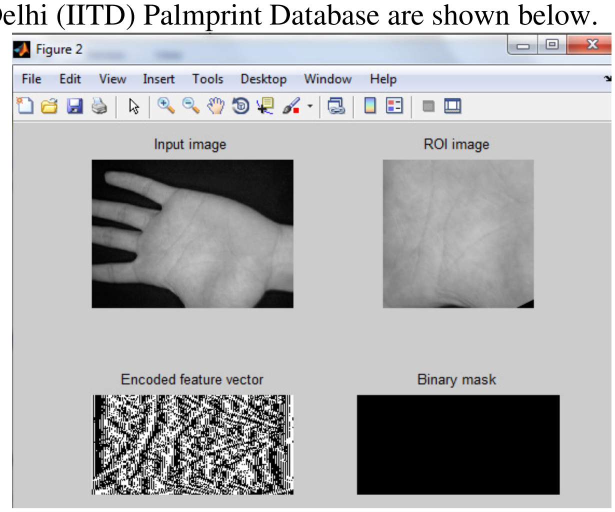

Fig.5 CASIA Palmprint Database (Datset1): Palmprint Feature Extraction

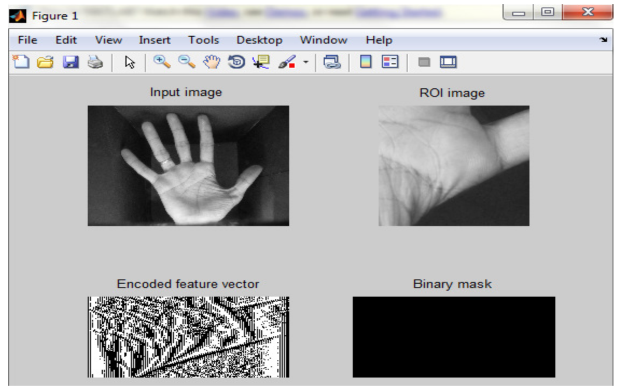

Fig.6 IIT Delhi Palmprint Database (Datset2): Palmprint Feature Extraction

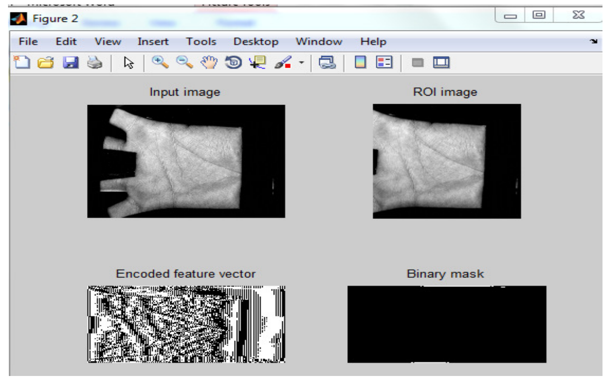

Fig.7 Hong Kong PolyU Segmented Palmprint Database (Datset3): Palmprint Feature Extraction

The ED Values are calculated and recorded for 160 images of CASIA Palmprint Database, IIT Delhi Database and Hong Kong PolyU Palmprint Database.

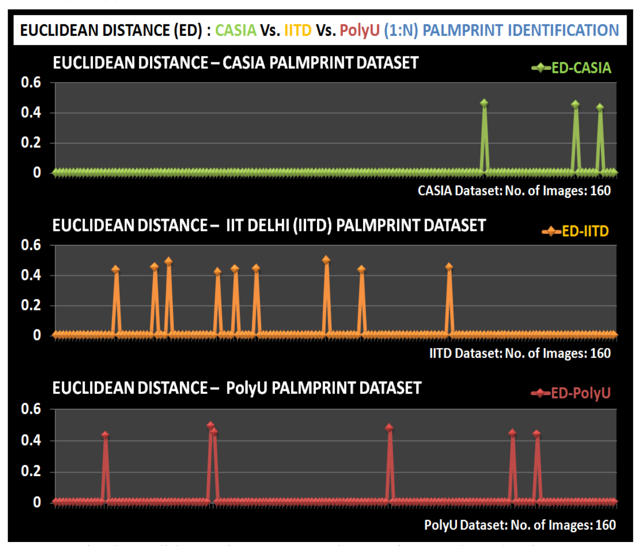

Fig. 8 Euclidean Distance (ED) Comparison and Evaluation

The % accuracy on the basis of number of imaged matched is calculated and show in the graph.

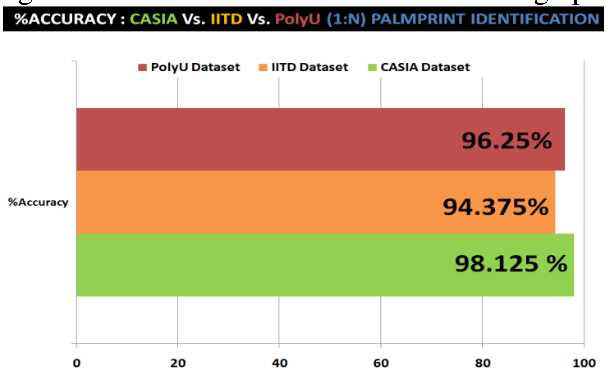

Fig. 9 Performance Comparison and Evaluation (%Accuracy)

The % error on the basis of number of imaged matched is calculated and show in the graph.

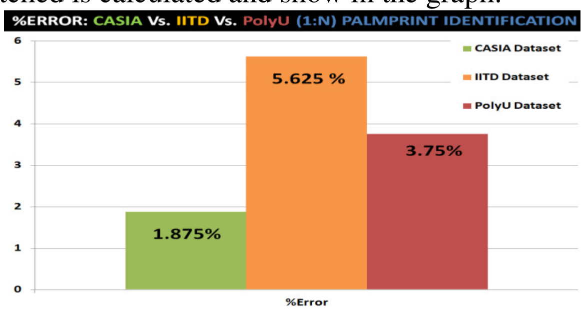

Fig. 10 Performance Comparison and Evaluation (% Error)

The CASIA Palmprint Database Dataset1 has 157 accurate image class matches out of 160 and 03 inaccurate matches. The IIT Delhi Database has 151 accurate image class matches out of 160 and 09 inaccurate matches. The Hong Kong PolyU Database has 154 accurate image class matches out of 160 and 06 inaccurate matches.

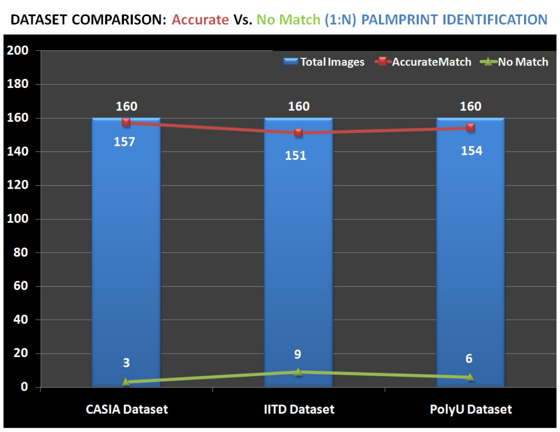

Fig. 11 Performance Comparison and Evaluation (Accurate Vs. Inaccurate Matches)

The CASIA Palmprint Database Dataset1 has 48 accurate image class matches out of 48 and zero inaccurate matches. The IIT Delhi Database has only 10 accurate image class matches out of 48 and 38 inaccurate matches. The Hong Kong PolyU Database has 48 accurate image class matches out of 48 and zero inaccurate matches.

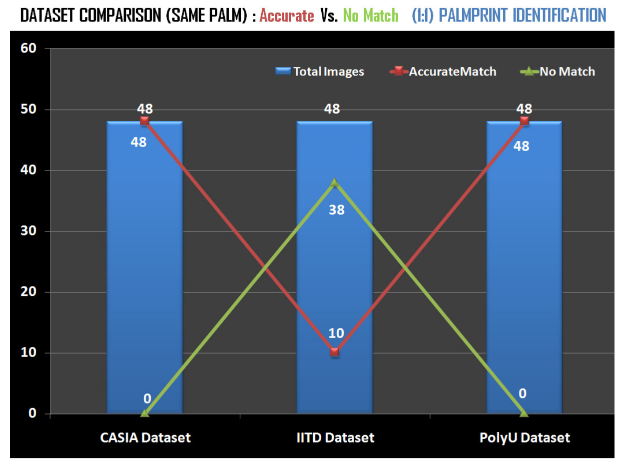

Fig. 12 Performance Comparison and Evaluation (Accurate Vs. Inaccurate Matches) (1:1 Matching)

The CASIA Palmprint Database Dataset1 has 48 accurate image class matches out of 48 and zero inaccurate matches with 100% accuracy and zero error. The IIT Delhi Database has only 10 accurate image class matches out of 48 and 38 inaccurate matches with %accuracy of 20.8% and %error of 79.1%. The Hong Kong PolyU Database has 48 accurate image class matches out of 48 and zero inaccurate matches with 100% accuracy and zero error.

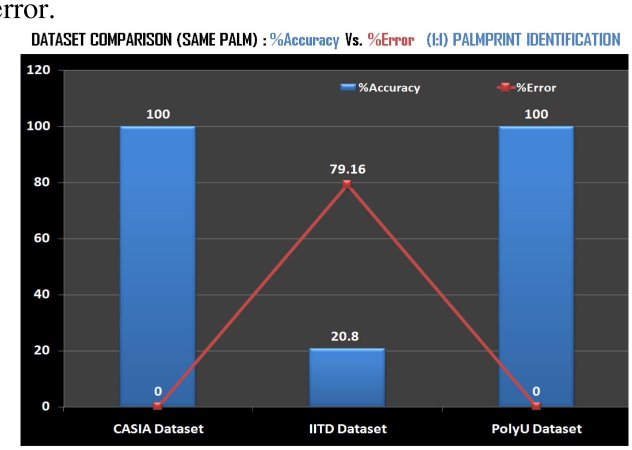

Fig. 13 Performance Comparison and Evaluation (%Accuracy & %Error) (1:1 Matching)

V. CONCLUSION

The CASIA Palmprint Database Dataset1 has 157 correct image class matches out of 160 leading to a high % accuracy performance of 98.125%. The IIT Delhi Database has 151 correct image class matches out of 160 leading to a slightly lower % accuracy performance of 94.375%. The Hong Kong PolyU Database has 154 correct image class matches out of 160 leading to a slightly higher % accuracy performance of 96.25% than IITD Palmprint Database and slightly lower % accuracy than CASIA Palmprint Database. The FFT-PCA palmprint recognition application shows considerably better performance when tested on CASIA Palmprint Database (Dataset1) and PolyU Palmprint Database (Dataset3) than IITD Database (Dataset3) with %accuracy deficit rate of 3.75% and 1.875 respectively. CASIA Palmprint Database Dataset1 has 03 incorrect image class matches out of 160 leading to a low % error performance of 1.875%. The IIT Delhi Database has 09 incorrect image class matches out of 160 leading to a slightly higher %error performance of 5.625%. The Hong Kong PolyU Database has 06 incorrect image class matches out of 160 leading to a slightly lower % error performance of 3.75% than IITD Palmprint Database and slightly higher % accuracy than CASIA Palmprint Database.

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