Int. j. inf. tecnol. (December 2020) 12:1281–1289
https://doi.org/10.1007/s41870-018-0230-0

ORIGINAL RESEARCH

Performance analysis of biometric recognition system based on palmprint

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Received: 19 May 2017 / Accepted: 23 July 2018 / Published online: 27 July 2018

Abstract Nowadays biometric authentication is one of the most preferred choice and in that also palmprint is becoming the most widely accepted technique because it can be captured easily and the algorithms can be implemented with ease. Detection of coarse lines in palm images is easy to the point that these lines can be revealed even by using a low determination camera. The integration of palmprint recognition with some other biometric recognition system does not require any special capture devices, so it can be done easily. Hence, this method suites best for individual verification. This research work is related to palmprint recognition in which the main aim is related to software based performance analysis of classifiers. The entire work is divided into three major phases namely palmprint pre-processing, feature extraction and accuracy estimation. Different functions and operators related to binarization, morphology and other operations are used for pre-processing; similarly feature extraction is carried out by using Frangi filter, Freak descriptor and FAST algorithm. After the final feature extraction procedure, classifiers are used to predict the accuracy in identifying right and wrong features for a given subject. This research work uses two classifiers namely discriminant analysis and K-nearest neighbor algorithm (KNN) where discriminant analysis shows 77% accuracy and KNN gives a better accuracy of 93%.

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Keywords Discriminant analysis · FAST algorithm · Frangi filter · Freak descriptor · KNN

Abbreviations

CLAHE	Contrast limited adaptive histogram equalization
CASIA	Chinese Academy of Sciences
DFT	Discrete Fourier transform
FAST	Features from accelerated segment test
FREAK	Fast retina keypoint
ID	Identification
KNN	K-nearest neighbor algorithm
ROI	Region of interest

1 Introduction

Biometrics refers to the programmed ID of a person with the utilization of one amongst different kinds of physiological attributes. The application with which a great many people utilize biometrics is security. Various biometric attributes are being created and are utilized for the validation of an individual's personality. The idea is to utilize uncommon attributes of a person to recognize him/her. Uncommon attributes for example, iris, face, signature, and so forth are being utilized in biometrics [1]. A biometric framework is an example acknowledgment framework which makes an individual ID by deciding the authenticity of a particular physiological or behavioral trademark controlled by the user. A biometric framework can be either an ID framework or a verification framework (authentication system), which is characterized as:

Identification One to Many: Biometrics can be utilized to decide a person's identity without his being aware of that.

Verification One to One: Biometrics can likewise be utilized for validation and authentication.

Biometric verification requires contrasting of a registered biometric test against a recently caught biometric test. This is a three-stage method (capture, handle, enroll) trailed by an identification (distinguishing proof) or a verification process. The determination of a specific biometric for an application includes a few components. A portion of the variables are: Universality implying that each individual must have that characteristic; Uniqueness implying that the attribute must be adequately unique among the people keeping in mind the end goal to recognize them from each other among a set of populace; Lastingness that identifies the way in which attribute changes after some time and Quantifiability that identifies the simplicity of securing or estimation of that attribute. Likewise the procured information must be in the shape that permits preparing and extraction of the applicable capabilities. Performance, another important variable relates to the precision, speed and heartiness of innovation utilized. Acceptability that relates to how well the individual recognizes the development to such a degree, to the point that they will have their characteristic or a feature captured and accessed is also a key variable used in biometrics [2]. Among the different biometric advances being viewed as the traits that meet the above qualities are fingerprints, facial highlights, hand geometry, voice, iris, palmprints and signature [3, 4].

A biometric framework can be arranged into two modules—(1) database preparation module and (2) confirmation or verification Module. The database preparation module includes two sub-modules: (a) enroll module and (b) training module while the other module, confirmation module can be partitioned into two modules: (a) coordinating module and (b) decision module.

Among the distinctive biometric characteristics, palmprint recognition is being explored over the past 10 years as a valuable biometric methodology. Palmprint is the inward piece of a person's hand. For a considerable length of time, the palm line designs have tremendously been recognized to be able to foresee a person's future. Regardless, its uniqueness and limit with respect to recognizing people has come to fore correspondingly beginning late. Palmprint is comparatively one of the reliable approaches since it possesses a bigger number of elements than that of the other methodologies, for example, principal lines, minutiae, orientation, singular points and so forth. Likewise palmprint methodology is extraordinary for every individual, in addition to being widespread. Palmprint recognition is used as a piece of regular applications, law necessity and various such applications where access control is compulsory [5].

Palm incorporates different components like geometric features, principal lines features, delta point's features, minutiae, creases and ridges. Principal lines contain the three most prominent lines—the heart line, the head line and the life line. Figure 1 indicates the inner surface of a palm. These principal lines separate palm into three areas: Interdigital, Hypothenar and Thenar. Furthermore, Hypothenar is in the middle of the Heart line and the Life line. From palmprint primary lines, particulars, edges elements can be extricated for distinguishing proof.

In this paper, sections are sorted out as follows: Sect. 2 gives the brief literature review. Section 3 gives the working model of the proposed method. Section 4 describes the implementation of the proposed method. Section 5 depicts the performance analysis of classifiers in graphical and tabular form. Section 6 gives the conclusion of the current work.

2 Literature survey

Early examines on quick palmprint distinguishing proof can be generally ordered into two classes, hierarchical matching (progressive coordinating) and palmprint classification (palmprint arrangement). Hierarchical matching methodologies normally include extricating different sorts of components and then looking in a layered manner. Easier components which can be immediately removed and coordinated are utilized at higher layers since they permit a substantial number of possibilities to be disposed off. The downside is that the formats disposed off at higher layers may contain the objective or target. Classification methodologies frequently make utilization of master information to plan the grouping rules. They continue by separating palmprints into a few classes and coordinating the inquiry just with the formats in its class. The downside here is that the underlying grouping may have put the query and its objective format into various classes, making an effective match incomprehensible. In this way, while both

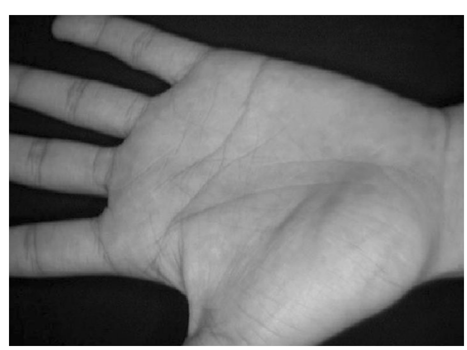

Fig. 1 Inner surface of palm

procedures quicken the ID procedure, they do all things considered to the inconvenience of precision.

Gyaourova and Ross [6] have introduced an ordering policy that can either utilize the biometric matcher that is as of now present in the biometric framework or utilize another autonomous matcher. List codes are generated for every approach utilizing the comparing matcher. During retrieval, the list code of the test is looked at against those in the display utilizing a closeness measure to recover a rundown of hopeful characters for biometric matching. The proposed ordering procedure on a chimeric multimodal database brought about a diminishment of the search space by a normal of 84% at a 100% hit rate. The principle figure for the measure of speedup during identification was the infiltration rate of the ordering.

Dai and Zhou [7] presented high determination method for palmprint acknowledgment in which many features like principal lines, orientation, minutiae and density, are taken for extraction. For estimation of orientation, the discrete Fourier transform (DFT) and radon-transform-based orientation Estimation are employed. And to concentrate the principal line features, Hough change is used. SVM is utilized as the combination strategy for the confirmation framework and the proposed heuristic run for the recognizable proof framework.

Huang et al. [8] have suggested a novel algorithm for the improved request of low-resolution palmprints. In any case the focal (principal) lines of the palm are portrayed using their position and thickness. A game-plan of directional line detectors is prearranged for extraction of principal lines. By using these detectors, the potential line initials of the central lines are removed and thereafter, in light of the isolated potential line initials, the principle lines are evacuated totally using a recursive methodology. The close-by information about the extracted segment of the principal line is used to pick a ROI and after that a proper line discoverer is evacuated the accompanying some part of the first line in this ROI. Ensuing to isolating the principal lines, a couple of standards are shown for palm print gathering.

Kong and Zhang [9] have introduced a novel feature extraction method, the competitive coding scheme for palm print recognizable proof. This plan extricates the introduction data from the palm lines and stores it in the competitive code. An angular match with a viable execution is created for looking at competitive codes. Add up to execution time for check is around 1 s, which is sufficiently quick for genuine time applications. The suggested coding scheme has been considered using a database with 7752 palmprint images from 386 distinct palms and this technique can work at a high genuine acceptance rate of 98.4% and a low false acceptance rate of 3×10^{-6} for verification.

Zhang et al. [10] have proposed Online Identification of Palmprint in which palmprints are taken online using low resolution images. Boundary tracking algorithm and low pass filter is utilized as a part of pre-handling stage (pre-processing phase). Circular gabor filter is used for extraction of features and 2-D gabor phase coding is used for representation of features and a normalized hamming distance is applied for matching the features.

Li et al. [11] have offered an effective indexing and searching scheme for an image database to encourage quick retrieval when the extent of a palmprint database is huge. Indexing, feature extraction, and matching are the three fundamental issues that are to be considered in this scheme. As a rule, in an image database, the removed elements are regularly related to the first pictures as indices. A scan for the best coordinating is led in a layered manner, where one feature is initially chosen to lead the inquiry by decreasing the set of applicants. At that point, different components are utilized to reduce the hopeful set further. Such a procedure will be reused until the final output is resolved in light of the given coordinating criteria. The determination of features assumes a vital part for effective pursuit. A compelling component determination plot should avoid the most impossible candidates, think about effectively, compare easily and require little size of space for capacity.

Jiaa et al. [12] have presented the validation of palmprint on the lines of robust line introduction code. For the extraction of elements, Modified Finite Radon transform is utilized. The line coordinating system has been utilized for matching of test image with a training image which depends on pixel-to-territory calculation.

Cappelli et al. [13] have given palmprint recognition framework using high determination relying upon extraction of minutiae. To achieve pre-processing, segmenting of foreground image is done from its background. To upgrade the quality of picture, local orientations and local frequencies are considered. Local orientation is evaluated utilizing unique fingerprint orientation extraction approach and local frequencies are evaluated by tallying the quantity of pixels between two sequential peaks of gray level along the heading typical to nearby ridge orientation. Minutiae feature is extricated in feature extraction stage. To remove the minutiae features relevant separating with Gabor filters approach is applied and to match the features of minutiae, minutiae cylinder code has been used.

3 Proposed method

The work carried out in the area of palmprint recognition uses various parameters for determining the efficiency of the method used. Some of these parameters are equal error rate [6], computational speedup, [7, 8]. These existing algorithms did not take into account the accuracy and also were not able to handle noise and distortion. Accuracy of the palmprint recognition system is very important due to it's use in criminal and forensic applications.

In this research, CASIA palmprint image database is used out of which 17 subjects comprising 156 images of palmprint are used for implementation and analysis of the proposed algorithm as shown in Fig. 2.

The region of interest (ROI) for each sample is acquired from the pre-processing module. The features of palmprint are extracted from the ROI by using Sobel and morphological operations. Now to extract the features from the enhanced images, a combination of features from accelerated segment test (FAST) algorithm, Frangi filter and FREAK descriptors is employed. At last, the discriminant analysis and KNN algorithm are used in the verification stage.

4 Implementation of the proposed method

In this section, a stepwise procedure for the implementation of the proposed system is discussed along with the outputs and results of each step.

4.1 Selection of database

In this research, 17 subjects and in total of 156 images of palmprint are used. For each subject, images of palmprint are utilized from both left and right palms. All images of palmprint are 8 bit gray level JPEG files created by palmprint recognition device of CASIA.

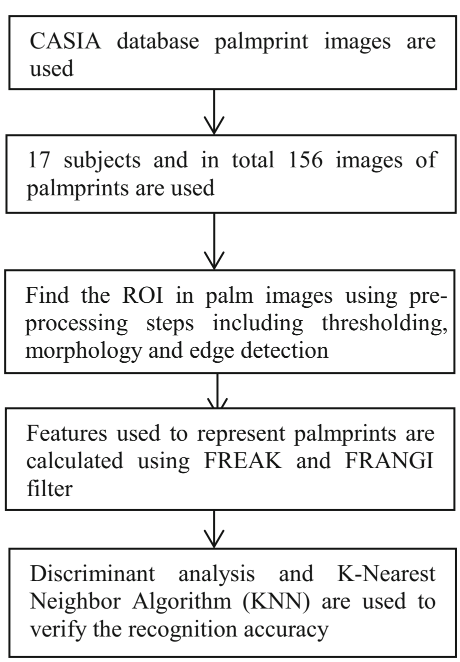

Fig. 2 Flow diagram of working algorithm

4.2 Preprocessing

For the most part, images caught by cameras are noisy and such images should be processed (pre-handled/pre-processed). Pre-processing is a phase in which all the undesirable noise is to be expelled from the picture. In pre-handling different sorts of morphological activities and improvement systems are to be connected on the image.

In this method preprocessing is used to line up different palmprints, remove misrepresentations and alterations, and to crop the ROI for extraction of features [5]. The pre-processing steps implemented on palmprint images include: segmentation of ROI and image enhancement (refer Fig. 3).

4.2.1 Segmentation of ROI

Segmentation is the process of segmenting or dividing the image in order to eliminate the undesirable or useless information from the image and to get the Region of Interest (ROI). In this procedure different morphological tasks are to be connected on the original image keeping in mind the end goal to get ROI.

The input palmprint image captured contains two things, palm portion and its background. However, no required information is present at its background. So the palm portion is the region of interest (ROI). The binarization is applied to the palmprint image using a selected threshold value for ROI segmentation. Because of irregular illumination, some undesirable portions of background get connected to the required palm regions [14]. These undesirable regions are detached by following steps: At first, morphological operation 'opening' and 'filling' is applied to the image (which involves erosion followed by dilation and dilation followed by erosion, respectively, utilizing the same organizing component. Opening has a tendency to augment little gaps, evacuate little objects, and separate items. Closing holds little objects, evacuates gaps, and joins objects) and after that a Sobel edge detector (recognizing points in an image at which the image brilliance or brightness changes strongly or, all the more formally, has discontinuities) is applied to the input image. Then the resulting edge map is subtracted from the binarized image and the morphological operation 'erode' is applied to the subtracted image which yields the ROI mask. Figure 4 demonstrates the steps that precisely segment the ROI mask (The ROI mask organizes image pixels as having a place with either the region of interest or the background).

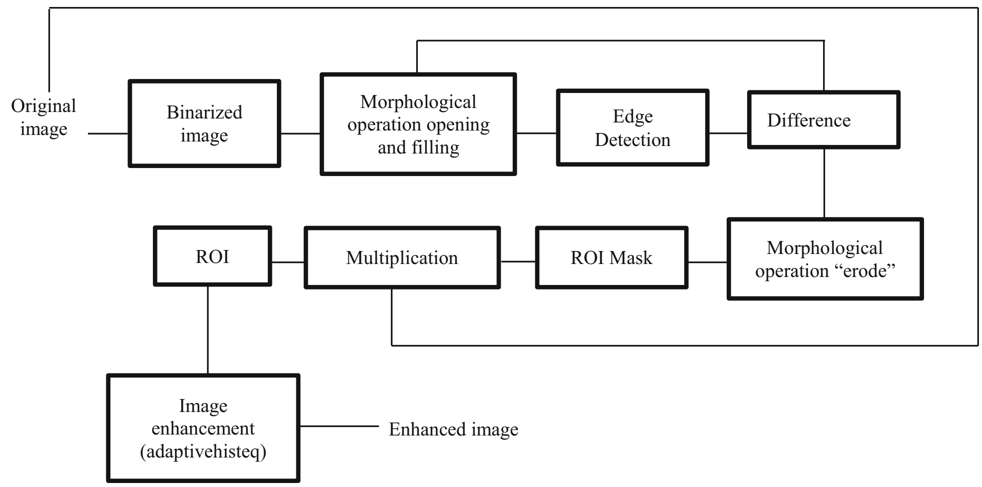

Fig. 3 Block diagram of preprocessing step

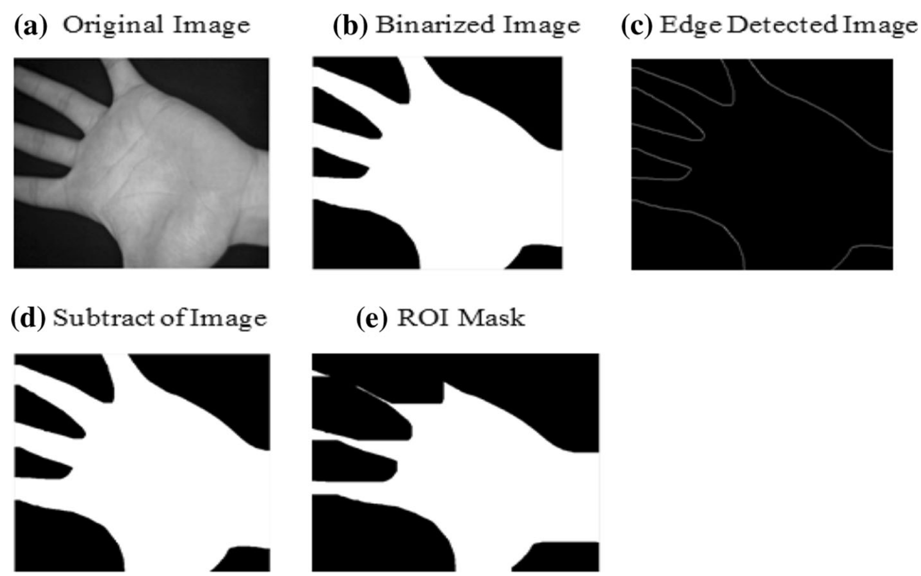

Fig. 4 Segmentation of ROI from input palmprint image

The required ROI from the input (original) palmprint image as shown in Fig. 5 is segmented by using the resulting binarized ROI mask.

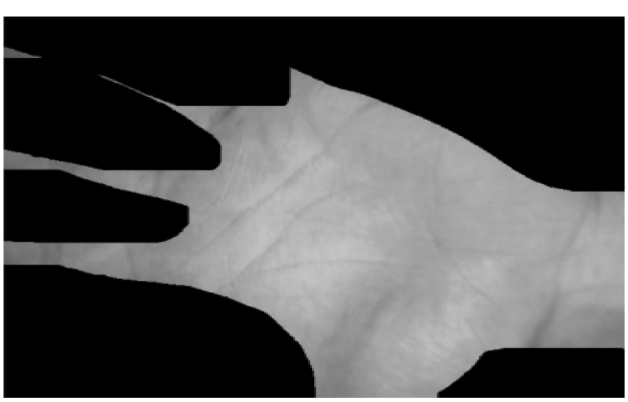

Fig. 5 ROI of palmprint image

4.2.2 Image enhancement

The organisation of palmprint is faulty or defective because of which the palmprint images are very little clear. So, we have to improve the quality of these images and this should be possible by any of these three techniques i.e. imadjust, histeq and adapthisteq. In this section, the image so obtained is a complete segmented image representation of palm classed with two regions. The prime region is palm, which is the ROI and the rest of the region is the undesired region which is black. This image is a consequence of overlapping of two images, original image and image after a complete filtering, noise removal and subtraction.

The aim of this image as shown in Fig. 6 is to reduce the task of computation complexity which is achieved by reducing the exact region of image by deleting the nearby background which is not important for the calculation of imperative features.

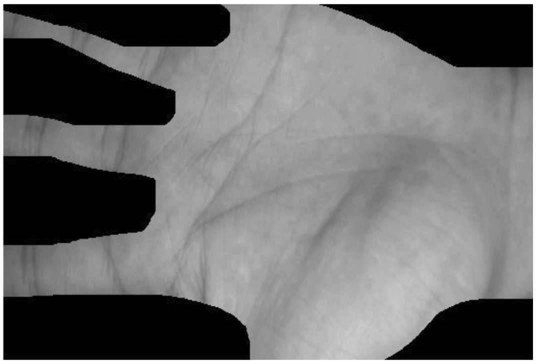

Fig. 6 Reduced dimension of region of interests

Because of the uneven illumination and defective arrangement during the imaging, the palmprint details in the images are not much clear, so these images are enhanced in this work. There are three techniques that can be used to enhance the images and these are imadjust, histeq and adapthisteq (as discussed earlier). In this research, we are using adapthisteq as it divides the image into 30 × 30 small rectangular blocks and the contrast of each block is enhanced by adjusting their local histograms and applying Rayleigh distribution. This scheme is also known as contrast limited adaptive histogram equalization (CLAHE). Figure 7 shows the enhanced image of palmprint.

4.2.3 Feature extraction

Features play a vital part in the area of image processing. Before getting features, different feature preprocessing strategies like binarization, thresholding, resizing, and so on are connected on the examined image. From that point forward, include extraction systems are connected to get features that will be helpful in grouping and acknowledgment of images. As features characterize the behaviour of an image, they demonstrate its place as far as capacity taken, productivity in characterization and clearly in time utilization too.

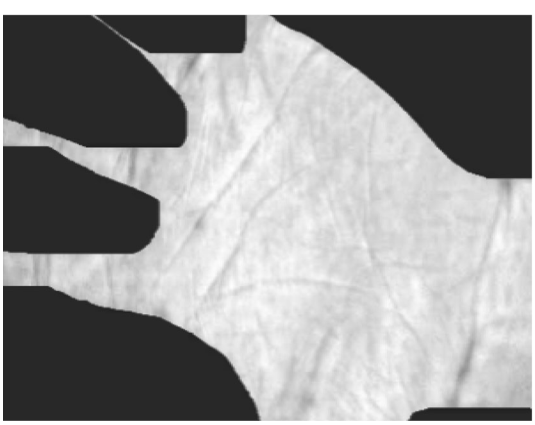

Fig. 7 Enhanced image

Feature extraction is utilized for dimensionality reduction. In this the input information is changed into set of highlights or features known as feature extraction.

Features of palmprint can be extracted by utilizing different sorts of filters such as Gabor filter, median filter.

The palmprint feature extraction process (block diagram) is shown in Fig. 8. The Frangi filter is used on the enhanced image of palmprint to extract the feature map of the image. It can be utilized to distinguish non-stop edges, for example, vessels and wrinkles. It utilizes the Eigen vectors of the Hessian to calculate the likeliness of an image area or region to contain vessels or other image edges or ridges, as indicated by the technique depicted by Frangi [15]. It bolsters both 2D images and 3D volumes.

After extracting the feature map of palmprint image, the FAST algorithm is used to find the point of interest from the palmprint feature map. Features from accelerated segment test (FAST) is a corner location strategy, which could be employed to extricate feature points. The most encouraging preferred standpoint of the FAST corner indicator is its computational efficiency or productivity. Alluding to its name, it is quick and undoubtedly it is speedier than numerous other surely understood element extraction techniques. Additionally, when machine learning techniques are applied, predominant execution or higher performance as far as calculation time and resources can be realised. The FAST corner detector is exceptionally appropriate for real-time video processing application as a result of this high-speed performance. Then a FREAK descriptor is extricated for every point centered around on it to create binary combinations which designate the distinct final features. It is a “binary descriptor” because of the way that their data is exhibited as bit strings. This property is particularly helpful to accomplish computationally productive—and straightforward-correlations. Given two binary descriptors created by a similar calculation, one can utilize the Hamming distance to gauge what number of their separate bits vary. The resulting value is estimation on how comparable the depicted points are, a littler value demonstrates a more prominent similitude.

4.2.3.1 Frangi filter The image processing technique relies on the examination of Eigen values in Hessian matrix. Originally, it was developed for detection of blood vessels in medical images. It can also be used in those areas where there is a need of finding line-like structures in the image. The Eigen values of the Hessian matrix are used to choose locally the likelihood of a vessel present in the region [14].

1. Analysis of the Eigen values of the Hessian matrix:

Fig. 8 Process of palmprint feature extraction

A Hessian matrix is obtained from the image by applying second order partial derivatives for a given pixel of the input image and is given by,

$$H = \begin{matrix} \frac{\partial}{\partial x}\frac{\partial I}{\partial x} & \frac{\partial}{\partial x}\frac{\partial I}{\partial y} \\ \frac{\partial}{\partial y}\frac{\partial I}{\partial x} & \frac{\partial}{\partial y}\frac{\partial I}{\partial y} \end{matrix}$$

where, H is the Hessian matrix, I is the grayscale input image, and x and y are the coordinates of a pixel within I. The difference in intensity of pixels in the neighbourhood gives the partial derivatives. The second order local image intensity differences around the nominated pixel are defined by Hessian matrix. Eigen value λi is tabulated for obtaining Hessian matrix. Using this theoretical behaviour of Eigen value, the conclusion can be made if the analysed pixel belongs to the structure being searched.

In general, blob-like and plate-like structures within the image can be detected by Hessian Eigen value analysis. In order to extract feature map from the image, the Frangi filter is used.

The resulting feature map image $w(x, y)$ is binarized into binary image $J(x, y)$ as follows:

$$J(x,y) = \begin{cases} 255 \; if \; w(x,y) > 0 \\ 0 \; if \; w(x,y) > 0 \end{cases}$$

4.2.3.2 FAST algorithm The FAST algorithm is utilized for the recognition of corners in order to extract the feature points (to find the point of interest). It was published in 2006 and was introduced by Roster and Drummond.

In this method, firstly a candidate point p with intensity value of Sp is chosen, around which a circle of 16 pixels with radius of value 3 are taken. These pixels are labelled with integer values running from 1 to 16 as shown in Fig. 9. If the N contiguous pixels in a circle are all brighter than Sp plus the chosen threshold (t) or these N points darker than Sp minus the chosen threshold point (t), then p is said to be the corner point. The value of N is usually 12. This test can be applied to all other remaining candidate points to determine the corner points. Squares that are white colored in figure are the one used for detection of corners and the dashed lines passing through continuous pixels are the pixels that are brighter than p [14].

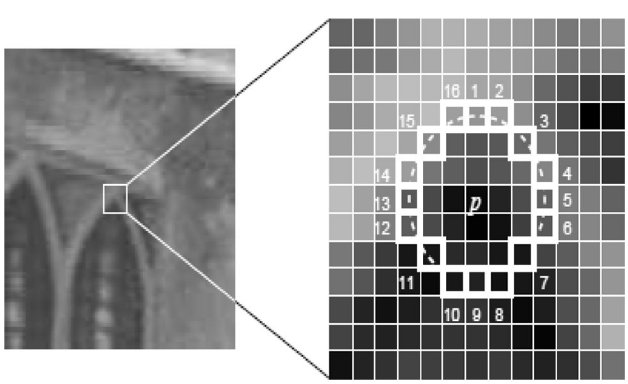

Fig. 9 Twelve point segment test corner detection in an image patch [16]

4.2.3.3 FREAK descriptors Once the corners are detected we need to find the values of these corner points, so fast retina keypoint (FREAK) descriptor is used. This method is used to get binary combinations that are the final features and is also used for calculating corner values. To portray a keypoint, a binary descriptor tests regions around it, and analyses their intensities in a pairwise way. Each bit in the descriptor's bit string means the correlation of one examining pair. Every binary descriptor differs in three viewpoints: which territories around the key point to test, how to change on the record of turn, and which regions to use as pairs in the last correlation step. For the most part, the further the inspected territory is from the keypoint, the bigger it is, to represent coarseness. The use of binary descriptors is advantageous as the calculation of Euclidean distance is much more difficult and complex than Hamming distance [16]. Also, the binary descriptors are faster to calculate with lesser memory load and these descriptors are more robust [17].

5 Performance analysis of classifiers

Image classification is a procedure of mapping numbers to symbols. With a specific end goal to arrange or classify a set of information into various classes, the connection between the information and the classes into which they are ordered must be well comprehended.

In this section, the performance of the two classification algorithms (discriminant analysis and KNN algorithm) used in this research work is discussed, represented and analysed for comparison.

Discriminant analysis This method is mostly used for dimensionality reduction. It additionally discovers its use in statistics, pattern recognition and in machine learning to figure out how to discover direct mixes of information that are utilized to separate at least two classes of items [18]. In our research, we use machine learning's discriminant analysis (supervised learning algorithm) which gives 77% accuracy.

K-nearest neighbor algorithm To classify objects based on nearest training sets in the feature space, the k-nearest neighbor algorithm is used. K is a positive integer and thus an object is classified while being allocated to that class which is most common among its k-nearest neighbors [19]. In our research we use a KNN algorithm which shows 93% accuracy.

The bar graph in Fig. 10 and the Table 1 show the comparison between two techniques used in the work in terms of accuracy of the features abstracted from the images of palmprint patterns of the given subjects.

6 Conclusion

In this age of smart systems it is very hard to keep the data secure in the smart devices like mobile phones, laptops or tablets. Every now and then we hear news about the hacking of online bank accounts, debit cards and credit cards of some particular person. Due to the increase in forgeries of smart systems, there is a need to make our security system smarter and reliable. Although we do have many existing reliable and secure systems, still they are not so secure. So for contributing in the enhancement of their security, this research work focusses on developing a new biometric system based on palmprint which is more reliable.

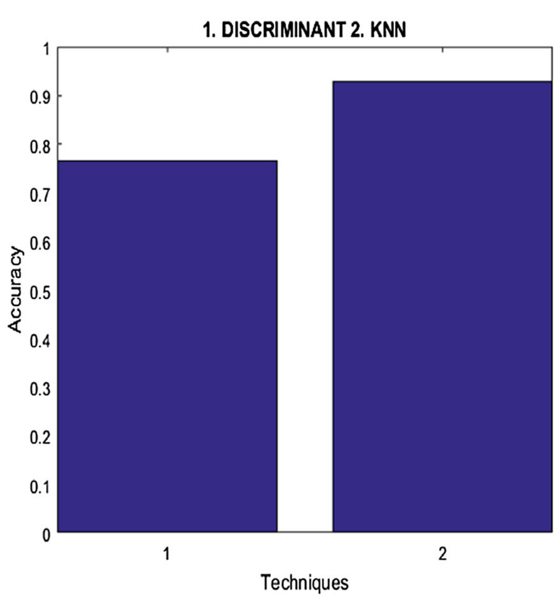

Fig. 10 Recognition accuracy of two techniques

Table 1 Comparison of two techniques

Classifier	Accuracy (%)	No. of observations
Discriminant analysis	77	17
KNN	93	17

In this paper, an attempt has been made to improve the accuracy of palmprint authentication using two different classification algorithms—discriminant analysis and KNN, keeping all the initial stages of preprocessing, segmentation and feature extraction same. Then accuracy is calculated from the human palmprint features which have been already extracted from the enhanced images in this work. The accuracy calculated using discriminant analysis is 77% and by using KNN is 93%. Here it is concluded that KNN is the better technique among the two for the classification of palmprint pattern's features as its accuracy is much higher. As the procedure has been carried out on a small dataset, so there is scope of further improvement in accuracy by working on a larger and more varied dataset. Moreover, the proposed work is much feasible for classification and authentication of real time data with good accuracy.

Thus it is concluded that KNN classifier is going to boost the biometric authentication system while using the unique physiological trait of palmprint for enhanced security.

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