Iris Recognition System with Frequency Domain Features optimized with PCA and SVM Classifier

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Abstract

Applications such as immigration control, aviation security, bank and other financial transactions, access to defence organization requires a more reliable and authentic identification system. Iris is now considered to be one of the most time invariable biometric features of a person for recognition. Several iris recognition techniques were proposed with considerable focus on improving the false acceptance rate and minimizing false rejection rate. Most of the proposed techniques are tested with Mat lab and not keeping the detection and recognition time in mind. In this work we propose a novel iris recognition system with iris localization to segment and recognize color iris with highest speed and accuracy. Custom software for iris image processing is developed in C#.Net (.Net 3.5). Frequency domain magnitude and phase features are used for image feature representation. Support vector machines with "winner takes it all" configuration are used for classification. Tests shows 97% accuracy with average time of 31 milliseconds seconds for classifying each test image.

Keywords: *SVM, iris Recognition, PCA, FFT, C#.Net.*

1. Introduction

Personal identification is gaining more importance owing to increased security requirement of modern day man. Some of the few methods for personal identification and verification are token based method which makes use of ID cards for identification/authorization and memory based method which requires the user to know passwords for identification purposes. The disadvantage of these traditional methods is that they are not reliable as the tokens can be lost or the passwords might be forgotten. In the present day scenario, with increased dependence on computers and electronic devices there is a need for highly precise and automatic reliable authentication technology. As a result of which, a new robust and advanced method for personal identification namely biometrics has been developed in recent years and has surpassed the past techniques. In accordance with a method for authentication, biometrics uses the physiological or behavioral characteristics such as fingerprints, face, voice, iris and retina to identify a person. There has been a satisfactory performance by iris recognition in the field of classification and recognition.

The human iris is the annular part between pupil and sclera, and has about 266 distinct characteristics [2] such as freckles, filaments, corneas, stripes, furrows, crypts, arching ligaments and so on. These irregularly shaped microstructures are so randomly distributed patterns which make the human iris as the most reliable biometric character recognition system. Compared with other biometric features, personal authentication based on iris recognition can obtain high accuracy due to the rich texture of iris patterns. Therefore, iris recognition has many potential applications such as access control, network security, etc. in various fields. Compared to other biometric features, Human identification using iris recognition can provide high precision and accuracy, due to diverse texture of iris pattern.

2. Related work

Zhonghua Lin and Bibo Lu [1] suggested the iris recognition method based on the optimized Gabor filter. The iris image was preprocessed and normalized to reduce it into 512 columns by 64 rows of rectangular image. The image was segmented according to the parameters of Gabor filter and edge response of different directions was obtained. The feature vector was created using iris code and Hamming distance method was used for recognition and matching. Zhang Shunli et al., [2] proposed the iris feature extraction and recognition algorithm based on empirical mode decomposition. The iris signal was decomposed into several Intrinsic Mode functions using Empirical Mode Decomposition. Among n intrinsic mode functions only the best performing intrinsic mode functions were selected to form feature vector. Hamming distance was used for matching. Zhong hua Lin [3] proposed the iris recognition method based on the Natural Open eyes. The noisy features like eyelid, eyelashes were removed using edge directional operator, canny edge operator and voting mechanism. The iris feature points were obtained using directional information, length information, width information of texture to form feature vector. Matching was performed using pattern matching methods. Karen P Hollingsworth et al., [4] proposed the algorithm of Iris recognition using fusion of Hamming Distance and Fragile bit distance. All the bits in iris code are not very consistent. There will be some bits called as fragile bits which change their value for different images of the same iris. The location of the fragile bit tends to be consistent for the same iris. In the algorithm the fragile bit distance of two iris codes was taken as metric to define the feature of the iris. The scores of the fragile bit distance and Hamming distance were fused to generate the feature vector for classification. Christian Rathgeb and Andreas Uhi [5] proposed the method of bit reliability driven template matching for iris recognition. During feature extraction phase the texture was divided into strips to obtain ten, one dimensional signals. A dyadic wavelet transform was applied to get twenty sub-bands. From each sub-band using suitable threshold bit code was generated. In the second phase Log Gabor function was applied on a row wise convolution pattern to get another feature vector. Using reliability mask binary iris code was formed. Matching was performed using Hamming distance code. Nawal Alioua et. al., [6] presented a method for eye state analysis using iris detection based on circular Hough transform. The Circular Hough transform is applied to segregate the eye from the image of the face. The eye state analysis using Circular Hough transform was compared with the other methods like prewitt, Sobel, Log and canny edge operators. Ali Abd Almisreb et al., [7] suggested enhancement pupil isolation method in iris recognition. The method involves converting the original pupil into white using morphological process. Thus the exact dimension of the pupil is obtained as feature vector for iris recognition. Fitri Arnia and Nuriza Pramit [8] proposed iris recognition system based on Phase Only Correlation. The test and database images were subjected to preprocessing. Phase Only Correlation is applied on the normalized iris images and reduced to one fourth of original size to create the feature vector. The matching was achieved using Hamming distance code. Sambita Dalal and Tapasmini Sahoo [9] proposed selective feature matching approach for iris recognition. After normalization Daubechies wavelet is applied on the iris. The normalized correlation was evaluated on test or query iris along with data base irises. The feature vector was created using the normalized correlation. Then Euclidean distance was calculated for matching and recognition. P Radu et al., [10] presented concept of fusion of features derived from Red, Green and Blue channels of iris images. The entropy distribution for Red, Green and blue channels were calculated. Feature vector was formed by fusing the features extracted from all the color channels and Hue saturation Intensity spaces for classification. Bhawna Chouhan and Shailja Shukla [11] suggested the algorithm of fusion of canny edge operator and Wavelet decomposition for iris recognition. The Canny edge operator was used for segmentation. Using Hough transform centre of the pupil and its radius were calculated. Feature vector was created using Complex valued two dimensional Gabor filter. Hamming distance code was used for matching. M Z Rashad et al., [12] proposed the algorithm of iris recognition based on Local Binary Pattern and combined Learning Vector Quantization classifier. After the preprocessing steps involving Canny edge operator, Hough transform and Daugman's rubber sheet model, Local Binary Pattern and Histogram properties were presented to extract features. Histogram statistics includes range, mean, geometric mean, harmonic mean, standard deviation, variance and median. The combined LVQ classifier was used for classification. Manikandan and Sundararajan [13] presented iris recognition method based on Discrete Wavelet transform. The algorithm uses the Discrete Wavelet transform for feature extraction. Hongying Gu et al., [14] proposed iris localization algorithm based on standard deviation. The standard deviation was used to calculate the inner boundary between iris and pupil. Similarly the outer boundary between sclera and iris was also calculated. The radius of both the circles required for the location of the iris. Mohan and Venkataramani [15] proposed the compression scheme for iris. Iris images were decomposed using wavelet based Directional transform and coded by modified Set Partitioning in Hierarchical Trees encoder. The binary output of the encoder is grouped to form vectors inputs to a Self Organizing Feature Mapped Vector Quantizer. The vectors are then matched. Su Li et al., [16] presented the algorithm of eyelash occlusion detection using end point identification. The iris images after binarization were thinned using morphological process. The feature points of eyelashes were extracted using 3 X 3 templates for occlusion detection. Assuncao et al., [17] presented the methods for feature extraction in iris using Two Dimensional Linear Discriminant Analysis and Diagonal Linear Discriminant Analysis. The iris images from UBIRIS data base were processed for segmentation and normalization using the Hue Saturation Intensity color space and Artificial Neural Networks. Features were extracted using image matrix based linear Discriminant analysis. Classification was performed using Nearest Neighbor Classifier and the Euclidean distance metrics. The performance was compared with Diagonal Linear Discriminant Analysis. Anand Deva Durai and Karnan [18] presented the algorithm of iris recognition using Hierarchical Phase based matching technique. The input iris image is preprocessed. The iris image is then divided into five sub regions. The phase only correlation (POC) function was calculated for the first sub region of the iris image and compared with POC of the second sub region of data base images. If the match occurs for some n images, then the reduced set of n images were formed. In the second level, the POC values were calculated for the next sub region and compared with n images to selects few images which match in the second sub region. The comparison will be continued for the third sub region and so on until all the five sub regions are matched for classification.

Iris Recognition Problem

An iris recognition problem is subdivided into three sub problems

a) *Iris Segmentation:*
This is the process in which iris part is separated from rest of the eye images. Daughman's [7] method is still the most accepted and adopted technique for iris segmentation. In this work we have proposed a unique color based iris segmentation technique which does not require any user input for segmentation.

b) *Iris Feature Extraction:*
The features of Iris images are mainly categorized as
i) Gray Level Co-occurrence features or texture features. ii) Phase based features iii) features on the wavelet and Fourier domain iv) statistical features v) shape based features. In this method, Iris images are sub sampled into many independent images which are filter outputs of the Gabor filters with different orientation. Though proven efficient and is adopted widely, the technique is time consuming because filtering is a convolution operation and the same is computationally not linearly optimizable[5]. Therefore in this work we focus on Fourier domain features by extracting the significant feature set over the Fourier transformed data and show that the technique is not only fast but is accurate at the same time. Further not all the extracted features are of same significance or importance in the context of pattern recognition. Therefore storing and considering insignificant features not only consumes more storage space but also takes more time in recognition. Hence the principal components are best suited to understand the significance of each class of features.

c) *Classification:*
There are various classifiers presented for iris recognition. But most of the biometric recognition systems are migrated to kernel based techniques which reduces the dimensionality of the extracted feature vectors by converting scalar features to vector feature space. Therefore vector oriented classifiers have got more significance over other classifiers like neural network and nearest neighbor classifier. Support vector machine is essentially a two class classification problem. This technique transforms feature vector from low dimensionality plane to high dimensionality plane in such a way that features are easily separable. Various kernel functions like Gaussian, RBF and Linear functions are used for the same transformation. In this work we develop a 64 class iris recognition solution for color iris database. In our work two class support vector machine is used in recursion as “one versus all other” and thus the model is extended as multiclass problem

3. Contribution

The proposed iris recognition system is implemented with C#.Net which is considered as fastest processing language after C++. The C#.Net language is selected keeping in mind of the type of applications that the system may get integrated with .Net platform provides a real time interface for connecting to networks through web services and XML protocol. All the media types are serializable as XML data. Therefore the developed system acts as a test bed to test various Iris recognition techniques over the network. The contribution of the paper is also significant in designing and modeling support vector machines of two classes in C# and extending it for a multiclass problem. The segmentation algorithm is developed for color images and fast segmentation is possible with any user input.

Organization: The paper is organized into the following sections. Section 2 is an overview of related work. The iris recognition model is described in Section 4. Section 5 is the algorithm of iris recognition system with methodology and feature extraction. Classification is presented in Section 6 and Conclusion is contained in Section 7.

4. Model:

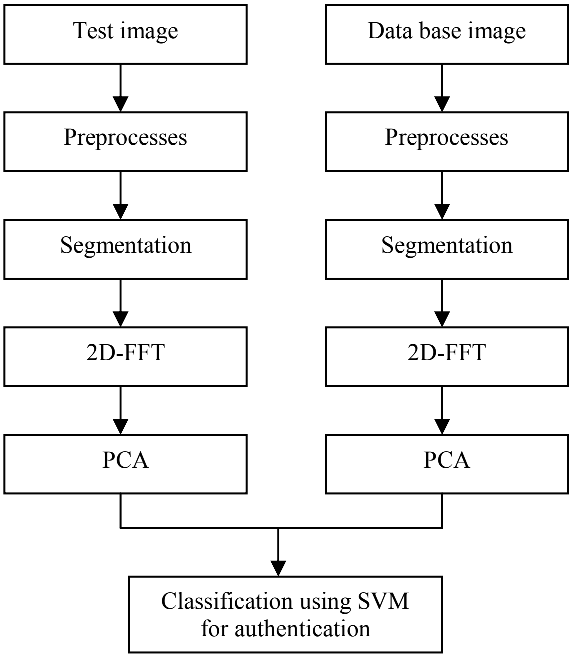


Fig 1. Model of the Iris recognition algorithm

5. Methodology

5.1 Segmentation

During image acquisition an iris image has pupil and outer retina as unnecessary parts in the image. If not segmented properly, then the feature extraction process takes into account the properties of these parts also. This reduces the overall recognition efficiency. The proposed work emphasizes on fast processing of the data. Therefore we developed a novel Iris segmentation as proposed below.

1. Scan Iris Image
2. Extract the image pixels satisfying the following criteria
3. I=I<50;
4. Remove the extra noise by eroding the image with a 3x3 square structural element
5. Fill the holes in the mask. Segment original image with this mask. After segmentation a part of pupil still appears in the image. In order to remove this part, dilate the image with a disk structuring element with R= 3 and N= 4.
6. Segment the image with new mask.
   Step 1 to 6 removes the pupil part efficiently. Now the following steps are adopted to remove the outer boundary or the retina part of the image.
7. Convert the segmented image to gray scale image. Apply histogram equalization. This step enhances the retina part to a brighter color.
8. Remove the brighter retina part with hard thresholding.
   Pixel values over 200 are made as zero.
9. Convert the image to binary image.
10. Remove independent noise by erosion operator with a square element of size 2x2.
11. Fill the image by applying dilation with a disk operator of size R=8, N=8.
12. Re-segment the result of step 11 with the new mask to obtain an image with only the iris part.

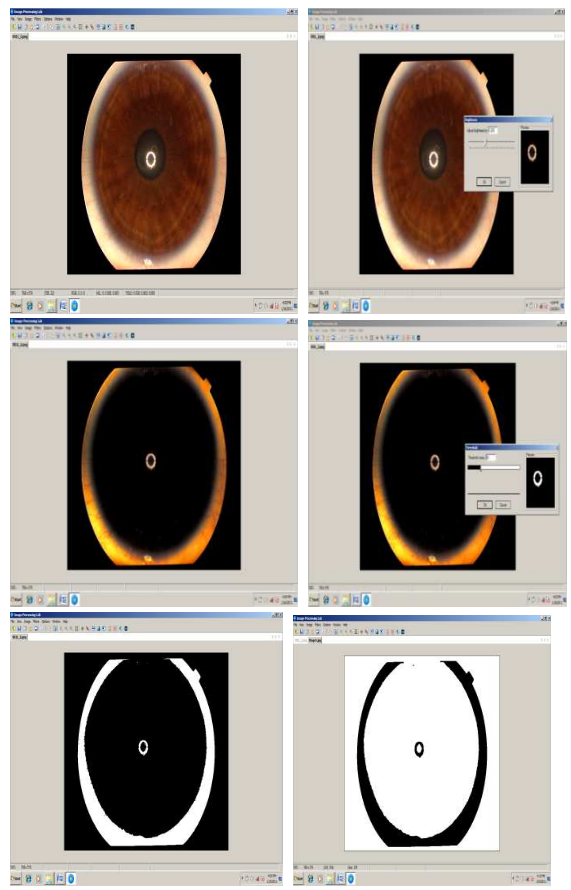


Fig 2a. Sample Iris Image and the Step wise Segmentation Result

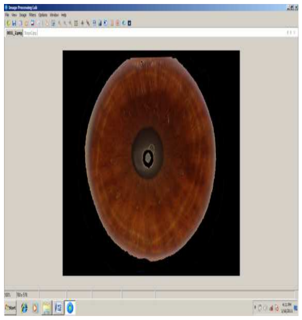


Fig 2b. Sample Iris Image and the Step wise Segmentation Result

5.2 Feature Extraction in Phase and Frequency Domain

The 2-D Fourier Transform is the series expansion of an image function (over the 2D space domain) in terms of "cosine" image (orthonormal) basis functions.

The definitions of the transform (to expansion coefficients) and the inverse transform are given below:

F(u,v) = SUM{ f(x,y)*exp(-j*2*pi*(u*x+v*y)/N) } …(1)
and
f(x,y) = SUM{ F(u,v)*exp(+j*2*pi*(u*x+v*y)/N) } ….(2)

where u = 0,1,2,...,N-1 and v = 0,1,2,...,N-1
x = 0, 1, 2,..., N-1 and y = 0,1,2,...,N-1
SUM means double summation over proper x,y or u,v ranges

Once an image is transformed to frequency domain, the features of these images are mainly represented by the magnitude and the phase components. Magnitudes is the FFT magnitude of the repeating components where as the phase provides the approximation angle of repetition of the images.

Note that f(x, y) is the image as it is REAL. But F(u, v) (abbreviate as F) is the FT, in general it is COMPLEX as shown in equation (1) and (2).. Generally, F is represented by its MAGNITUDE and PHASE rather than REAL and IMAGINARY parts, where:
Magnitude(f)=sqrt(real(f)^2+imaginary(f)^2) (3)
phase (f) = atan(imaginary(f)/real(f)) (4)

MAGNITUDE will be the intensity of certain frequency component where as the PHASE indicates the frequency component of the image.

The iris image is scaled to a size of 256x256. The magnitude or the phase components will have 256 elements where the most high frequency elements are at the center or around the vertical and the horizontal axis due to the fact

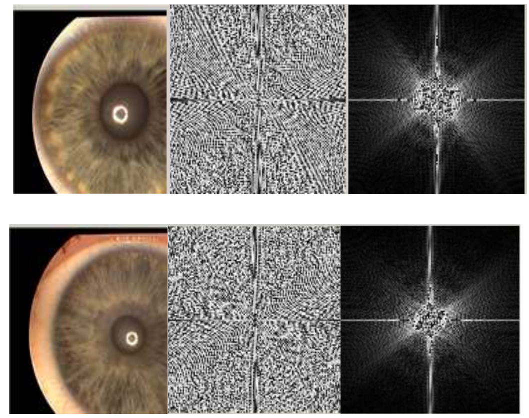


Fig 3. Two samples of iris images with their Phase and Frequency Plots

that most iris images are circular and the central iris has most invariability. The actual iris pattern information will be present outside the central block of values. Iris images will be symmetric around the center. Following steps are performed to reduce 256x256 features describing the iris pattern.

1. Maxima on the magnitude plot are located.
2. 15% values on the left and on the right of the central maxima are discarded and named as point1 and point2 respectively.

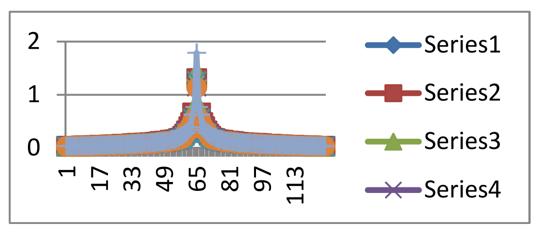


Fig 4 shows the Magnitude plot of 7 iris images from the database where FFT is carried out on scaled images of size 128x128.

3. As the iris image is symmetric on the center, two groups are declared, one group is from 1 to p1 and the other group from p2 till the end and labeled as group1 and group2.
4. Element wise mean of both group1 and group2 are calculated to obtain a reduced set of features which will be about 70% of the original features. Thus in a 128 pixels scaled iris, total features will be about 90 features. The lower components will have more invariability than the higher frequency component. These feature vectors are taken as set 1.
5. In order to find the significance of the features, extract this pattern from at least 25% of the total training images from database. Extract the principal components from the feature set.

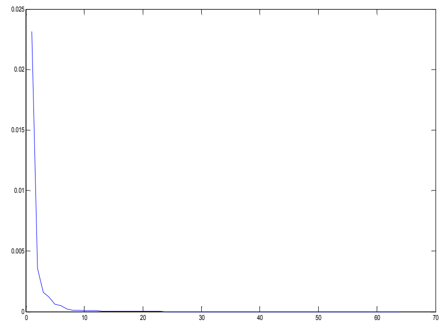


Fig 5. Plot of Variance of Principal components of the Iris magnitude reduced set1 of scaled Iris images of size 128x128.

6. The principal component analysis also justifies that the Fourier Magnitude pattern presents maximum information on Iris images in the low frequency.
7. Find first N Non Zero components in this curve and retain first N features from the actual set1.

This technique has a unique significance. Fourier features are not the only features which are attributed here for iris recognition purpose. Therefore retaining the principal component deviates the natural feature vectors. Hence we use principal components to eliminate unwanted features from the actual set.

Principal Component Analysis (PCA)

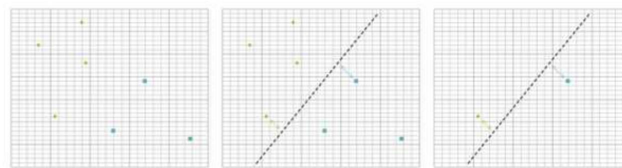
The Principal Component Analysis (PCA), also known as Eigen-XY analysis is applied on the extracted Fourier features. To reduce the dimensionality of the image PCA technique is used. This technique extracts the main variations in the feature vector and reduces the amount of computation needed. PCA identifies the strength of variation along different directions in the image data. Computation of Eigen vectors and corresponding Eigen values is the process involved in PCA. The Eigen vectors with largest associated Eigen values are the principal components. These components correspond to maximum variation in the data set.

Eigen vectors can only be found in square matrices. Not every square matrix has Eigen vectors. For a given $n \times n$ matrix that has Eigen vectors, there are n of them. Eigen vectors of a square matrix are the non-zero vectors, which being multiplied by the matrix remains proportional to the original vector.

6. Classification

6.1 Support Vector Machines

Support Vector Machines (SVMs) is a supervised learning method which can be used for both classification and regression. In its simplest form, given two set of data points with same dimensions, SVM can form a decision model so that a new set of points can be classified as either of the two input points. If the examples are represented as points in space, a linear SVM model can be interpreted as a division of this space so that the examples belonging to separate categories are divided by a clear gap that is as wide as possible. New examples are then predicted to belong to a category based on which side of the gap they fall on.



A B C

Fig. 6 Support Vector Machine as a maximum margin classifier. The (A) shows a decision problem for two classes, blue and green. (B) Shows the hyper plane which has the largest distance to the nearest training data points of each class. (C) Shows that only two data points are needed to define this hyper plane. Those will be taken as support vectors, and will be used to guide the decision process of new input data which needs to be classified.

A linear support vector machine is composed of a set of given support vectors **z** and a set of weights **w**. The computation for the output of a given SVM with N support vectors $z_1, z_2, \ldots, z_N$ and weights $w_1, w_2, \ldots, w_N$ is then given by:

$$F(x) = \sum_{i=1}^{N} w_i \langle z_i, x \rangle + b \quad (4)$$

A decision function is then applied to transform this output in a binary decision. Usually, sign (.) is used, so that outputs greater than zero are taken as a class and outputs lesser than zero are taken as the other.

6.2 Multi-class Support Vector Machines

Support Vector Machines (SVM) does not generalize naturally to the multi-class classification. SVMs are binary classifiers, they can only decide between two classes at once. However, many approaches have been suggested to perform multi-class classification using SVMs. The approach we adopted here is one against all classification. In order to model SVM as multiclass problem, the following technique is adopted.

k=1;
do
Create an initial SVM problem as AxB where A=k, b={k+1,k+2,….n}

Suppose the test vector is T
Class=classify(SVM(A,B),T)
Where classify is SVM classification problem.
If(class==A)
Break;
Else
K++;
While(k>=(n-1));
Actual class=Class

The support vector machine is built on Accord.Net computer vision library which provides various techniques for real time pattern recognition.

Results

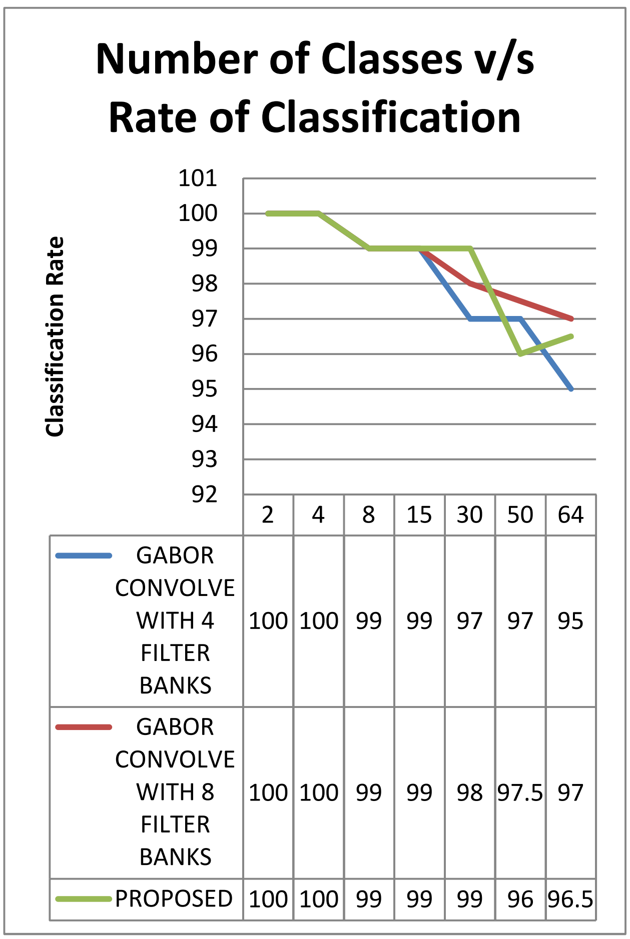


Fig 7. Number of Classes v/s Rate of Correct classification comparison with proposed technique, Gabor based filter bank features and SVM classifier.

Figure 7 and 8 presents an important findings corresponding to the iris recognition problem. The results shows that with the increase of filter banks for feature extraction, efficiency can be improved and false detection is reduced. But figure 8 shows that as number of filter banks are increased, processing time is also increased, which takes significant time for classification of the images.

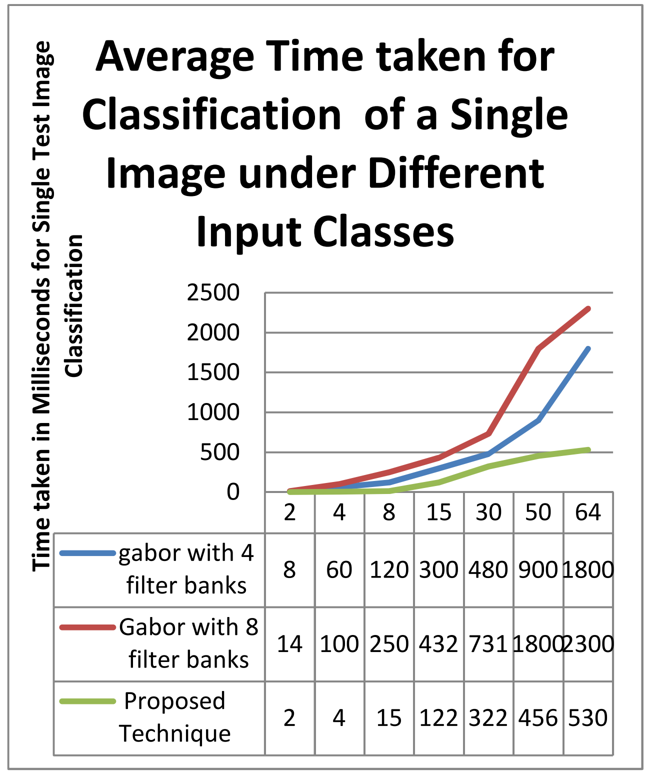


Fig 8. Number of Input classes v/s Classification time

7. Conclusion

The performance gain in terms of classification accuracy compared with classification time is non linear. Increasing the accuracy by a percent, then processing time is also increased several folds. This is avoided in the proposed technique. One of the interesting facts that come up is that when number of person classes is below 15, the efficiency of the proposed technique is better than that of conventional Gabor filter based technique. Though for any practical applications, number of classes may be huge. Higher accuracy can be achieved by either increasing number of samples per class in the training phase or combining a hybrid approach of Gabor convolve and proposed technique such that the Gabor features are extracted and considered for higher number of classes in series with proposed frequency domain features optimized by principal components.

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