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# A New Approach to Biometric Person Identification from Retinal Vascular Patterns

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## Abstract

***In this paper, a novel method for biometric person identification has been proposed by using retinal vascular patterns present in the retina. Retinal vascular patterns crossing the optic disk in the eye is a unique feature and varies from person to person. Here, singular value decomposition (SVD) is used for feature extraction and a 7-State hidden Markov model (HMM) is used for identification. The blood vessels patterns are segmented from the green-channel fundus image using Gaussian matched filter based segmentation method as Gaussian matched filter segmentation method segment the blood vessels more accurately than the other methods.The segmented fundus image is then manually cropped at the optic disc region. A top-down observation sequence of overlapping sub-image blocks is considered for finding SVD coefficients of each retinal image.A small number of SVD coefficients are used as features associating each block, which makes the training andrecognition process faster. The proposed system has been evaluated on the Digital Retinal Images forVessel Extraction (DRIVE) database, Glaucoma database and Automated Retinal Image Analysis (ARIA) database. The system achieved a recognition rate of 95% when examined on 40 fundus images from DRIVEdatabase, a recognition rate of 83.33% for 18 glaucoma affected fundus image from Glaucoma database, and a recognition rate of 100% for the 132 fundus images from ARIA database. The proposed methodper forms fast and reliable identification even for retina affected by pathologies or glaucoma. This methodalso works well for the fundus images affected by salt and pepper noise.***

**Keywords:-** retinal vascular pattern, fundus image, SVD, HMM, person identification

## 1. INTRODUCTION

Biometrics has been an important area of interest in the last few decades due to its potential to change the security, authentication and access control systems forever. The use of biometrics for authorization is an accurate, secure and cost-effective alternative to the traditional knowledge based and token based techniques, such as passwords, personal identification numbers (PIN) and magnetic cards. Biometric solutions address the fundamental problems of computer-based frauds such as hacking and identity theft, as an individual's biometric data is unique and non-transferrable. Biometrics refers to the automated process of identification of human beings by their physical characteristic or personal behavioral traits. In computer science, biometrics forms a basic backbone for security and accessing control by distinguishing between an authorized user and an imposter. The merit with biometric authentication is that it cannot be lost or forgotten, as the person has to be physically present during the point of identification process. Thus, biometrics is inherently more reliable and capable than traditional knowledge based and token based authentication techniques. The commonly used biometric identifiers include fingerprint, signature/handwriting, face, iris, voice, hand geometry, and body odor etc.

Signature/Handwriting based recognition is a dynamic operation which measures the speed, direction, pressure of writing and the time the stylus is in and out of contact with the paper. Signature recognitiontemplates typically consume 50 to 300 byte. Handwriting is a behavioral trait of an individual which is proneto changes and thus does not provide long-term reliability. Further, signatures can be easily forged, lacksaccuracy and is not cost effective. Fingerprint recognition analyzes the fingerprints for person identification, which generally requires the comparison of several features of the print pattern. These include patterns, which are aggregate characteristics of ridges, and minutia points. These are unique features found withinthe patterns [1]. The structure and properties of human skin must be known in order to successfully employsome of the imaging technologies. A fingerprint recognition system comprises of a fingerprint acquiringdevice, minutia extractor and a minutia matcher. The limitation with this system is that fingerprints can bespoofed easily. Face Recognition systems work by recording the spatial geometry of distinguishing featuresof the face. The different algorithms for face recognition focus on measuring the key features of the face. The problem with facial recognition system is that it can be spoofed easily. The system fails in recognizingidentical twins and for people with beards

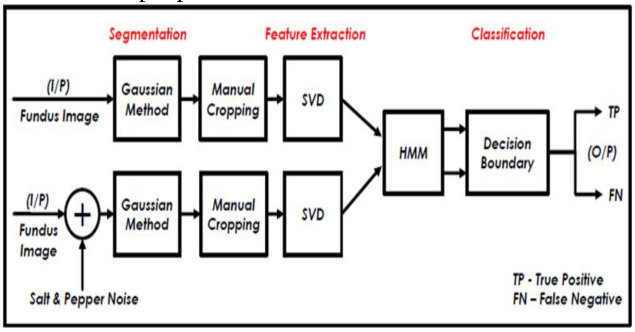


**Figure 1**Proposed method for person identification from color fundus images

Voice recognition uses the acoustic pressure of speech for identifying individuals [2].

These features have been found to differ among people. The acoustic patterns reflect both anatomy (i.e., size and structureof the vocal cavity and mouth) and learned behavioral patterns (i.e., pitch of the voice, and speaking style/accent). The limitations of voice recognition are similar to that of other behavioral biometrics, i.e., itis prone to changes. The quality of voice of a person changes over time due to ageing. Also, the recognition system may fail to identify a person suffering from common cold or sore-throat. Thus it is unreliable in along run.

Iris recognition [3] has been found to be more reliable and accurate for authentication purposes. Irispattern are formed due to agglomeration of pigment on its stroma. These colored patterns form the basisfor iris recognition. Iris patterns are highly unique and cannot be spoofed or modified. This may fail incase of people affected by cataract as the iris patterns are not clearly visible.

Above discussed limitations of biometric identifier has motivated us to develop a person identification system based on retinal vascular patterns of the retina. These blood vessel patterns are intrinsically isolatedand protected from the external environment. A retinal vasculature is rich in structure and is exclusive to each individual and each eye, and is almost impossible to forge and can form a suitable distinguishing feature between individuals. On account of these properties retina qualifies as one of the best choice forbiometric identifier. In this paper, a novel biometric person identification system based on retinal vascular pattern in themultiscale has been proposed. The proposed system employs 1-D Discrete Hidden Markov Model (HMM)[4], [5], [6] as classifier and singular value decomposition (SVD) [7] coefficients as features for retinarecognition. A 7-State HMM is used to model the retina configuration. The proposed approach has beenexamined on DRIVE, Glaucoma, ARIA databases, and recorded data from IIT Guwahati, India.The rest of the paper is organized as follows. The proposed method is described in Section II. In SectionIII and Section IV results and conclusions are discussed respectively.

## 2. Proposed Method for Identification of a Person

The proposed method employs a 7-State one-dimensional discrete HMM to model the retina image along with SVD for feature extraction. Images are segmented using Gaussian matched filter (MF) as the pixel values of the cross section of blood vessel has a Gaussian shape [8]. The segmented retinal images are then subjected to the training process using the proposed model. Another set of retina images are used for testing purpose which are created by degrading the fundus images by salt and pepper noise with variance0.02, since fundus images are generally affected by salt and pepper noise while taking a photograph of the retina. The test images were then subjected to the recognition process based on the HMM classifier. The block diagram in *Figure 1* shows the proposed retina recognition model. The important blocks are Gaussian MF based segmentation, feature extraction by SVD and classification by HMM.

**Gaussian based segmentation:** Gaussian MF is used for extraction of the blood vessel patterns from the fundus image as it provides better segmentation with comparatively low complexity. The pixel values of the cross section of blood vessel have the shape to that of a Gaussian function and it has an intrinsic property of noise reduction.

Feature extraction is done by calculating the SVD. Before calculating the SVD the segmented imageis cropped across the OD region. This is shown in Figure 2. Then the observation sequence is generated by dividing the retina image of width W. and height H into overlapping blocks of width W and height L. A WXL sliding window is moved from top to bottom on the image which creates a sequence of overlappingsub image blocks. Here, the successive sub-image blocks are the referred interpretation. The number of blocks $B_2$ extracted from each retina image is given by

$$B_L = \frac{H-L}{L-P} + 1 \tag{1}$$

where,P is overlap between two successive blocks. While a high percentage of overlap between successive blocks significantly boosts the performance of the system, it also increases the computational complexity. From the study it has been observed that as long as is significantly large $(P \leq L-1)$ and $L \approx H/10$, the recognition rate is not very sensitive to the variations of L.

In order to reduce the computational complexity and memory consumption, the retinal images are resized to 46 × 56 which results in data loss from the images. Singular value decomposition (SVD) [7] is used for feature extraction which compensate the data loss and obtain a set of uncorrelated features about the cup and OD. It is used due to its stability and robust feature extraction technique for retinal images. The SVD coefficients are used as features in the sampling windows (blocks). A sampling window of 46 × 5 pixels have been used with an overlap of 80% in vertical direction (L=5, P=4). Observation vector is composed of large number of WXL blocks (W=46, L=5), each containing 230 pixels. The number of blocks of a 46×56 image is 52. The SVD coefficients of each block is computed and used as features. A sub-image block of size 46 × 5 generates an matrix with same dimensions, which implies that there are 46 distinct singular values present for each of the 52 blocks. Among the 46 singular values, only a few big singular value and their related vectors convey information about the energy and information of an image. The SVD of a $m \times$ matrix X is given by

$$X = U\,\Sigma\,V^T (2)$$

where, $U_{(m\times m)}$ and $V_{(n\times n)}$ are mutually orthogonal matrices, and $\Sigma$ is and $m \times n$ diagonal matrix of singular values with components $\sigma_{ij} = 0$ for $i \neq j$ and $\sigma_{ij} > 0$ for $i = j$. Further, there exist non-unique matrices $U$ and $V$ such that $\sigma_1 \geq \sigma_2 \geq \cdots \geq \sigma_n$.

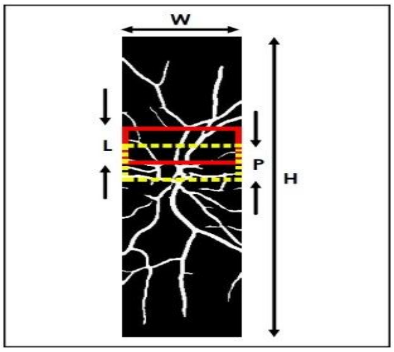


**Figure 2**Sequence of observation

Coefficients obtained from SVD are continuous valued sequence, which shape the observation vectors. If considered in the same continuous form, infinite possible observation vectors will be encountered that cannot be modeled using discrete HMM. So there is a need to quantize the features described above. This is normally handled by a process of rounding, truncation, flooring or other irreversible, nonlinear processes which causes information loss. Here, quantization is done by using the following algorithm. Assume a vector $W = (w_1, w_2, \ldots, w_n)$ with continuous elements. Suppose is to be quantized into distinct levels. So the difference between two consecutive quantized values will be

$$\Delta_i = \frac{(w_{imax} - w_{imin})}{D_i} \quad (3)$$

where, $w_{im}$ and $w_{in}$ are the maximum and minimum values that can assume in all possible observation vectors respectively. Knowing , element will be replaced by its quantized value computed as

$$W_{iquantized} = \frac{(w_i - w_{imin})}{\Delta_i} \quad (4)$$

Thus all the element of W would be quantized. At the end, each quantized vector is linked with a label i.e., an integer value. So, each of the sub-image block is mapped to an integer. Considering all the blocks of an image, the retina is mapped into a series of integer values that is considered as an observation vector. Now that the images are interpreted as a 1-D sequence of numbers. The sequence of numbers can be easily model using HMM [4], [5] for classification. A discrete-time HMM, can be viewed as a Markov Model whose states cannot be explicitly observed. Every HMM is related with non-observable states called the hidden states and an observable emission sequence generated by each of the hidden states individually. HMMs generally work on sequences of symbols called the observation vectors, while an image is represented in a 2-D matrix form. Thus in the case of person identification problem using one dimensional discrete HMM, recognition is based on frontal view, where the retina image is divided into seven regions. Each of these portioned retinal regions are assigned to a state in a left to right one dimensional HMM model. The major advantage of the above model is its simple structure and small number of parameters to adjust. The output of different stages is shown in Figure 3.

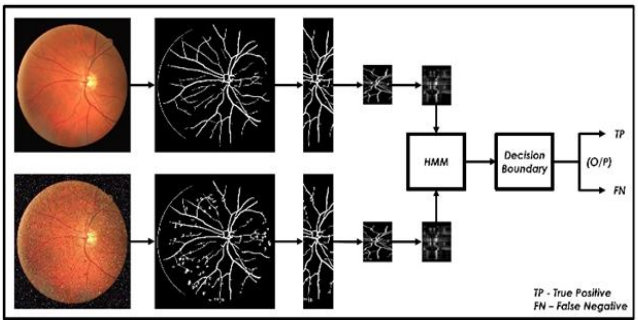


**Figure 3**Output of different stage of HMM-SVD based person identification

## 3. RESULTS AND DISCUSSION

The proposed system was examined on the standard retina databases such as DRIVE, Glaucoma, ARIA and the recorded data at IIT Guwahati. We achieved a recognition rate of 97.5% which corresponds to one misclassified images. For drive data base the computational cost is 0.2134 sec and the recognition rate 95%.

In this case, the misclassification occurred due to improper segmentation of the blood vessels as illustrated in Figure 4. The Figure 4 (a) shows the segmented blood vessels of color fundus image without noise and Figure 4 (b) shows the segmented blood vessel image with salt and pepper noise. In Figure 4 (b) it can be seen that a portion of blood vessel gets deleted during segmentation which may be the reason for misclassification. This can be rectified by using a better segmentation algorithm for extracting the blood vessels. In case of glaucoma database and ARIA database the recognition rate are found to be 100%. Recognition rate of 83.33% is achieved for people affected by glaucoma in the presence of salt and paper noise. Blood vessel segmentation is performed in multi-scale domain. Here the green channel of the color fundus image is considered. To the green channel image, 5-level wavelet decomposition is applied by db4 mother wavelet. Nirmal et al., found that different wavelet subband highlights different feature information in retina [9]. Wavelet subband-2 and subband-3 contain more blood vessel information as compared to the other subbands. The Gaussian based segmentation is applied to 2nd and 3rd level and the segmented blood vessels are used for recognition. Segmentation algorithm is applied to subband-2. This reduces the computational time.

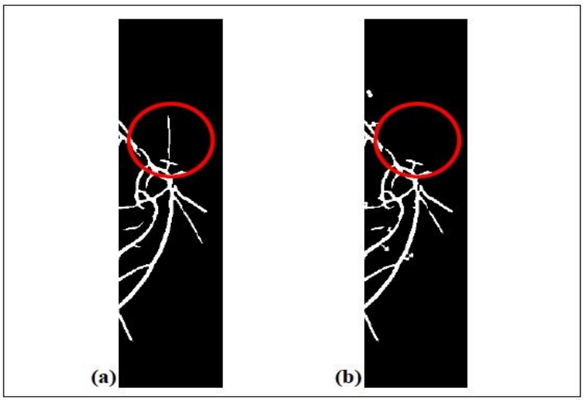


**Figure 4**Misclassification due to presence of noise

## 4. CONCLUSIONS

In this paper, a novel method was proposed for fast and efficient system for biometric person identification based on retinal vascular patterns of the eye. The blood vessel patterns were extracted from the retinal image/fundus image using Gaussian matched filter based segmentation method and converted into a sequence of blocks. Singular value decomposition method is used for feature extraction and hidden Markov model is used for classification. Simulation results on four different standard retina databases show that the proposed method has high accuracy in recognizing different persons based on their retinal vascular patterns. Also the system has achieved appreciable recognition rate for persons whose retina is affected by pathologies and glaucoma. Recognition rate of 83.33% is achieved for people affected by glaucoma in the presence of salt and paper noise. 100% accuracy is achieved for people affected by age-related macular degeneration. This method works efficiently in the presence of salt and pepper noise. Low computational overhead and low memory requirement are other advantages of the system that make it suitable for use in real-time identification systems. Computational complexity is reduced by applying the segmentation to the wavelet subband, as different wavelet subband highlights different retinal features. The use of a better segmentation technique for extracting blood vessel patterns from retinal images may improve the recognition results considerably. The cost of the fundus camera affects the popularity of the retinal recognition. Institutions requiring ultra-high security and authentication system such as defense, nuclear projects and bank currency printing, where cost is not a matter of concern, can use this recognition technique.

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