International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:10, No:10, 2016

A Robust Eyelashes and Eyelid Detection in Transformation Invariant Iris Recognition: In Application with LRC Security System

R. Bremananth

Abstract—Biometric authentication is an essential task for any kind of real-life applications. In this paper, we contribute two primary paradigms to Iris recognition such as Robust Eyelash Detection (RED) using pathway kernels and hair curve fitting synthesized model. Based on these two paradigms, rotation invariant iris recognition is enhanced. In addition, the presented framework is tested with real-life iris data to provide the authentication for LRC (Learning Resource Center) users. Recognition performance is significantly improved based on the contributed schemes by evaluating real-life irises. Furthermore, the framework has been implemented using Java programming language. Experiments are performed based on 1250 diverse subjects in different angles of variations on the authentication process. The results revealed that the methodology can deploy in the process on LRC management system and other security required applications.

Keywords—Authentication, biometric, eye lashes detection, iris scanning, LRC security, secure access.

I. Introduction

BIOMETRICS based authentication is an essential security task for protecting any kind of systems. Especially, providing authentication in outdoor environment is a computationally challenging task. The recent research challenge is, how to incorporating biometrics, in the existing applications without tremendously changes. Contrast with other biological features of biometrics such as the palm, retina, gait, face, fingerprints, ear, footprint and lips, the peculiarity of the iris is stable in a person's lifetime [1], [2]. Biological features of an iris are hysterically scattered and well suited for recognizing the person throughout their lifetime with an enlistment. Iris recognition system (IRS) is observed as a most capable biometric identification technology to incorporate in the public to make sure a secure communication with high exclusivity and immovability. Furthermore, this system has the advantages such as non-invasiveness, minimum distortion, and single enlistment. IRS has a challenging issue of segmentation in noisy environment to identify a person in non-invasive manner, for instance, from a short distance. It provides high security in any public domain application such as remote-authentication, passport-verification, surveillance monitoring based on iris, e-election, bank transactions, network login and other automatic person identification systems.

Many research studies reported to improve the performance of iris recognition systems [1]-[5]. However, in the state-of-the-art iris algorithms and technologies, there are quite a lot of important challenges that have to be addressed to utilize the iris recognition system in the real-life scenario. Primarily, iris recognition is seriously affected by the iris segmentation process, especially, eyelashes and eyelid are entrenched on the top and bottom portion of the iris pattern. The foremost challenge here is how to improve the efficiency of the iris segmentation process without affecting iris matching process. This paper mainly concentrates on efficiently detecting eyelashes and eyelid portion and makes sure to improve the performance of the IRS.

The remainder of this paper is organized as follows: Section II reveals the literature review and research motivations. Proposed Robust Eyelash Detection methodology is described in Section III. Section IV depicts the framework. The results and analysis of the proposed framework is illustrated in Section V. The concluding remarks are given in Section VI.

II. Literature Review

Based on the literature review, IRS algorithm can be categorized into four major types such as Quadrature-phasor encoded, Texture analysis, Zero-crossing and Local variation [1], [2], [5]. However, these methods have limitations such as masking bits for occlusion avoidance of eyelashes/eyelids, shifting of feature bits and several templates required to make a system as rotation invariant when using in outdoor environment. In recent research of IRS, the researchers unfocused their concentration to remove eyelashes from the iris images, which were acquired in the noisy and uncooperative environments [11], [6]. Furthermore, the iris orientation estimation is an important problem in order to put away the selective orientation parameters. Seven relative orientations were used for iris best matching process by Daugman [2] and seven rotation angles (-9, -6, -3, 0, 3, 6 and 9 degrees) were utilized by Li Ma et al. [5]. In the real-life imaging, due to the head tilt, mirror angle and sensor positions, iris images are captured in widely varied angels or divergent positions. Another serious issue is how to remove unacceptable patterns from the acquired iris images before recognition. Iris portion is occluded by improper patterns such as eyelids, eyelashes, eye-wear reflection or other artifacts. These patterns should be perceived and removed before the feature extraction process.

Computer vision based fabric defect detection was proposed by Kumar in [7]. Kernel and contrast based eyelash detection

Ramachandran Bremananth is with the Information Systems and Technology Department, Sur University College, Sur, Sultanate of Oman, Affiliated to Bond University, Australia (e-mail: bremananth@suc.edu.om).

method was suggested by Kang et.al., [10] to improve the performance of eyelash detection. The sizes of the kernels and detective thresholds were adaptive with different focus scores. According to their experiments, the results were satisfactory on the CASIA database. However, due to diverse factors such as shift, rotation, position, illumination, and other source of artifacts, this method is infeasible when the contrast in iris textures is too high for some challenging iris databases, such as Indian Institute Technology, Delhi iris database and Our own iris database [1], [13], [14]. In another research study, a set of directional filters is utilized for eyelashes' detection proposed by Yalin et al. [15]. However, this method could fail when diverse rotation, shift, translation of eyelashes and eyelids occluded on the acquisition of iris. Furthermore, there is no eyelid detection documented if the eyelid occluded about + or - 90 degree of iris portion. In addition, due to diverse elucidation, in-door and out-door conditions, direction of eyelashes may not detect properly using pre-fixed threshold as mentioned by Yalin et al. [15]. In order to overcome these different issues, we have motivated to do further research on IRS to concentrate on rotation, scale and translation iris segmentation in different elucidation scenario exclusive of prefixing thresholds for adaptation.

A. Research Motivation

In connection with our previous research works [1], [13], [14], the recognition algorithm has enhanced and got the better performance of in system. However, the main squabble is for assuring the sturdiness, exactness and promptness of the non-cooperative and noisy environment IRS. It is not fully being addressed in the literature. Motivated by these challenges, in this paper, we address the main issue of iris segmentation in noisy environment such as eyelash's detection and removal. Furthermore, iris patterns are invariant with the size of the iris acquired in the diverse scenarios such as distance from the sensors to subjects' eye positions and the external illumination of the environments. It makes the changes in the pupil diameter as well. Another invariant factor is the translation that is explicitly iris features be a positional independent and iris pattern can occur anywhere in the acquired eye image. In this paper, we address the issue of eyelash's removal and rotation invariant iris features extraction.

III. Proposed Methodologies

Robust Eyelash Detection (RED) using pathway kernels and hair curve fitting (HCF) synthesized model are proposed. The void features such as eyelashes, eyelids, and other acquisition noises should eradicate from the iris. These void features are detected and removed by the pathway kernels and HFC synthesized model. This is shown in Fig. 1.

Step 1. Two scanning boundaries are fixed by this model such as Γ_1 and Γ_2. Scanning process starts from Γ_1 by checking pixels based on their prefixing threshold Φ.

Step 2. The starting location Γ_1 is computed and then scanning process is proceeded such as $\forall\ \Gamma_1\ \varepsilon\ \Phi$.

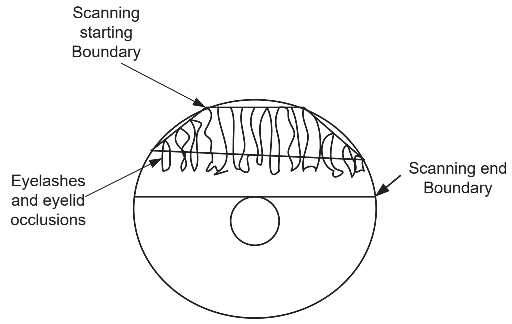

Fig. 1 Representation of hair curve fitting synthesized model for detection of occlusion of eyelashes/eyelids in iris

$$\oint \Gamma_1 <= \Phi. \tag{1}$$

Step 3. The HCF model is formed from a n^{th} polynomial function [16]. It has been defined as

$$\Psi = \sum_{l=0}^{n} \rho_l \Theta^l. \tag{2}$$

To construct the cubic polynomial for hair curve fitting model using pathway kernels, we have to specify each pair of pixel Γ_1 with $n = 3$.

$$x = \sum_{l=0}^{n=3} \rho_l \Gamma_1^l \tag{3}$$

$$y = \sum_{l=0}^{n=3} \Theta_l \Gamma_1^l \tag{4}$$

Coefficient values are determined from the boundary condition using the curve fitting. It consists of two conditions. First condition is two adjacent curve fitting have the same ordinate position of the boundary between Γ_1 and Γ_2. Another condition is that continuous curves encounters in the counterpart of two curve slopes at the boundary. Continuous curve fitting is formed with the splines. Each splines has the boundary when HCF starting from Γ_1 to Γ_2.

Fig. 2 shows eyelashes and eyelids occlusion during training and testing processes. When subject patterns' degree-of-freedom is differently varied, 20-30% chances of eyelashes' hair pertain in the iris pattern during training and testing processes. This is depicted in Fig. 2 (a). Fig. 2 (b) illustrates 30% of eyelids occluded in the iris pattern. Eyelashes' hair and eyelids are occluded in the iris pattern as shown in Fig. 2 (c). Efficient results of HCF are shown in Fig. 2 (d). It performs on hair pattern and extracted odd patterns from the portrayed iris patterns. Fig. 2 (e) depicts the extraction of eyelids from the occluded iris patterns, and this pattern is ready to transform into feature code processing. Nearly 50% of occluded patterns has aptly extracted by the curve fitting algorithm as shown in Fig. 2 (f).

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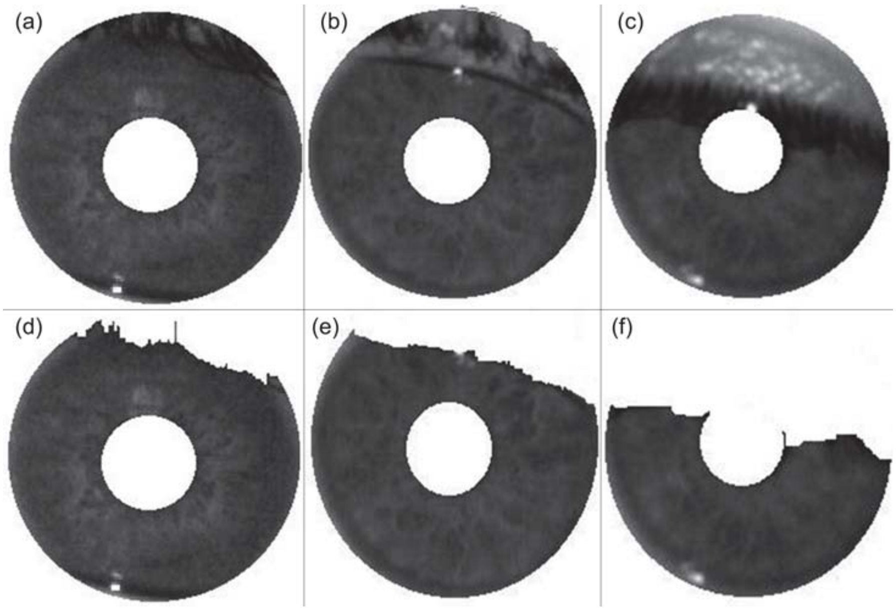

Fig. 2 Eyelashes and eyelids occlusion (a), (b), (c); Hair Curve fitting detection process (d), (e), (f)

IV. Learning Resource Center (LRC) Using Iris Scan

The scenarios of user entry and exit are monitored by iris recognition cameras. On iris-enrollment process, users can conscript their irises to get permission to access Learning Resource Center (LRC). On entry, once scanning is completed then the iris authentication process has been invoked. The proposed process of RED has been performed to localize unwanted pixel areas from the acquired patterns. Furthermore, the obstacle portions of eyelashes and eyelids are also localized aptly for the feature extraction algorithm. Once features are extracted from the currently accessing users then iris-matching algorithm has been called for iris-testing process, which is further included in the number of independent observations. Autonomous observation of iris pattern during enrollment of user can allow to access the materials of LRC as per the computation efficiency of the difference between the number of independent observations and estimated observations.

Once authentication is done by the iris scan system, entrance has been opened and user allows inside the LRC. On exit, user iris is scanned along with the opted LRC materials. If LRC materials are authorized to be taken outside by scanned the iris, then the system gives the process of the opted material otherwise rejects the current process and waits for the next user's request. A framework of the system is depicted in Fig. 3. It consists of two main processes for on exit user from the LRC. The first process is the scanning of LRC access codes. The second process is the scanning of iris of opted user. If the user is authenticated, the opted material is also eligible to access by the user. Then chosen material will be delivered otherwise the current process will be terminated, and process goes to the next user request.

A. Authentication

The two primary operations are performed to authenticate LRC security using iris scan such as extracting iris feature set and iris matching process. In the LRC environment, eye image acquisition is a complex task because it has the open area with diverse illuminations. Due to diverse illuminations, acquiring clear image using the standard camera with regular lighting effect is a challenging task. In this module, a biometric camera is used to capture the user's eye images. It acquires images by passing NIR (Near Infra Red) waves. The acquisition distance is normally between nineteen and thirty six inches and the average capturing time is one and half seconds [1], [13], [14].

Due to acquisition distance or illumination changes, recognition process may produce diverse verification or recognition rates. Perhaps, the same genuine candidate's iris features may slightly vary at sunlight and twilight or room lights reflections. However, the system confines the Euclidean distance of the same candidate features in the iris discriminator phase. Research on iris image acquisition has been made in non-invasive imaging with just a few meters' distance of separation [1], [2], [5]. The image acquisition phase should consider three main aspects, namely, the lighting system, the positioning system, and the physical capturing system. Usually, in the enrolment phase, iris images are captured without any eyewear that helps to encode the iris features accurately. However, the use of spectacles or contact lens by the user during verification does not affect the recognition process.

The system here can work both in outdoor and indoor environments without any hot spot of lighting intensities. However, unlike face, palm and fingerprint's acquisition, irises are internal organs, which are present inside the closed area of the eyelids. For this reason, users must provide full cooperation

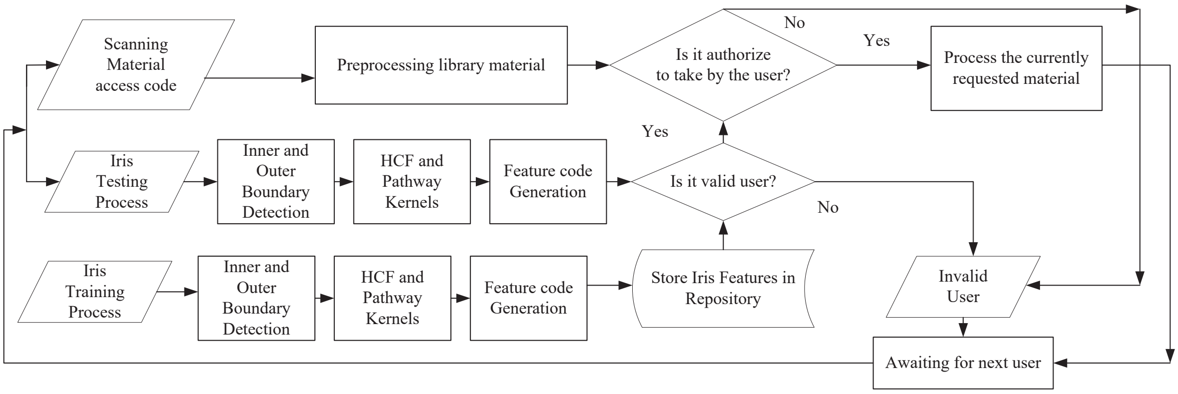

Fig. 3 Proposed framework using RED Pathway Kernel and HCF in LRC

Fig. 4 Depiction of Inner boundary detection and Occlusion of eyelashes/eyelids on the iris Patterns

Fig. 5 Illustration of Outer boundary detection and Occlusion of eyelashes/eyelids on the iris

for acquiring their eye images.

B. Iris Extraction from Eye Image

Iris extraction is the process to remove unnecessary data such as pupil, eyelashes and other portions from the eye images. They are not required for the Iris feature code generation and iris identification or recognition process.

1) Internal Periphery Localization:
The first step is to extract the iris which is called internal localization. In this process, we utilize eight-way symmetry circular method for filtering the inner periphery of the pupil [2], [8]-[10]. This is shown in Fig. 4.

2) External Periphery Localization:
This module utilizes four-way symmetry circular that localizes the external periphery of the iris [2], [11], [12]. Fig. 5 illustrates the outer periphery localization.

C. Removal of Eyelid/Eyelashes

The portion of eyelid or eyelashes is removed from the eye images using proposed methods RED Pathway Kernels and HCF. Kernel's coefficient values are determined from the boundary condition from the HCF. It has two conditions such as two adjacent curve fitting and continuous curves. Two curve slopes are determined from the boundary. Continuous curve fitting is formed with the splines. Based on these two conditions, eyelid and eyelashes are removed from the localized images. Fig. 6 depicts the result of removal process using Java's interface.

D. Iris Code Feature Extraction

After removal of eyelid and eyelashes, iris pattern is ready for feature extraction. The feature code of iris is extracted based on applying Gabor filter banks [2], [12], [13]. Each bank of filter has 24 kernels, and then iris pattern is subdivided into four consecutive signals. In this system, 96 features are extracted from a person in order to accomplish the identification process.

Gaussian envelope has a set of frequency from two to sixty four and incremented by power of two. The rotation angle, theta ranges from the zero degree to 135 degrees by increasing 45 degrees each. Once the kernels have been formed then extracted iris patterns are operated by the Gabor filters in order to fetch the feature codes.

Fig. 6 The proposed RED Pathway Kernel and HCF and implementation using Java interface

E. Iris Administration

Registration of new user: After the user, personal information is entered and then bio-metric camera is enabled to acquire eye images of users. Initially, both left and right eye images of a user are captured. The processed features are extracted as stated in the framework. The feature set is stored on the database for the verification or recognition. Options for the admin module are as follows.

- Iris Recognition: This is a one-to-many testing processes against entire iris database. LRC user can opt to give either left or right eye to recognize the system as a registered user. Once authentication is provided by checking the appropriate iris feature code, then user is allowed to access the chosen materials.
- Iris Verification: In this module, user has to enter his or her LRC code in the system and then biometric camera is enabled to capture either left or right eye in order to do the matching process. This is an one-to-one matching.
- Iris Code Modification: If required by the system, then registered user iris may call for re-enrollment. However, it is an option on the system but iris patterns never change in his or her life time.
- Iris Code Deletion: Registered users can remove from the database once their record is no longer required by the administration.
- Iris Code and Privileged Users: Based on users' iris code, certain materials in the LRC are restricted to use by the diverse classes of users.

F. Data Flow of Enrolment Process

During the enrolment process, users requires to remove their eyewear in order to extract the protected iris features. The iris camera interface is utilized to acquire the sequence of frames for the eye images, among them a suitable frame is extracted for preprocessing. Once basic extraction of the suitable frames process is completed then the acquired image is passed on to the preprocessing and feature extraction modules. As a final point, iris code is appropriately stored with the registered user personal details on the database.

G. Data Flow of Verification Process

Verification process has two different approaches such as recognition and identification/verification. During the recognition process, user's iris feature code are examined with the remaining feature code in order to determine its accuracy and to detect the presence Iris in the database. However, this process may cause more false positives while the iris data store has millions of iris codes. Alternatively, the verification process normally causes minimum false positives even though the iris data store has a huge amount of data entries. However, it requires an indexing key such as user identification to match the registered iris code exactly. This process may cause false alarm due to the distance that iris is acquired by the system or other sources of external artifacts.

V. Result Analysis

The proposed framework was implemented in Java. Results were analyzed using MATLAB. Iris database has 1250 iris images from 1250 diverse subjects. The option of giving left and right is also considered while registering the new users. In the iris matching process, bury and non-bury classes of iris features are efficiently estranged, and they prevent impostors from entering into the secure system. To authenticate any genuine user in the LRC, iris feature sets are treated as trained sets and stored in the encrypted database. Verification subjects' irises are represented as test sets. The same subject iris feature codes may vary due to external noises, lighting, illuminations and other factors such as closed eyelashes or eyelids. This could lead to different iris template for an eye, even though iris is unique in nature. In order to study the variation of external artifacts, we have done the simulation of the eyelashes and eyelid's pixel supremacy in the iris portion as shown in Fig. 7. It depicts the eyelashes and eyelid pixels which are portrayed about 20-35percentage of the portion on the irises.

A. Statistical Analysis of Iris Verification

In order to classify iris features, 1D feature vector of size 'n' is framed for each subject. Iris features code is employed for recognition process. Each code denotes the signal of the feature which is convolved by the Gabor filter bank. These sensitive features are the arithmetic mean of Gabor kernel convolution. The feature vector is determined by the number of decomposition of sub images and number of Gabor kernels. Euclidean Norm Distance Measurement (ENDM) discriminator is utilized to separate iris patterns among subjects. It can be computed by dividing standard deviation of known-iris code with the difference between enrolled known-iris code and unknown-iris codes.

During the testing process standard deviations of unknown-iris codes are not used for computing ENDM. It can compute from mean values of the unknown-iris code. That's why, in the testing process a discriminator requires n/2 features to recognize different sets of iris codes. To authenticate any genuine user, iris feature sets are treated as known-patterns that are already stored in the encrypted database. Verification candidates' irises are treated as an unknown set.

International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
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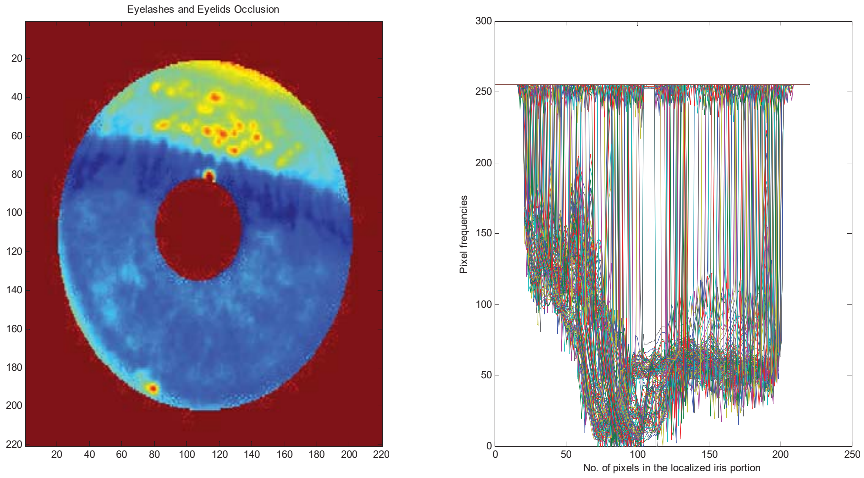

Fig. 7 Occlusion of eyelashes & eyelids and its frequency variations

B. Iris Database and Binomial Distribution

Binomial distribution involves N identical traces in the iris database. Each traces has only two possible outcomes that are denoted as either iris is successful or failure to authenticate. The terms p and q remain constant throughout the experiment, where the term p is denoted the probability of getting a success irises on anyone trace and the term q = (1 - p) is the probability of getting a failure on anyone trace.

Based on the theory, the system needs an idealized situation where the iris statistical threshold is measured more and more accurately for a large population of irises. In the recognition control scenario, the proposed algorithm is looking for unknown iris which is not enrolled in the iris database. The system provides the success and doesn't consider for rejecting, then it means False Positive Rate (FAR). The algorithm is trained using left-iris when testing the system recognizes as left-iris of a person, then it is treated as Genuine Acceptance Rate (GAR).

A normal distribution (ND) provides distribution analysis between the relative frequency density and iris code weighted variations. In this framework threshold value at the decision boundary of ENDM is set from 0.0 to 0.5. This statistical threshold is fixed by considering the factors such as Mean, Standard deviation and Degree-of-freedom for the system.

C. Receiver Operator Characteristics

The following metrics of iris verification was performed:

- Genuine Accept Rate (GAR) If the system validated, and the result are also positive for the genuine subject, then it is referred as GAR
- False Rejection Rate (FRR) If the system verified false subject and outcome is also negative, then it is known as FRR.
- True Rejection Rate (TRR) If the system tested genuine subject but the response is negative, then it is called as TRR.
- False Positives Rate (FPR) If the false subject verified by the system and response is positive, then it is referred as FPR.

VI. Conclusion

In this manuscript, we contributed two paradigms such as Robust Eyelash Detection (RED) using pathway kernels and Hair Curve Fitting (HCF). These two approaches provided better accuracy in outdoor and distance based iris recognition system. Furthermore, based on RED and HCF, rotation invariant iris recognition is enhanced. The proposed framework has been tested in real-life iris data of LRC (Learning Resource Center) accessing users. Recognition performance is significantly improved based on the contributed schemes by evaluating real-life iris database. In addition, the framework for LRC security using iris scan and authentication algorithm has been implemented using Java. Recognition Experiments were performed based on 1250 diverse subjects in different angles of variations in the authentication process in LRC. The results motivated that the proposed framework can aptly deploy in the present process of LRC management system or other secure places to enhance the safe transaction for any real-time applications such as attendance entry in classroom, unauthenticated border entry, biometric-voting, unique identification, passport authentication and other applications. In our further research, this system will be enhanced to recognize few more meter distances, auto removal eye-wears from acquired images and deploying in diverse outdoor environment in real-life utilization.

Acknowledgment

Authors would like to thank the Management of Sur University College (SUC) to provide necessary research environment and Monetary assistant to do this research in a successful manner.

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Bremananth R received the Bachelor and Master degrees in Computer Science from Madurai Kamaraj and Bharathidsan University in 1991 and 1993, respectively. He obtained Master of Philosophy degree in Computer Science and Engineering from Government College of Technology, Bharathiar University, in 2002. He received his Doctor of Philosophy degree in 2008 from Department of Computer Science and Engineering, PSG College of Technology, Anna University, Chennai, India. He has completed his Post-doctoral Research Fellowship (PDF) from the School of Electrical and Electronic Engineering, Information Engineering (Div.) at Nanyang Technological University (NTU), Singapore, 2011. Before joining NTU, Singapore, he was a Professor and Head, Department of Computer Science and Application, in India. He has 23+ years of experience in teaching, research and software development at various Institutions. Currently, He is an Associate Professor for Information Technology and Head of Information Systems and Technology (IST) Department, Sur University College, Sur, Oman, affiliated to Bond University Australia. He is an associate editor of various International Journals in USA and he is an active reviewer of various IEEE International conferences/Journals. His fields of research are Acoustic holography, Acoustic imaging, Pattern recognition, Computer vision, Image processing, Biometrics, Multimedia, Computer network, Software engineering, Soft computing and Microprocessors.

Dr. Bremananth received the M N Saha Memorial award for the Best Application Oriented paper in the year 2006 by Institute of Electronics and Telecommunication Engineers (IETE). His continuous contribution of research was recognized by Who's who in the world, USA and his biography was published in the year 2006. He is a member of Indian society of Technical Education (ISTE), Advanced Computing Society (ACS), International Association of Computer Science and Information Technology (IACIT) and Institute of Electronics and Telecommunication Engineers (IETE).