

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/261448809>

Novel multimodal template generation algorithm

Conference Paper · July 2013

DOI: 10.1109/ICCI-CC.2013.6622228

CITATIONS

5

READS

92

2 authors, including:



Padma Polash Paul

University of Oxford

54 PUBLICATIONS 867 CITATIONS

SEE PROFILE

Multimodal Biometrics using Cancelable Feature Fusion

Padma Polash Paul

Dept. of Computer Science
University of Calgary
Calgary, Canada
e-mail: pppaul@ucalgary.ca

Marina Gavrilova

Dept. of Computer Science
University of Calgary
Calgary, Canada
e-mail: marina@cpsc.ucalgary.ca

Abstract—Multimodal Biometric system is very proficient because of the advantageous aspects over unimodal biometric system. Feature fusion based multimodal system is one of the best in its genres because it only stores single template and decries the privacy and security threats as well as the system memory. However, biometric templates from traditional feature fusion for multi-biometric systems are vulnerable in terms of template protection, where it can only improve the performance. On the other hand, proposed cancelable fusion is a new type of feature fusion for multimodal biometric system that can achieve both improved performance for multimodality and cancelability at the same time. In other word, proposed cancelable fusion keeps all the characteristics of multimodal biometric systems and ensures the template security in addition so that hackers cannot use the multi-biometric template to break the authentication system even if the template is compromised.

Keywords—Cancelable Fusion; multimodal biometric system; random projection; feature level fusio;

I. INTRODUCTION

Multimodal biometric system is fairly a new approach that can be achieved by fusing features, decisions, ranks etc. of multiple biometric traits to overcome the problems of unimodal biometric system such as intraclass and interclass distributions, quality, non-universality, sensitivity to noise and other factors [1]. It can improve the performance of a biometric system significantly as well as it can effectively reduce the spoof attack, increase degree of freedom for the system, improve population convergence, reduce user tie for an individual biometric traits [2]. However, stored multimodal biometric templates are not secure because hackers can reverse engineer to get the person's identity. Studies have shown that the compressed images, extracted features, and combined features can be recovered from the template stored in the system [3]. For example, reconstruction of fingerprint from minutiae points is possible [4]; face images can be reconstructed from the feature template stored for future authentication [3]. Since biometrics is unique and unchangeable for an individual, it is possible that the identity of an individual can be compromised if template is stolen or hacked. Therefore, template protection and security for both unimodal and multimodal system is very important aspect in designing biometric security system. Vulnerability of the biometric

system is not new to the researchers thus, some scholar suggested storing the encrypted template so that keys are needed to extract the template [5, 6, 7]. Encrypted templates are not always efficient depending on the computational time and complexity in real time. Furthermore, some researches have shown that biometric crypto system can be hacked; as a result biometric can be compromised [12] for an individual. Another group of researchers suggested combination of cancelable transformation and encryption at the same time for better security [8, 9, 13].

In biometric template protection, authors suggested the dependency of cancelable biometric algorithm on security, discriminability, recoverability, performance, and diversity of the system [1, 9]. They also noted that it should be computationally hard to reconstruct the original template from the transformed template. Performance, the revocability, and diversity are the most important characteristics of Cancelability [2] because cancelable system should not compromise the performance and template itself. Most of the cancelable biometric systems are based on unimodal biometric system but some works can be found on Multimodal cancelable biometrics, which is a new direction of biometric research [10, 11, 13, 14].

In this paper, we have proposed a multimodal biometric system using feature fusion of face and ear biometric traits. We have introduced a new type of fusion called cancelable fusion that is similar to the feature fusion in addition with the cancelability of the fused feature. The proposed cancelable fusion keeps all the properties of multimodal biometrics and cancelable biometrics.

II. RELATED WORKS

Although storing biometric traits and their use for authentication purposes have been a subject of study for half of the decade, it has not been until very recently that the matter of combining a number of different traits for person authentication has been considered. Several approaches have been proposed and developed for the multimodal biometric authentication system starting with 1998 work by Hong and Jain [19]. This was the first bimodal approach for a PCA-based face and minutiae-based fingerprint identification system with a fusion method at the decision level [13].

Recently, feature based fusion become very popular because of template management, privacy issues, and security purpose. Template protection is getting more and

more attention due to the attacks of biometric system. Many crypto system based multi-biometric system is presented in the research community [12, 13, 14]. Generation of new key from the biometric trait and reusing them during the authentication are the focus points of available systems. These approaches are called biometric crypto system that can protect the fused template from the security threats.

Most of the feature fusions are on the raw or transformed (dimensionality reduction, discriminated features) features. The application of the security measures are on the fused feature. If the crypto system is conceded [12], the fused features will be vulnerable and there is possibility of the original trait being forged by the attackers. In our proposed cancelable feature fusion, fused features are secure because of the non-invertible transformation of feature domain. The system is open for next level of security such as crypto system or another level of cancelability that will be our future research direction. This paper only emphasized the fusion process and the performance after the fusion.

The concept of cancelable biometric or cancelability has become popular very recently [10, 13, 14]. This new trend focuses on how to transform a biometric data or feature into a new one so that users can change their single biometric template in a biometric security system. Until now, multimodal system cancelability has not been considered. However, this can be argued that template protection is even more crucial in such systems. Multimodal biometric system uses numbers of biometric credentials so it is cooperative to the attackers to get more evidences if they manage to break the system. Once templates from multimodal system are compromised, individual loses all the sensitive data stored in the current security system and all other systems related to that individual. This is why, it is crucial for a multi-biometric system to provide the template security and cancelability. It can be claimed that using cancelability for each biometric trait separately in multimodal biometric system can solve the problem. However, this is not as easy as it looks: the solution may be costly in term of computation efforts and performance. If one trait gets compromised, similar method can be used to break other traits.

According to our literature review on template security, practically no research has concentrated on investigating fusion itself will be cancelable. To the best of our knowledge, this is the first time that face and ear biometrics are fused in a way that the fusion is cancelable. If the parameters for the fusion are changed, the resulted feature will be completely different from the previous one but with same biometric characteristics of an individual.

In our proposed method, we have used random projection for non-invertible transformation to achieve the cancelability. The system is simple and easy to implement but with the better performance and security. The loss of the fusion process is very low because of the projections. Concatenation and addition for feature fusion suffer from information loss where projection keeps all the information.

III. PROPOSED CANCELABLE FUSION

A. Proposed Architecture

Proposed cancelable fusion is divided into four main parts: a) split the biometric sample into n blocks, b) generate n random projection matrixes with the same dimension of the block, c) projection of each block using random projection matrix, d) project each randomly projected ear block using randomly projected face block. These four steps are for cancelable fusion. Once the fusion is completed, cancelable template is now ready for the feature extraction. This paper only presents the cancelable fusion not the feature extraction. For the evaluation purpose, we have taken the mean of the fused blocks of face and ear. In this case, the number of features is equal to the number of blocks. Figure 1 shows the proposed architecture of cancelable fusion for a multi-biometric training and testing models.

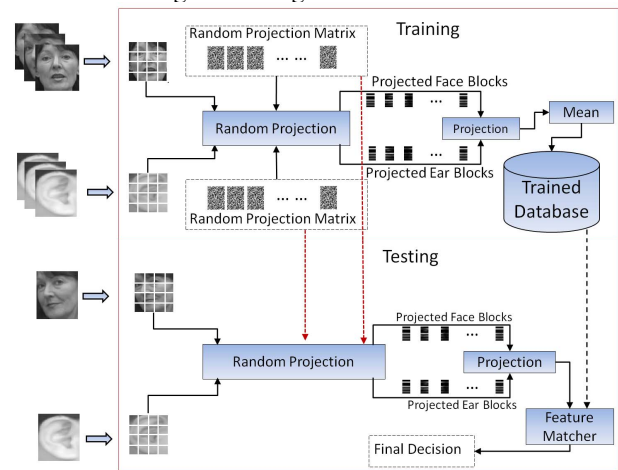


Figure 1: Block diagram of proposed cancelable fusion for multimodal biometric template protection.

Our main goal is to find if the cancelable features keep the interclass discrimination and intraclass similarity. To find that we have applied k-NN one without any further feature extraction method. The k-NN is the simplest classifier that provide better performance if the features are extremely good in terms of interclass separation. Another reason of using only the mean of the fused cancelable blocks is to find the feature quality after the cancelable transformation. Our hypothesis is that if the performance is improved by using only mean feature and k-NN classifier, fused features preserves the property of cancelability.

B. Cancelable Fusion of Face and Ear

In this paper, we have presented a novel method of fusion using cancelable transformation of biometric traits. We named the novel mechanism as cancelable fusion. For this purpose, face and ear biometric traits are used. In the first step of cancelable transformation, we have divided the face and ear sample into n numbers (in this paper $n=25$) of blocks. Dimension of the block is measured based on the resolution of the sample images. We used 75×50 samples and the block dimension is 15×10 , i.e., 150 pixels per block. One of the advantages of the proposed method is reduced

feature size that is only 25 and it can be changed based on the block dimension. It is better to take optimal number of blocks because too many blocks may increase the feature space size and too small number of blocks may reduce the discriminative features from the feature space. Figure 2 shows the steps of computing cancelable feature from face and ear.

For each block of face and ear, we have assigned a random projection matrix. Dimension of the random projection matrix is similar to the block dimension. Two random projectors are applied in this system, one for face, and another for ear. Random projectors project each block using corresponding random projection matrix. In figure f and e are the sets of blocks cropped from face and ear samples respectively. Two sets of random projection matrixes r_1 and r_2 are generated for random projection purpose. Random projector projects each block using the following equation 1 and 2.

$$P_1 = r_1' \times e \quad (1)$$

$$P_2 = r_2' \times f \quad (2)$$

where f and e are the face and ear block respectively. r_1 and r_2 are the random projection matrix for each block. The next step of the cancelable fusion is to fuse projected face and ear together. In his case, we may think about adding or taking the average of the projected blocks that are cancelable.

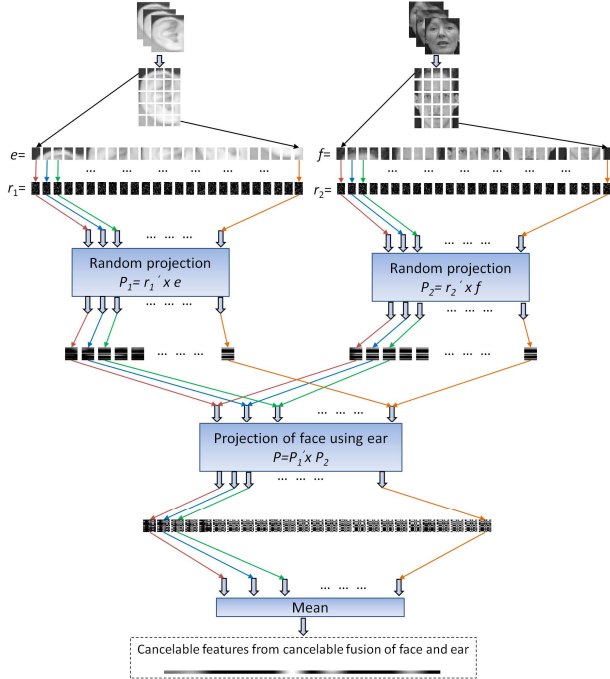


Figure 2: Steps of cancelable fusion for face and ear biometric based multi-biometric system.

We did not take any addition of subtraction operations because these linear operations have problem with discrimination reduction. Therefore, we have selected the cross product of the two projected blocks. Before taking the

cross product of P_1 and P_2 we have transposed P_1 so that it agrees with the dimensions that depend on the block size. This operation is also similar to the projection of randomly projected face using randomly projected ear. The final step is to take the average of P for each block. Since we have taken 25 blocks we will get 25 mean features at the end of the process and used for classification.

C. Random Projection

Johnson and Lindenstrauss [24] first develop the idea of random projection. Number of researcher used random projection for cancelable biometric system [9, 10, 25]. Random projection technique is used as an alternative of PCA for dimension reduction of data [26]. The main goal of random projection is to project vector on to a reduced dimensional space called Euclidian space [24]. The main property of the random projection is to keep the Euclidean distance similar in some extent before and after the projection of vector. Random projection changes the vector and transform into new vector but it keeps the statistical property of the original [25]. In the proposed method, random projection matrix is calculated in two steps. In the first step, a random matrix is generated based on the random seed. In the second step, random matrix is transformed in to orthogonal matrix using Gram-Schmidt orthogonal transformation. The Gram-Schmidt transformation is used to orthonormalize a set of vectors (2D matrix) in Euclidean space R_n [23]. This transformation allows the projection to keep the distance of projected feature same in Euclidean space.

IV. EXPERIMENTS AND RESULTS

We have designed cancelable multi-biometric system using MATLAB 2009b and C# on Intel Core i7 2.7GHz Windows 7 Enterprise workstation. Developed system is menu-driven Graphical User Interface (GUI) that supports both 32-bit and 64-bit version of Windows. Multimodal virtual database is preprocessed and saved as MATLAB standard database file with mat extension. Each biometric trait is scaled into the 75x50-resolution grayscale bitmap image. GUI is designed using C# that includes a button to selection of database for connection. As soon as a database is connected, it automatically retrieves all the dimension information and number of samples form the database. Developed system has the capability of processing biometrics of different resolution and this processing is automatic. User can also input number of fold for cross validation process. To improve the training and testing process ten-fold cross validation of the dataset is used. All the results presented within this paper are from 3-fold cross validation, and system can automatically create the dataset for 10 folds to use them in training and testing. In addition, random indices and random projection matrix can be changed using another configuration GUI module. Figure 3 shows a snapshot of the designed interface for experiment.

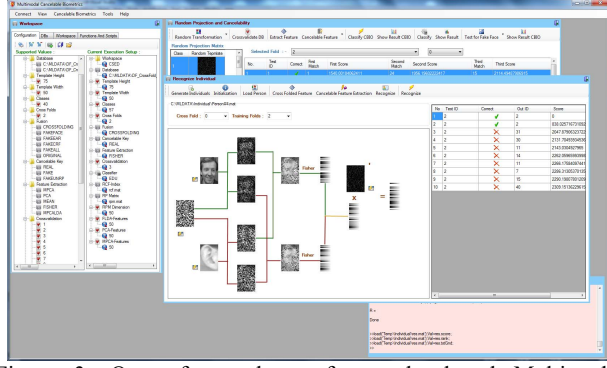


Figure 3: One of snapshots of our developed Multimodal Cancelable Biometric System.

A. Experimental Setup

To validate the proposed methodology, we have designed comprehensive test settings involving five biometric databases. The tests were intended to examine system behavior in respect to cancelability, specifically on recognition performance of the cancellable system (the higher the better) and on possibility to reconstruct original template from cancellable template (the lower the better). To ensure successful training, database selection and pre-processing is necessary and crucial. For testing our method, we have used a virtual database that contains data form two different unimodal biometric databases for face and ear. FERET [20], VidTIMIT [21], and Olivetti Research Lab Database [22] are chosen for face samples. Subject selection from the face database was random and different sets of virtual databases are generated. Two databases called University of Science and Technology Beijing (USTB) Image Database I & II [23] for ear are selected to generate virtual multimodal Face-Ear. To generate the virtual database all the images of the ear databases. Table 1 shows the virtual database setup for five sets of virtual database. Sample of virtual multimodal biometric database are shown in Figure 4.

	SET	SET-01	SET-02	SET-03	SET-04
	FERET	100 (3)	80 (3)	120 (3)	80(3)
Face	VIDTIMIT	23 (3)	33 (3)	13 (3)	43(3)
	AT&T	20 (3)	30 (3)	10 (3)	20(3)
	USTB I	66 (3)	66 (3)	66 (3)	66(3)
Ear	USTB II	77 (3)	77 (3)	77 (3)	77(3)
	No. of Samples	858	858	858	858
	Dimension	75x50	75x50	75x50	75x50

Table 1: Different sets of virtual multimodal databases showing number of face an ear samples taken from unimodal databases for the experiment purpose.

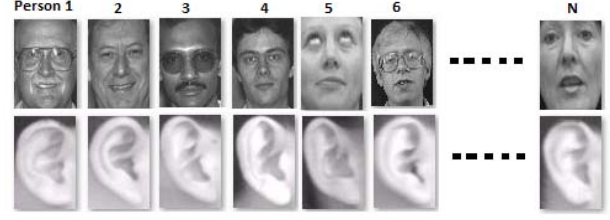


Figure 4: Some sample images from virtual multimodal database.

B. Experimental Results

In the experiment, the goal was to check the performance of multimodal cancelable biometric system using the proposed method. Performance of cancelability depends on both recognition accuracy and the cancelability of the biometric system. To achieve this goal, the following scheme is designed.

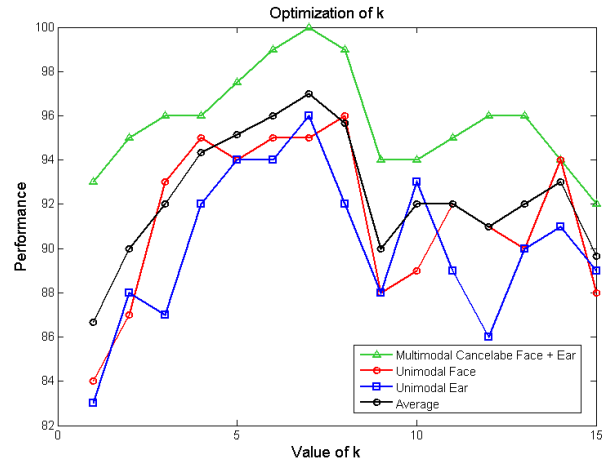


Figure 5: Optimization of k for k -NN classifier.

Properties of cancelable biometric are tested, such as keeping interclass variability (improved performance), issuing new template, and reverse processing to generate an original template. As a result, it is shown that using cancelable biometric template achieved a better performance than the matching performed on original image. Figure 6 shows the ROC curve for cancelable biometric template after cancelable fusion and the original face and ear template.

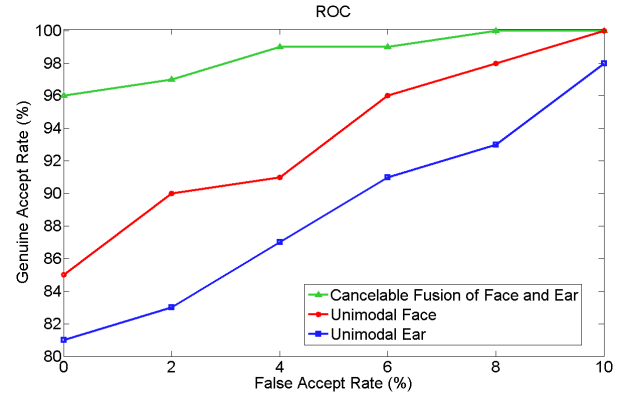


Figure 6: ROC curve for proposed cancelable fusion of Face-Ear vs. unimodal Face and Ear.

Results presented in the figures ensure that cancelable features do not degrade discriminability. Cancelable face template gives better performance than original template. For cancelable feature, performance improved by 12% on average over unimodal face. Same experiment is performed for ear biometrics. It also shows that cancelable template enhance the performance by more than 14% (on average) over original ear template.

In Figure 7, the similar comparative result for cancelable face-ear feature and traditional (concatenation of Linear Discrimination Analysis based feature) face-ear feature are also shown. Cancelable fusion improves the performance over 4% on average compared with traditional fusion. In this experiment, we have used only mean features and k-NN classifier, which is reliable only for very good features. By using both face and ear, it should improve the performance comparatively with unimodal face and/or ear biometrics. From the analysis, result it can be established that using cancelable fusion of face and ear biometrics improves the performance hence keeps discriminability properties of both biometric traits. Therefore, cancelable fusion is capable of preserving the properties of cancelability for multiple biometric traits.

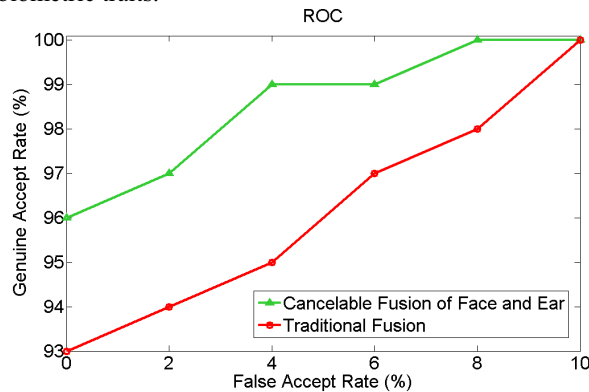


Figure 7: ROC curve for proposed cancelable fusion of Face-Ear vs. traditional fusion of Face-Ear.

C. Cancelability Analysis

Proposed system is secure because of the two different reasons; first, the random projection is non-invertible transformation. Once the blocks are projected randomly features of the blocks transformed in another domain. After the projection of randomly projected face block using randomly projected ear block the fusion become more secure. Second level of projection is also non-invertible. System is capable of generating several random projectors so that it can re-issue the template repeatedly or for a new system.

Secondly, the average of each block is also making the system secure. It is computationally hard to restore the block from single value. If attackers want to reconstruct the original biometric template they need to solve 150 (block resolution is $15 \times 10 = 150$) equations from one value which is theoretically impossible. For example, if we want to solve equations of three variable we need at least three equations.

In our case, hacker should solve 150 variables from one equation.

Let us assume that hackers already get the random projection matrixes that are the coefficient of the 150 equations. Then they need to estimate the another 150 values that came from face or ear each because we have actually 300 variable to solve, 150 for face and another 150 for ear. The mentioned process is only for one block, to reconstruct the face and ear image, it needs 25 times repetition of the process. Therefore, it is hard to reconstruct the multimodal templates that are fused using cancelable fusion.

From the performance analysis, it can be found that using simple k-NN classification provides better performance. Another proof of cancelability is found that performance does not degrade after the transformation. From our preliminary study it is found that cancelable fusion can combine two different biometric into single trait that is secure.

V. CONCLUSION AND FUTURE WORKS

A novel cancelable biometric template generation algorithm is presented using cancelable fusion of biometric traits. Random projections are applied in the proposed method. Since the cancelable fusion preserved the feature characteristics, it is possible to apply multi-level cancelable approaches such as crypto-system, another level of non-invertible transformation etc. The latest result implies that the proposed method can effectively produce cancelable template for multimodal biometric system. More analysis for the cancelability measure can address more challenges of Cancelable Biometric system. However, adopting another biometric trait may improve the cancelability and security of the system. In the future, hybrid template protection mechanism can be applied. This is the first step of multimodal cancelable fusion based multi-biometric template protection system.

REFERENCES

- [1] A. K. Jain, P. Flynn, A. Ross, "Handbook of Biometrics" Springer, 2007.
- [2] S. Prabhakar, S. Pankanti, A. K. Jain, "Biometric Recognition: Security and Privacy Concerns," *IEEE Security & Privacy*, pp. 33-42, 2003.
- [3] A. Alder, "Sample images can be independently restored from face recognition templates," *Elect. Comput. Eng.*, vol. 2, pp. 1163-1166, 2003.
- [4] A. K. Jain, K. Nandakumar and A. Nagar, "Biometric Template Security," *EURASIP Journal on Advances in Signal Processing*, vol. 2008:579416, 2008.
- [5] C. Soutar, D. Roberge, A. Stoianov, R. Gilroy and B. V. K. Vijaya K., "Biometric Encryption using image processing," in *Proc. SPIE, Optical Security and Counterfeit Deterrence Techniques II*, 1998.
- [6] A. Juels and M. Wattenberg, "A fuzzy commitment scheme," in *Proc. Sixth ACM Conf. Comp. and Commun. Security*, 1999.
- [7] A. Juels and M. Sudan, "A fuzzy vault scheme," in *IEEE International Symposium on Information Theory*, 2002.
- [8] N. Ratha, S. Chikkerur, J. Connell and R. Bolle, "Generating cancelable finger-print templates," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 29, no. 4, pp. 561-572, 2007.

- [9] Y. C. Feng, P. C. Yuen and A. K. Jain, "A Hybrid Approach for Generating Secure and Discriminating Face Template," *IEEE Trans. On Information Forensics and Security*, vol. 5, no. 1, pp. 103-117, 2010.
- [10] P. P. Paul and M. Gavrilova "Cancelable Fusion of Face and Ear for Secure Multi-Biometric Template", *IJCINI* 7.3 (2013): 80-94. Web. 27 Mar. 2014
- [11] P. P. Paul and M. Gavrilova "A Novel Cross Folding Algorithm for Multimodal Cancelable Biometrics", *IJSSCI*, Vol. 4, No. 3, pp. 21-38, 2012
- [12] W. J. Scheirer and T. E. Boult, "Cracking fuzzy vaults and biometric encryption", *Biometrics Symp.*, Baltimore, MD, Sep. 2007.
- [13] Nagar, Abhishek, Karthik Nandakumar, and Anil K. Jain. "Multibiometric cryptosystems based on feature-level fusion." *Information Forensics and Security, IEEE Transactions on* 7.1 (2012): 255-268
- [14] Y. Sutcu, Q. Li, and N. Memon, "Secure biometric templates from fingerprint-face features", *CVPR Workshop Biometrics*, Minneapolis, MN, Jun. 2007
- [15] Karmakar, Dhiman, and C. A. Murthy. "Generation of new points for training set and feature-level fusion in multimodal biometric identification." *Machine Vision and Applications* 25.2 (2014): 477-487.
- [16] Conti, Vincenzo, et al. "A frequency-based approach for features fusion in fingerprint and iris multimodal biometric identification systems." *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on* 40.4 (2010): 384-395.
- [17] Wang, Zhifang, et al. "Multimodal Biometric System Using Face-Iris Fusion Feature." *Journal of Computers* 6.5 (2011).
- [18] Yang, Jinfeng, and Xu Zhang. "Feature-level fusion of fingerprint and finger-vein for personal identification." *Pattern Recognition Letters* 33.5 (2012): 623-628.
- [19] L. Hong and A. K. Jain, "Integrating faces and fingerprints for personal identification," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 20, no. 12, pp. 1295-1307, Dec. 1998.
- [20] Phillips, J. P., Wechsler, H., & Rauss, P. (1998). *The FERET database and evaluation procedure for face-recognition algorithms*. *Image and Vision Computing*, 16(5), 295-306.
- [21] Sanderson, C., & Paliwal, K. (2002). *Polynomial Features for Robust Face Authentication*. *IEEE International Conference on Image Processing*, 3, 997-1000.
- [22] Samaria, F., & Harter, A. (1994). *Parameterization of a stochastic model for human face identification*. *2nd IEEE Workshop Appl. Comput. Vis.*, (pp. 138-142). Sarasota, FL.
- [23] Zhichun, M., Zhengguang, X., Yuan, L., & Wang, Z. (2003). *A New Technology of Biometric Identification-Ear Recognition*. *The 4th Chinese Conference on Biometric Recognition*, (pp. 286-289). Beijing, China.
- [24] Johnson, W. B., & Lindenstrauss, J. (1984). *Extensions of Lipschitz mappings into a Hilbert space*. *Int. Conf. on Modern Analysis and Probability*, (pp. 189-206).
- [25] Pillai, J., Patel, V., Chellappa, R., & Ratha, N. (2010). *Sectorized Random Projections for Cancelable Iris Biometrics*. *IEEE International Conference on Acoustics Speech and Signal Processing*, 1838-1841.
- [26] Achlioptas, D. (2011). *Database-friendly Random Projections*. *ACM SIGACT-SIGMOD-SIGART Symp. on Principles of Database Systems*, (pp. 274-281).