Multimodal Biometrics: A Review

Noorjahan Khatoon*
Advanced Technical Training Centre,
Bardang, Sikkim, India
Email: njk_gtk@yahoo.com

Mrinal K Ghose
Department of Computer Science and Engineering,
Sikkim Manipal Institute of Technology,
Majhitar, Sikkim, India.
Email: mkghose@smu.edu.in

Abstract: Biometric system comprises methods to examine the unique physical or behavioral traits that can be used to determine a person's identity. Fundamentally, it is a pattern recognition system which involves feature extraction and comparison of these features against the template set in a database. Multimodal biometric systems use more than one trait for person recognition. These systems are becoming more and more popular, even though they are complex than unimodal system due to the fact that they offer more accurate results in comparison to the unimodal systems. In this paper we have made an attempt to provide an overview of the different multimodal biometrics system and the fusion techniques associated with them. Discussion is also being made on the design issues, challenges and advantage of such systems over unimodal biometric system.

Keywords: *Multimodal, Biometrics, Fusion, Future biometrics*

I. INTRODUCTION

Identification systems can be grouped into three classes that is, something we possess as in an ID cards, something we know, and something unique about us **[7]**. Possessions (e.g., keys) can be easily lost, forged, or duplicated. Knowledge can be forgotten as well as shared, stolen, or guessed. Biometrics, which is something unique about us, is intrinsically secure since they are unique features the person has. The science of biometrics is a solution to identify an individual and avoids the problem faced by possession-based and knowledge-based security approaches **[7]**.

Moreover, unimodal biometric systems perform recognition based on a single source of biometric trait **[11]**. These systems are sometimes affected by the following problems **[21][12]** as summarized below:

- Noisy Data: Noise is one of the factors which affect the performance of a biometric data. These noises are mainly due to the improperly maintained sensors. This may lead to false rejection.
- Non-universality: Biometric data are supposed to be universal in nature, which is the basic requirement for a biometric identifier. This non-universality leads to Failure to Enroll (FTE) and/or Failure to capture (FTC) errors in a biometric system.
- Non-individuality: A small proportion of the population can have nearly identical facial appearance due to genetic factors (e.g, mother and daughter, father and son, identical twins etc.)This lack of individuality increases the False Match Rate (FMR) of a biometric system.
- Non-invariant representation: The intra-class variations due to improper interaction of the user with the sensor(e.g., changes due to angle, translation, and pressure applied when the user places his finger on a fingerprint sensor, changes in the pose and expression when the user stands in front of a camera etc.), use of different sensors during enrolment and verification, changes in the ambient environment conditions and also the inherent changes in the biometric trait (e.g., wrinkles, scars) are the causes of non-invariant representations. These variations usually increase the False Non-Match Rate (FNMR) of a biometric system.
- Finally, unimodal systems are very susceptible to spoofing, wherein the data can be imitated or forged e.g. rubber fingerprints can be used to spoofing. In case of face recognition, heavy make-ups and plastic surgery may pose greater challenges, which could be considered as a spoofing.

Due to these problems, the error rates associated with unimodal system paves ways to design of high valued Multimodal systems. Multimodal biometric systems use more than one trait for person recognition. In order for the biometrics to be very secure and to provide maximum accuracy, more than one form of biometric identification is required **[19]**. Hence the need arises for the use of multimodal biometrics.

Discussed below are some of the popular biometric modalities used for person identification and verification:

1. **Fingerprint: [18]** History of fingerprint recognition dates back more than 100 years **[29]**. Over the past few decades, research and active use of fingerprint matching and indexing have been developed drastically which has also made our understanding of the power as well as limitations of fingerprint recognition **[29]**. Constant increase in the processing capabilities of processors and memory at reduced cost, availability of cheap fingerprint scanners and growing demand of security have definitely lend to wider use and acceptance of this recognition technology**[8]**. Due to the poor and latent quality of fingerprint image, the technology fails to provide most accurate results. In fact, when the ridge prominence is

*Corresponding Author

poor(especially for users engaged in heavy manual work and elderly people), the fingers are too dry, or fingers are improperly placed, most of the scanners produce poor quality images, which still remains a challenge for further improvement**[29]**.

2. **Voice: [28][34]** Speech is a natural means of information exchange between humans. It has been used in variety of assistive contexts, including home computers, mobile telephones, and various public and private telephone services. Despite having lots of potentials and its growing presence, commercial speech recognition technologies are still not easily employed for individuals who have speech or communication disorders **[28]**. While such disorders are common in older adults, there has been relatively little research on automatic speech recognition performance with older adults. Also, human emotional experience is so varied that accurate simulation or recognition of emotional states is usually impractical **[15]**.
3. **DNA:** The Deoxyribonucleic Acid (DNA) is present in nucleus of every cell in human body and therefore a highly stable biometric identifier that represents physiological characteristics **[10].** The DNA structure of every human being is unique, except from identical twins, and is composed of genes that determine physical characteristics (like eye or hair colour). Human DNA samples can be acquired from a wide variety of sources; from hair, finger nails, saliva and blood samples. However DNA matching process is expensive, time consuming and therefore not yet suitable for large scale biometrics applications for civilian use **[10]**.
4. **Face:** Humans often use faces to recognize individuals and advancements in computing capability over the past few decades now enable similar recognitions automatically **[1]**. Early face recognition algorithms used simple geometric models, but the recognition process has now matured into a science of sophisticated mathematical representations and matching processes **[32]**. Major advancements and initiatives in the past years have propelled face recognition technology into the spotlight **[2]**. Face recognition can be used for both verification and identification. An excellent survey of existing face recognition technologies and challenges is given by Stan Z. Li. **[1]**. The problems associated with illumination, gesture, facial makeup, occlusion, and pose variations adversely affect the recognition performance. While face recognition is non-intrusive, has high user acceptance, and provides acceptable levels of recognition performance in controlled environments, robust face recognition in non-ideal situations continues to pose challenges **[32]**. This of course is minimized a little by 3D technologies **[2]**.
5. **Iris [9]**: Iris recognition is one of the most reliable and accurate biometric identification systems available. The iris is an externally visible, yet protected organ whose unique epigenetic pattern remains stable throughout adult life **[8]**. Most commercial iris recognition systems use patented algorithms developed by Daugman **[3]**, and these algorithms are able to produce perfect recognition rates. However, published results have usually been produced under favourable conditions, and there have been no independent trials of the technology. The iris is a thin circular diaphragm, which lies between the cornea and the lens of the human eye **[3]**.The iris is perforated close to its centre by a circular aperture known as the pupil. The function of the iris is to control the amount of light entering through the pupil, and this is done by the sphincter and the dilator muscles, which adjust the size of the pupil **[8]**. The average diameter of the iris is 12 mm, and the pupil size can vary from 10% to 80% of the iris diameter **[26]**.
6. **Conjunctival Vasculature:** A new biometric indicator based on the patterns of conjunctival vasculature was initially proposed by Reza Derakhshani et.al. **[22].** Conjunctival vessels can be observed on the visible part of the sclera that is exposed to the outside world. These vessels demonstrate rich and specific details in visible light, and can be easily photographed using a regular digital camera **[22]**. In the paper they discussed the methods for conjunctival imaging, pre-processing, and feature extraction in order to derive a suitable conjunctival vascular template for biometric authentication. Experimental results suggest the potential of using conjunctival vasculature as a biometric measure **[22]**.

However, the recognition accuracy of individual biometric traits outlined above may not be adequate to meet the requirements of some high security applications. Hence there is a need for the multimodal biometric systems. In this system, more than one trait is combined to achieve greater accuracy **[23]**. Another advantage of multimodal systems is that it can potentially offer protection against spoof attacks, because it would be extremely difficult to spoof multiple modalities simultaneously**[23] [27]**.

II. OPERATIONAL MODES:

There are three different modes of operation in a multimodal biometric system. They are as discussed in **[25]**:

- **Serial Mode:** In this mode, the output of one modality is exclusively used to narrow down the number of possible identities before the next modality is used. Therefore, multiple traits do not have to be acquired simultaneously. Also, decision could be reached at before acquiring all the traits that would reduce the recognition time which is a major requisite in real time systems.
- **Parallel Mode:** Such modes use multiple traits simultaneously for the recognition process.
- **Hierarchical Mode:** Individual classifiers are combined in a treelike structure in this mode. Such modes are useful and relevant in the situations where the number of classifiers is large.

III. ISSUES RELATED TO DESIGNING

When a multimodal biometric system is designed, it is important to consider application scenario. The literature is rich in the designing aspects of multimodal biometrics differing in terms of **[17]**:

- Architecture
- Choice of biometric modality
- Total number of modalities to be fused
- Level at which evidences are accumulated
- Level and methods used for fusion
- Safe and user friendliness
- Cost verses the matching performances
- Level of security and reliability
- Verification Vs Identification mode
- Assigning weights to biometrics
- Multimodal database

Accuracy is the factor which determines the performance of any biometric system. False Accept Rate (FAR) and False Reject Rate (FRR) are the two widely used benchmarks to determine the accuracy of a system. FAR is the number of imposters who are incorrectly granted access and FRR is the number of authorised users who are incorrectly denied access **[17]**.

IV. FUSION IN MULTIMODAL BIOMETRIC SYSTEMS:

In case of multimodal biometric systems, there are four possible levels of fusion. They are **[16]**:

- **Sensor level fusion:** In sensor level fusion, it fuses the biometrics traits coming from sensors like fingerprint scanner, video camera, iris scanner etc., to form a complete biometric trait.

- **Feature level fusion:** In feature level fusion signal coming from different biometric channels are first processed, and feature vectors are extracted separately, using specific fusion algorithm these feature vectors are combined to form a composite feature vector. This composite feature vector is then used for classification process.

- **Matching score level:** Here, rather than combining the feature vector, it is separately processed and individual matching score is found, then depending on the accuracy of each biometric channel fusion is done at matching level to find combined matching score which will be further used for classification.

- **Decision level fusion:** Each modality is initially classified independently. The final classification is based on the fusion of the outputs of the different modalities.

- **[13]** They have combined the modalities for speech and signature, the fusion technique adopted by them is matching score level of fusion using product of likelihood **[35]**. Matcher scores are simply added with no normalization. The scores are neither rescaled, nor weighted to account for different in matcher accuracy.

Some of the other techniques like sum rule, z-norm have been used for comparison with their results, which has shown that product of likelihood gives better results.

- **[31]** They have used tanh technique for the matching scores. This robust and efficient method was introduced by Hampel et al **[11]** and it works well with noisy training scores. In their study, combination of face and iris scores based on the product and sum rules is used to fuse the normalized scores. Compared to product rule, usually sum rule is more efficient to meet the requirement especially under circumstances with high level of noise. They have compared their face-iris multimodal system with unimodal system using ROC(Receiver Operator Characteristics) analysis. False Accept Rate (FAR) and False Reject Rate (FRR) are used as functions of decision threshold which controls the trade-off of these two error rates. The unimodal system (face and iris) methods achieve the performance of 2% EER (equal error rate). The multimodal face and iris method achieve a performance of 0.525% EER. This clearly indicates that the multimodal systems drastically improve the system performance.

- **[33]** Their work presents an investigation into the fusion of face and iris biometric from a single sensor. They have presented a multi biometric framework that utilises both multi-sample and multi modal fusion techniques to improve recognition rates. In their experiments the combination of face and iris modality via match score summation provided a 5.4% increase in the recognition rate over the best single modality approach that was tested.

- **[30]** They have designed & built an identity verification system based on the fusion of face and iris data. The two strategies being used for fusion (i) weighted/unweighted summation of the outputs (ii) treating the classifiers as 2D feature vector, and using a Fisher discriminant analysis classifier and a neural network classifier. Fusion based on the RBF neural network produced the highest verification accuracy. They found that weighted sum rule is the best approach when compared with the sum rule and fisher rule.

- **[6]** They have adopted fusion at the matching score level. The result they achieved was found to be very encouraging and promising for the research in this field. The overall accuracy of the system is more than 99%. With EER less than 1.21%. They also argue and provide evidence that multimodal system performs better as compared to unimodal biometrics with accuracy of more than 97%.

- **[5]** In this paper, they have proposed multimodal biometric algorithm for face and iris. The algorithm proposed first extract face feature based on eigenface method and iris feature using 2D even Gabor filter and then they adopted Z-score normalization model to eliminate the difference of the order of magnitude and the distribution between face features and iris features. The normalized features are combined in series and take Euclidean distance as a classifier. Their experiments show that the algorithm proposed improves the performance of two unimodal biometrics combined and outperforms sum rule fusion and weighted sum rule fusion.

- **[18]** In this paper, they have presented techniques for performing multibiometric fusion at the rank level. By incorporating quality information in the fusion rule, it was observed that the performance of rank-level fusion schemes can be significantly improved. In particular following two observation were made: (i) the performance of classical rank-based fusion schemes is degraded upon encountering poor quality input data; and (ii) by incorporating the quality factors in the fusion schemes, the performance of rank-level fusion can be substantially improved thereby indicating the importance of proposed modification systems.

- **[24]** In this paper they proposed computationally efficient biometric fusion information from biometric images into a single composite image using multi-level discrete wavelet transformation. The proposed algorithm, as they argue, not only reduces the memory requirement by 75%, but is also resistant to common tampering attacks such as smoothing, cropping & filtering. The qualitative validation process establishes that the integrity of the biometric features used for personal verification system is not compromised. The effectiveness of the fusion algorithm is experimentally validated by computing the matching scores and the equal error rated before fusion, after reconstruction of biometric images, and when the composite fused image is subjected to both frequency and geometry attacks.

- **[14]** They have presented for the first time, a low cost and usable multimodal system based on keystroke dynamics and 2D face recognition. Different fusion methods have been seen tested on a database containing two kinds of biometric template for 100 users. The various different fusion methods which have been used are min, max, mul, sum, weighted sum configured with genetic algorithm and two 2D face recognition ones. This system, they argued and proved the overall performance of the system. The EER for the proposed fusion system provide the result of 2.22% on ROC.

- **[4]** In this paper they have showed that face and signature based bimodal biometric system can improve the accuracy rate about 10%, than single face/signature based biometric system. They have adopted matching score level fusion, and have used simple sum rule fusion technique based on face and signature trait of the user.

- **[20]** They proposed that a framework for the optimal combination of match scores that is based on the likelihood ratio test. The distributions of genuine and impostor match scores are modelled as finite Gaussian mixture model. The proposed fusion approach is general in its ability to handle 1) discrete values in biometric match score distributions, 2) arbitrary scales and distributions of match scores, 3) correlation between the scores of multiple matchers, and 4) sample quality of multiple biometric sources. Experiments on three multibiometric databases indicate that the proposed fusion framework achieves consistently high performance compared to commonly used score fusion techniques based on score transformation and classification.

It has been observed that fusion at matching score level is the most popular due to its ease in accessing and consolidating matching scores. Performance gain is also drastically prominent when uncorrelated traits are used in a multimodal system **[36]**.Also, combination of Face and iris identification have been employed in various biometric applications due to its various advantages over other biometric traits.

V. CHALLENGES

Based on the information/facts detailed in the previous sections, several challenges in designing multimodal system come out to be prominent. They are observed **[36]** as follows:

- The sensors that have been used must be versatile enough to show consistency in various operating environment. Also, settings of sensors could be adjusted to provide optimal data.

- Strong hold on the understanding of biometric technologies would pave way to better design.

- Requirements for operation of the system and the privacy principles to ensure beneficial public debate on where and how biometric system should be used, enhancing public confidence in biometric technology and safeguard personal information.

- The other aspect to be considered is by enhancing matching algorithms, the system could be made more powerful.

- Scalability improvement and quality measures to assist decision making in matching process.

- Open standards for biometric data interchange formats, file formats, application interface, testing methodology, adoption of standard based solutions, guidelines for auditing biometric system and records.

VI. CONCLUSION:

This paper presents the various issues of multimodal biometric systems. The various popular biometric modalities have been discussed in brief. Combining various modalities for identification and verification system would definitely improve the performance. Various fusion levels used in the multimodal systems are discussed, leading to the fact that the more diverse the traits are the more efficient system becomes. It has been observed that fusion at the match score level is the most popular fusion method owing to the fact that it is easier to access and combine matching scores. Also, it became evident that the most widely chosen modality are face and iris because of face is one of the biometric traits that possess the merit of both high connivance to acquire and has very low intrusiveness. Also, iris recognition technology has been proved to be the most accurate.

[1]Stan Z. Li -Center for Biometrics and Security Research (CBSR) & National Lab of Pattern Recognition (NLPR) Institute of Automation, Chinese Academy of Sciences: Face Recognition: Methods and Practice ICB Tutorial Delhi, India, 2012

[2]Preeti B. Sharma, Mahesh M. Goyani (both from Department of Information Technology, Gujarat Technological University, India): 787 – "3D FACE RECOGNITION TECHNIQUES - A REVIEW" International Journal of Engineering Research and Applications (IJERA) Vol. 2, Issue 1,Jan-Feb pp.787-793, 2012

[3]Tutorial by Dr. J. Daugman: Iris Recognition: ICB Tutorial Delhi, India, 2012

[4]Kazi M.M(1), Rode Y.S(1), Dabhade S.B(1), Al-Dawla N.N.H(1), Mane A.V(2), Manza R.R(1) and Kale K.V(1)
(1. Department of Computer Science and IT, Dr. B.A.M. University, Aurangabad, MS, India. 2. Department of Digital & Cyber Forensic, Government Institute of Forensic Science, Aurangabad, MS, India)
Multimodal Biometrics System Using Face and Signature: A Score Level Fusion Approach: Advances in Computational Research Volume 4, Issue 1, , pp.-99-103 2012

[5] Zhifang Wang, Erfu Wang, Shuangshuang Wang and Qun Ding (Key Laboratory of Electronics Engineering, College of Heilongjiang Province,School of Electronic Engineering, Heilongjiang University, Harbin, China) : "Multimodal Biometric System Using Face-Iris Fusion Feature, Journal of Computers, Vol. 6, No. 5, May 2011

[6] Mahesh P K, M N Shankukha Swamy,(Deptt. Of Electronics and Communication, JSS research Foundation, Mysore University , India), "A Comparative Evaluation for Fusion Strategies for Multimodal Biometric System using Palmprint and Speech Signal", Journal of current Computer Science and Technology vol. 1 issue 4, 2011.

[7]Biometrics Market Intelligence. http://www.biometricsmi.com. Accessed January 2010

[8]John Daugman's Webpage. University of Cambridge,http://www.cl.cam.ac.uk/~jgd1000Accessed January 2010

[9]Daugman J and Malhas I (2004): Iris recognition border-crossing system in the UAE.BIOMETRICS. Accessed January 2010

[10]DNA Fingerprint Identification. http://www.fingerprinting.com/dna□fingerprint□identification.php, Accessed February 2010

[11]Anil K. Jain, Ajay Kumar Department of Computer Science and Engineering Michigan State University, East Lansing, MI 48824-1226, USA. Department of Computing The Hong Kong Polytechnic University, Hung Hom, Hong Kong: "Biometrics of Next Generation: An Overview" to appear in 'second generation biometrics' springer, 2010

[12]K. Sasidhar, Vijaya L Kakulapati, Kolikipogu Ramakrishna & K. MLRCET, (Hyderabad, India): "MULTIMODAL BIOMETRIC SYSTEMS – STUDY TO IMPROVE ACCURACY AND PERFORMANCE" International Journal of Computer Science & Engineering Survey (IJCSES) Vol.1, No.2, November 2010

[13] Mandeep Kaur(GNDEC, Ludhiana), Akshay Girhar(GNDEC, Ludhiana), Manvjeet Kaur(PEC,

Chandigarh", "Multimodal Biometric System using speech and signature modalities, International Journal of Computer Appication vol 5, no. 12, 2010.

[14] Ronmain Giot, Baptiste Hemery, Christophe Rosenberger(GREYC laboratory, EMSICAEN-Unicersity of CAEN-CNRS, Istanbul, Turkey), " low Cost and usable Multimodal Biometrics System based on keystroke Dunamics and 2D Face Recognition". Manuscript published in 20th International Conference on Pattern recognition, 2010.

[15] Mandeep Kaur, Student GNDEC,Ldh., Akshay Girdhar, Associate Professor,GNDEC.Ldh. Manvjeet Kaur,Lecturer,PEC,Chd. 'Multimodal Biometri System Using Speech and Signature Modalities' International Journal of Computer Applications (0975 – 8887) Volume 5– No.12, August 2010

[16] Ashish Mishra, "Multimodal Biometrics it is : need for the future system", International Journal of Computer Application, vol 3, No. 4, June 2010

[17] Analysis mmb: George Chellin Chandran J (Dr. MGR University), Dr. Rajesh R S(detp. Of Computer Science and Engineering, Macronmarium Sundaranas Unicersity), " Performanance Analysis of Multimodal Biometric System Authentication", IJCSNS-International Journal of Computer Science and Network Security, vol 9, no. 3, March 2009.

[18] Ayman Abaza and Arun Ross: "Quality Based Rank-Level Fusion in Multibiometric Systems" Proc. of 3rd IEEE International Conference on Biometrics: Theory, Applications and Systems (BTAS), (Washington DC, USA), September 2009

[19]Jain AK, Nandakumar K, and Nagar 'A Biometric template security.' EURASIP J Advances in Signal Processing, Special issue on Biometrics (2008)

[20] Karthik Nandakumar (Student Member, IEEE) Yi Chen (Student Member, IEEE) Sarat C. Dass (Member, IEEE) and Anil K. Jain (Fellow, IEEE) Likelihood Ratio-Based Biometric: "Score Fusion" Transaction on Pattern analysis and Machine Intelligence, Vol. 30, No. 2, FEBRUARY 2008

[21]C. Lupu, V Lupu, "Multimodal Biometrics for Access Control in an Intelligent Car", 3rd International Symposium on Computational Intelligence and Intelligent Informatics - ISCIII 2007 - Agadir, Morocco, March 28-30, 2007.

[22]Reza Derakhshani (Dept. of CS and Electrical Eng. School of Computing and Eng. University of Missouri Kansas City Kansas City, Missouri), Arun Ross, (Lane Department of Computer Science and Electrical Engineering, West Virginia University, West Virginia) Simona Crihalmeanu (Lane Department of Computer Science and Electrical Engineering, West Virginia University, West Virginia): "A NEW BIOMETRIC MODALITY BASED ON CONJUNCTIVAL VASCULATURE" Appeared in Proc. of Artificial Neural Networks in Engineering (ANNIE), (St. Louis, USA), November 2006

[23]Jain AK, Ross A, Pankanti S - Biometrics: A tool for information security. IEEE Trans Forensics Security, vol. 1, no. 2: 125-143(2006)

[24] Afzel Noore, Richa Singh and Mayank Vatsa(Lane Dept. Of Computer Science and Electrical Engineering, West Virginia University, Morgantown, WV), " Robust Memory-efficient Data level information fusion of Multimodal Biometric images". Submitted to Elsevier Science, Sept 2005.

[25] Arun Ross(West Virginia University, Morgantown, WV, USA), Amit K Jain(Michigan State University, East Lansing, USA), "Multimodal Biometrics: An overview". Appeared in Proc. Of 12th European Signal Processing Conference, Vienna, Austria, 2004

[26] Libor Masek, "Recognition of Human Iris Pattern for Biometric identities." Report submitted to the School of Computer Science and Software Engineering, University of Western Australia, 2003

[27] NIST Report to the United States Congress (2002) Summary of NIST Standards for Biometric Accuracy, Tamper Resistance and Interoperability, (2002)

[28] Ben Shneiderman, "The limit of Speech Recognition", Communication of ACM, Sept 2000

[29]History of Fingerprinting. -FINGERPRINTING.

[30]YunhongWang, Tieniu Tan, and Anil K. Jain (National Lab of Pattern Recognition, Institute of Automation,Chinese Academy of Sciences P.O. Box 2728, Beijing 100080, P.R. China, fwangyh,Department of Computer Sciences Engineering, Michigan State University East Lansing, MI 48824): "Combining Face and Iris Biometrics for Identity Verification"

[31] Maryam Eskandari* and Önsen Toygar ** (*Department of Computer Engineering, Eastern Mediterranean University, **Gazimağusa, Northern Cyprus, Mersin 10, Turkey)
"Person Identification Using Face and Iris Multimodal Biometric System"

[32] Pierre Buyssens and Marinette Revenu (GREYC Laboratory – CNRS UMR 6072 ENSICAEN, University of Caen, Caen, France):"Fusion Levels of Visible
and Infrared Modalities for Face Recognition"

[33] Ryan Connaughton, Kevin W. Bowyer and Patrick Flynn, University of Notre Dame (Department of Computer Science and Engineering Notre Dame, IN 46556): "Fusion of Face and Iris Biometrics from a Stand-Off Video Sensor "

[34] Victoria Young(intelligent Assistive Technology and System Lab, Dept. Of Occupational Science and Occupational Therapy, University of Toronto, Ontario), Alex Mihailidis(Institute of Biometrics

and Biomedical Engineering, Toronto, Ontario), "Difficulties in Automatic speech recognition of Dysarthric speakers and the implication for speech based application used by the elderly", A literature Review.

[35] Brad Ulery, William Fellner, Peter Hallinan, Austin Hicklin,Craig Watson andMitretek Systems, "Evaluation of Selected Biometric Fusion Techniques", Studies of Biometric Fusion report, National Institute of Standards and Technology,pp.1-14, 2006.

[36] Prof. Vijay M Mane and Prof. Dr. Dattaray V Judhav(Dept. Of Electronics Engineering, Pune, India), "Review of Multimodal Biometrics: Applications, Challenges and Research Areas". International Journal of Biometric and Bioinformatics, vol 3, issue 3.

AUTHORS BRIEF PROFILE

Dr. Mrinal k Ghose: A retired ISRO Sr. Scientist, Presently working as Head of department in Computer Science & Engineering cum Dean Reaserch and Development at Sikkim Manipal Institute of Technology, Majhitar, East Sikkim.

Noorjahan Khatoon: Working as lecturer in a govt. undertaking Polytechnic named Advanced Technical Training Centre, situated at Bardang, East Sikkim.