Voice Biometric Systems for User Identification and Authentication – A Literature Review

Amjad Hassan Khan M. K. [1, 2*], & P. S. Aithal [3]

[1] Department of Electronics, Kristu Jayanti College, Bengaluru-560077, India.
Orcid ID: 0000-0003-4299-7948, e-mail: itzamjad@gmail.com

[2] Institute of Engineering & Technology, Srinivas University, Mangalore-575001, India.

[3] Institute of Engineering & Technology, Srinivas University, Mangalore-575001, India.
Orcid ID: 0000-0002-4691-8736, e-mail: psaithal@gmail.com

Subject Area: Electronics.
Type of the Paper: Literature Review.
Type of Review: Peer Reviewed as per |C|O|P|E| guidance.
Indexed In: OpenAIRE.
DOI: https://doi.org/10.5281/zenodo.6471040
Google Scholar Citation: IJAEML

How to Cite this Paper:
Amjad Hassan Khan, M. K., & Aithal, P. S. (2022). Voice Biometric Systems for User Identification and Authentication – A Literature Review. *International Journal of Applied Engineering and Management Letters (IJAEML)*, *6*(1), 198-209. DOI: https://doi.org/10.5281/zenodo.6471040

International Journal of Applied Engineering and Management Letters (IJAEML)
A Refereed International Journal of Srinivas University, India.

Crossref DOI : https://doi.org/10.47992/IJAEML.2581.7000.0131

Received on: 10/02/2022
Published on: 20/04/2022

Voice Biometric Systems for User Identification and Authentication – A Literature Review

Amjad Hassan Khan M. K. [1, 2*], & P. S. Aithal [3]

[1] Department of Electronics, Kristu Jayanti College, Bengaluru-560077, India.
Orcid ID: 0000-0003-4299-7948, e-mail: itzamjad@gmail.com

[2] Institute of Engineering & Technology, Srinivas University, Mangalore-575001, India.

[3] Institute of Engineering & Technology, Srinivas University, Mangalore-575001, India.
Orcid ID: 0000-0002-4691-8736, e-mail: psaithal@gmail.com

ABSTRACT

Purpose: Biometric trends are used in many systems because of security aspects. The cryptosystem is such an example which uses a biometric. But due to stored biometric data for the authentication, this can be a dangerous issue. Therefore, in comparison to conventional used biometric system, voice biometric system provides an efficient safety, security and unique identity. Among various speech recognition or processing methods, there is one called automated speech conversion methods, which also used to convert the recorded voice into text format. The overall concept of voice reorganization and voice biometric system is based on the acoustic modelling. Therefore, for getting the perfect speech detection, robust acoustic modelling is required. Our analysis describes the advancement and usage of voice biometric system for user identification and authentication. This paper provides a descriptive review of different voice biometric systems, their advancement and applications in different fields.

Methodology: The core principles of the research issue have been well discussed in the literature review on speech biometrics. During this process, selected journals from a variety of secondary data sources, such as research papers published in a variety of reputed journals periodicals that are related to the topic are studied in the methodology.

Findings/Result: A vocal biometric system is a biological system that captures an individual's voice and assigns it a unique characteristic for authentication purposes. This speech biometric method is primarily used to provide secure, quick, and frictionless access to various electronic devices. In the last three years, rapid technological advancements in neural networks have improved the deployment of speech biometric systems in a variety of industries. The majority of speech biometric system designs are based on the CPU, necessary power, and memory concepts. The advancement of software and hardware interface has been dramatically enhanced and implemented for many applications in the last few years, including smart watches, mobile phones, and car locking systems, where the interface between humans and electronics devices is critical. Banking security, attendance system, file access system, security control, and forensic development system are some of the other commercial applications.

Originality: Following the literature study, the findings were utilized to conclude that, despite advances in biometric technology, there is still a significant gap in practical application, particularly for voice biometric systems. When building and developing a voice biometric system, it is necessary to integrate it with an IoT system.

Paper Type: Literature Review.

Keywords: Voice biometric, Speech Detection, Acoustic modelling, User Identification and Authentication

1. INTRODUCTION :

The biometric analysis is a branch of science that leads with the statistical analysis of any biological data of an individual human being. This is an important method and technique which is used for the identification and authentication of any user by different features. Human is having various biological aspect which is unique from each other in the different combinational form [1, 2]. In the present world,

we are surrounded by different biometric systems which we use in day-to-day life. Almost 75% of the worldwide individuals support the usage of biometric systems such as retina scans, fingerprints or voice recognition [3, 4]. There are the following properties as Uniqueness (different in every individual), Stability (which doesn't change with time), Non-Confront (Cannot be fooled easily), Acceptability (easily accepted by people), Universality (common in everyone), Measurability (easily measurable), and Performance (related to error-free, speed and reliability) which are generally considered to understand the biological features for the biometric system [5]. These are the properties that decide all the features related to the biometric system [6]. Each biometric division has its use in different applications such as for security, voting or crime investigation. The choice of biometrics also depends on the authentication and identification requirement. The most widely used biometric system includes the matching of DNA and also shows the behavioral and physiological characteristics of the person.

Finger Print Biometric:

The fingerprint-based biometric is the oldest and most conventional method due to the varied fingers print of human beings. All the biometric systems authenticate and validate an individual's identity based on stored data. Initially, it was only a part of forensic research for identifying fingerprints. The interdisciplinary research which includes forensics with computers advanced the fingerprint biometric system. At present all electronic devices such as mobiles, and door security is widely controlled by fingerprint biometrics. These electronic devices are used to store the varied and rigid structure of the human fingertip which is used for detection technologies. There are many advancements and modification has been observed in fingerprint biometric modelling systems [7].

Iris Biometric System:

Iris is a circular connector, with a flexible and thin layer present in the eye. The tissue also controls the diameter and size of the pupil, which limits the amount of light entering in eyes. Iris recognition is a very unique and safe method for identification and authentication. This method describes more precise and most significant aspects. This method has a very low rejection and false recognition rate. The iris biometric system is used to identify the iris in a photo-based on the dots of darkness. As the iris responds to light immediately produces essential secondary verification [8]. The unique property is that the iris pattern doesn't get modified or changed with age, alcohol intake or eye disease. The iris biometric system responds in a very quick manner, without any physical contact with the devices [9]. But due to the high cost of installation and maintenance, the iris biometric is not used in a wide range of applications.

Facial Biometric System:

The facial structure most common technique in day-to-day life to remember any other person. It is also considered a biometric system for the identification and authentication of individuals. In this present generation, there are excellent quality cameras that can capture facial expressions from very distance also and can also be used for safety and security purposes [10, 11]. The facial biometric implementation is very easy to implement by using some basic setup of cameras and software for facial recognition. This facial biometric is a very flexible approach and can evolve rapidly that many electronic devices which use this technique continuously increase camera quality, processing and complexity. This flexible technique of biometric system helps to unlock the security system which can also be a disadvantage of this particular biometric system [12]. But this biometric system is also evident for many frauds, scam attack and false recognition due to aging, injury and identical twins. Therefore, this technique is having very limited applications.

Voice Biometric System:

The human voice is depending on the combination of mouth and throat with its moving components which possess both physiological and behavioral characteristics. Based on different variables, voice can be used as a critical biometric system. The audio composition of the language with different frequencies and amplitude defines the uniqueness of the individual voice. The voice biometric system is a combination of engineering development with biological science. The voice biometric system got the attention of engineers and technologies due to its fast, inexpensive, frictionless and secure method [13, 14]. The uniqueness of this overall biometric system is its rigidness, accuracy and ineffective with environmental changes [15, 16]. In this present literature review, we will be providing detailed and systematic research works on voice biometric systems used for the identification and authentication of individuals. The technological improvement and advancement of voice biometric systems and their beneficial application in different fields will be presented in this survey.

2. PURPOSE OF THE REVIEW:

(1) To understand the historical background of various biometric systems and parameters.
(2) To find the studies that prove the advancement of voice biometric systems and their implementation for different sectors.
(3) To identify the research gap and scope of a voice biometric system for the identification and authentication of individuals.
(4) To conclude the proposed study with proper methodology and solution towards the implementation of a voice biometric system.

3. METHODOLOGY OF DATA/INFORMATION COLLECTION & REVIEW:

To understand the detailed knowledge about the various biometric system and parameters related to them, we have gone through 50 excellent and high-quality research and review articles related to a broad range of biometric topics. The study also incorporates various case studies and survey of voice biometric system which was implemented in various sectors such as education, banking and household machines for security purpose. The overall studies and literature review suggested the comparison of collected data and method of implementation which proves the efficiency and disadvantages of the voice biometric system irrespective of the applications.

4. DISCUSSION OF RELATED WORK :

The Voice recognition method consists of two phases, the first is the training phase and the second is the testing phase. In the first phase, the human recorded voice which is in analogue form is converted into digital signals. The digitized signal is having a complex structure that should be processed by the system and helps to extract the required features of voice. Suzuki, H., et al in year 2003 demonstrated the voice biometric system based on an acoustic modelling system that considers the changes in characteristics of voice [17]. In this research work, the acoustic models for voice characteristics were constructed using tree dependent clustering method. The dictated content was judged from linguistic diction understanding using a triphone modelling system. To build the acoustic models for voice characteristics, an individual speaker's voice will be labelled for test listening results. As the triphone dependent content will be more, that can be grouped into different clusters. For voice recognition, individual leaf node contains the same content with different characteristics of voice which is integrated as a mixed combination. In this particular research, the developed system is having the capability to capture two thousand sentences that were taken from 130 speakers of individual gender. Integrated training has been implemented before and after applying the acoustic models. The overall results from this particular research show that different models show different approaches in view of a different gender.
In year 2011, Revathi et al., developed and demonstrated continuous voice modelling and Isolated Digital Recognition (IDR) by using well-known models Hidden Markoy Model (HMM) and Vector Quantization (VQ), based on unique voice characteristics [18]. This research uses the HMM and VQ modelling system for voice recognition. By using the power computing spectrum, the unique features were extracted and grouped with respect to different bands. Further, the cube root and loudness equalization were done to integrate power hearing simulation. This study also incorporated the Inverse fast Fourier Transform and Linear programming techniques to obtain a cepstral coefficient. All the probabilities are compared and a related voice was selected. The average accuracy of the developed system was reported as 93%.
In the year 2012, another approach was developed by Dua et al., for the recognition of Punjabi automatic speech using the HTK method and HMM modelling system [19]. This study also developed the GUI based system for voice data preparation, acoustic generation and analysis and GUI decoders. In this work, the first phase was dedicated to mentioning and recording the voice signals. The developed signals were trained to capture 115 varied Punjabi words which were recorded using the unidirectional microphone. The second phase was based on extracting the unique features which can be converted into acoustic signal vectors. For the prototype generation, optimal parameters of HMM were estimated.
Another approach was carried out by Hemdal et al, to find the basic voice sound and provides it with distinctive phonetic clusters using different spoken language [20]. The studies were broadly classified with acoustic characteristic properties with respect to time to voice signal processing. According to the approaches used in this study, the voice is classified and extracted with relevant binary properties

related to acoustic modelling. But unfortunately, the approach was not relevant and feasible for commercial applications.

Auto-detection of voice biometric for authentication and identification, is the best evaluation method, for the security and performance of the biometric system. F. Monrose et al in 2002, demonstrated the extraction of stored input voice to perform a cryptographic process, for personal digital assistance [21]. The studies also proceed with the ceptral coefficient approaches using autocorrelation, for a robust method.

Carrara B. et al, in 2010 introduced the modified randomized biometric template (RBT) algorithm which was used to perform a voice biometric system [22, 23]. The study also demonstrates inter-user variation and low intra-user variation for the quantization method. In the present scenario, human voice recognition is based on the distinctive binary scale with the biometric templates system. In conclusion, the author represents the existing biometric in comparison to the modified version.

In year 2015, Vijayalakshmi et al, was also demonstrated the method of voice recognition, which was focused on transforming voice to text content [24]. Karpagavalli et al., in 2016, also developed the auto voice identification method which focuses on converting voice into a word in sequence. This technique included the voice methodologies, issues in voice, tools, and applications [25]. Similarly, Saini et al in 2013, demonstrated the voice recognition technique with respect to change in rate of extraction with different classes. The author also introduced the more accurate system which was the major conclusion from the studies [26]. The advancements in ASR's technologies towards the development of voice biometric system was also explored by Ghai et al in 2012 [27]. The proposed method developed a voice biometric system which was used to differentiate various languages. In year 2016, Neha et al., demonstrated the Designing a Real-Time Speech Recognition System using MATLAB [28]. In this study specific, nine words were collected and analysed which were separated with respect to associated energies. The output of the research work was in the form of text which also uses a code system to convert it into a paragraph. The defined system was very sensitive to noise. The recorded words have created a database and it also has a sensitive issue in regards to pronunciation tone.

Table 1: Review of related work along with focus and outcome.

S. No.	Area & Focus	Outcome	Reference
1	Enhancing Internet Service Security with Voice Biometric Authentication	Internet applications are supplied with a higher degree of certainty regarding a customer's identity and are protected from fraudulent transactions by applying the recommended architecture.	[29]
2	Authentication Model for IoT Devices Using Voice Biometrics	The appropriateness of text-dependent speech recognition systems is encouraged as a result of the IoT technologies' resource limitations. MFCC properties are also taken into account in the suggested system.	[30]
3	Voice Biometrics: An Authentication Method Using Your Voice	Voice biometrics is a new field of study. This paper provides an overview of the process of recognizing people using biometric data.	[31]
4	Voice Biometrics and Speech Recognition-Based Speaker Authentication System	Were able to achieve 70.45 percent system accuracy using the proposed algorithms, with identification module accuracy of 100 percent and recognition module accuracy of 70.45 percent.	[32]
5	Multi-modal biometric authentication based on face and speech	On the eNTERFACE 2005 multi-biometric database based on face and voice modalities, the finite mixture modal (GMM) is highly effective in modelling the genuine and impostor score densities, and fusion based on the generated density estimates produces a substantial performance.	[33]

6	Android-based Voice Biometric Identity Authentication System	GMM is used to properly train the voiceprint feature model using voice segment data. When the number of training samples is 5, the system authentication success rate is between 89 and 96 percent, and the time required to authenticate a speech sample is between 210 and 320 milliseconds, demonstrating excellent accuracy and good real-time performance.	[34]
7	An examination of automated biometric authentication methods	Intends to provide a high-level overview of the area of biometrics and a summary of various biometric authentication approaches, including their strengths and weaknesses.	[35]
8	For safe access control, an embedded voice authentication option is available.	The methods for verifying the speakers are provided, along with a discussion of implementation performance improvement methods. Biometrics of the voice and automatic speech processing are examined.	[36]
9	Voice and facial recognition fusion is used in a multimodal biometric method for human authentication.	Features fusion and scores fusion are used to combine voice and face biometric systems into a single multimodal biometric system. The computer simulation experiments demonstrate that using cepstral coefficients and statistical coefficients for sound recognition yields better results, whereas Eigen face and SVM trials yield better results for face recognition.	[37]
10	Voice biometrics for data access and security: talking passwords	Every person's biometric traits, such as voice, face, fingerprints, and retina, are unique.	[38]

5. SIGNIFICANCE OF THE STUDY :

The present world is having more concern about the security system by using different technological developments [39, 40]. This present literature review and survey analysis on the biometric system more specific on voice biometric system are discussed and implemented in the planned research work. The technological advancement, advantages, disadvantages and applications for authentication and identification of individuals using voice biometric systems are discussed in detail.

6. IMPACT OF RESEARCH :

Voice biometric system is related to biological science which captures the individual voice and is having a unique characterization because of authentication. This voice biometric system is most importantly functioning to make secure, fast and frictionless access to different electronic gadgets. Drastic technological development in the neural networks in the last 3 years improve the implementation of voice biometric systems in various sectors. In general, the PINs and passwords have been used for authentication in commercial applications, ID cards system used by government organizations and forensic applications are based on the different biometric systems. Sectors especially banking and corporate using voice biometrics claims the extensive and accurate platform for identification and authentication of employees [41, 42].

7. KEY ISSUES AND CHALLENGES :

There are many hurdles and disadvantages in implementing a voice biometric system specifically for any new system which needs identification and proof of address of an individual. Experience through user management systems can get a way for users to custom and teach new systems [43, 44].

(a) Broad network and vendor coordination: The voice biometric system needs special devices in addition to modified hardware and software, which can happen only with the coordination of vendors and third party (including government bodies). This system of getting and providing the hurdles information becomes a key challenge [45].

(b) Economic Challenges: The budget is very important for implementing any advanced technological development for regular usage. Apart from adoption, more importantly, the maintenance budgets should be planned properly. This is always a key challenge that should be clarified from the customer's and dealer's side [46].

(c) Functioning Hurdles: Many issues affect the function and authentication of voice biometric systems such as multiple voices during data collection, short utterness and bandwidth usage and availability of the used app.

(d) Security Concerns and Policy: Even after various formations, people and companies should show some more interest in the implementation of a voice biometric system. Removing the fear of adopting new technology, discarding alternate systems and including clear documentation will help us to be successful in the implementation of a voice biometric system [47].

Once these all-major challenges have been overcome, this voice biometric system can be implemented for safety, security and up-gradation in technology which will allow the participation without any barrier.

8. FINDINGS/RESULTS AND OBSERVATIONS :

After continuous and long-term research, voice biometric system and technology has started knocking on the door for applications in many sectors. Most of the voice biometric system design works on the concept of the microprocessor, required power, and memory. In the last few years, the evolution of software and hardware interface has been drastically increased and implemented for many applications such as smartwatches, mobile phones, and car locking system, where the interface between human and electronic devices are most important. There are some more applications used for commercial purposes, like banking security, attendance system, file access system, security control and forensic development system [48].

The key observation from these applications is a training of the system or app for the implementation of a voice biometric system is very important. The text-independent security system or authentication method can be a best practice without any obstacles. The identification and authentication, can also only be used when the data of an individual's voice has been collected without any disturbance. If the person at the time of voice collection is engaged in some other activity, then the voice biometric system may create trouble for authentication. Some biometric systems also asked for multiple utterances of the voice from the individual for absolute surety about the authentication of the person [49]. After reviewing many research works, we have found that there are many recommendations have been given for the improvement of performance and accuracy of the voice biometric system. First, the background noise should be reduced to a minimum for increasing the accuracy of the voice biometric system. Filtration will help for that but also increases the complexity of the amplitude range of the recognized voice. This will help the admin to record the correct voice of the individuals who comes with multiple sets of data, to gain accuracy in the system. It is also observed that the software can increase the blockage of incorrect data from being displayed [50].

9. SCOPE FOR FURTHER STUDY :

In the present arena, the voice biometric system started grabbing attention and increased the scope of usage. Banking and financial services are one of the major applications where the usage of voice biometric systems has been implemented. The increase in the online banking system has also given a chance and the greatest market share to voice biometric industries. These service industries ensure to provide an excellent and secure system for financial service which can also be used to prevent any kind of fraud. In future, this can be implemented for other banking facilities also [51, 52].

Another scope of voice biometric systems is the e-commerce industry. This finds the use of voice biometrics in consumer security, customer services, and performance. This also has a combination with the call centres which can connect and fins the authentication of customers and the agent bypassing the security question and matching the voice [53, 54]. To keep the security system and easy authentication access, the biometric system is capturing a way out with all consumer electronic devices such as home security, transportation, automobiles, logistic and defence as well [55-57].

The preference and usage of voice biometric systems are proved by the increase in voice search applications. Hence this is not a surprise if a voice biometric system is slated in a future for the verification and authentication of the individuals.

10. IDENTIFIED RESEARCH GAP :

Even after advancements in the technology of biometrics still, there is huge gap in the practical implementation, especially for voice biometric systems. There are very few research materials are available related to the implementation of a voice biometric system for the identification and authentication of an individual. Constructing and developing the voice biometric system needs interfacing with the IoT system, which is very hardly available in the literature. There are some small projects are available but do not provide sufficient information related to hardware and software interface. The storage condition in the biometric system which can be related to cloud computing systems also lacking behind to provide required authentication system [58].

Voice biometric system has many barriers to adoption such as:

(a) Weakness of the voice biometric system for live detection. Many electronic gadgets have been attacked successfully by using substitute biometric systems. This can offer high risk in the banking system.

(b) The health concern which disturbs the individual voice performance can create a hurdle during the authentication of any individual.

(c) The major task is differentiating between the male and female voices. Gender voice discrimination is sometimes becoming a hurdle for implementing a voice biometric system.

11. CONCLUSION :

This study summarizes the regular progress and technological development of the different biometric systems. The biometric system is a foundation and backbone of many securities systems for the authentication and identification of individuals. Among many biometric systems, these entire studies are concentrated on the implementation of a voice biometric system. A healthy e-commerce system with great security will also increase the global growth of the world's economy. Among many alternate approaches, the voice biometric system has been used in many important applications such as e-commerce and banking including registration and identification. The voice biometric system has many advantages over other biometric methods, due to easy use, acceptance and authentication. In this literature review, we are presenting the technological development, implementation, advantages and disadvantages of voice biometric systems for different applications. The gap and weakness of this particular technology must be measured and acknowledged by the research groups. In the present scenario, the biometric solution provides a user-friendly authentication, accuracy and cost-saving method. Therefore, at present, the usage of voice biometric systems is slow, but is having great future.

REFERENCES :

[1] Mohammad Al Rousan, Benedetto Intrigila (2020). A Comparative Analysis of Biometrics Types: Literature Review. *Journal of Computer Science*, *16*(12), 1778-1788.
Google Scholar↗

[2] Hossain, S. M. E., & Chetty, G. (2011). Human identity verification by using physiological and behavioural biometric traits. *International Journal of Bioscience, Biochemistry and Bioinformatics*, *1*(3), 199-205.
Google Scholar↗

[3] Kumar, D., & Ryu, Y. (2009). A brief introduction of biometrics and fingerprint payment technology. *International Journal of advanced science and Technology*, *4*(3), 25-38.
Google Scholar↗

[4] Galdi, C., Nappi, M., Riccio, D., Cantoni, V., & Porta, M. (2013, June). A new gaze analysis based soft-biometric. In *Mexican Conference on Pattern Recognition* (pp. 136-144). Springer, Berlin, Heidelberg.
Google Scholar↗

[5] Nilu Singh, Alka Agrawal, and R. A. Khan, (2018). Voice Biometric: A Technology for Voice Based Authentication, Advanced Science. *Engineering and Medicine*, *10*(1), 1–6.
Google Scholar↗

[6] Babich, A. (2013). Biometric Authentication, Types of Biometric Identifiers. Bachelor's Thesis, Degree Programme in Business Information Technology University of Applied Sciences (2013), pp. 1–56.

[7] Ali, M. M., Mahale, V. H., Yannawar, P., & Gaikwad, A. T. (2016, March). Overview of fingerprint recognition system. *In 2016 International Conference on Electrical, Electronics and Optimization Techniques (ICEEOT)* (pp. 1334-1338). IEEE.
Google Scholar↗

[8] Dua, M., Gupta, R., Khari, M., & Crespo, R. G. (2019). Biometric iris recognition using radial basis function neural network. *Soft Computing*, *23*(22), 11801-11815.
Google Scholar↗

[9] Ganorkar, S. R., & Ghatol, A. A. (2007, February). Iris recognition: an emerging biometric technology. *In Proceedings of the 6th WSEAS International Conference on Signal Processing, Robotics and Automation* (pp. 91-96). World Scientific and Engineering Academy and Society (WSEAS).
Google Scholar↗

[10] Cook, C. M., Howard, J. J., Sirotin, Y. B., Tipton, J. L., & Vemury, A. R. (2019). Demographic effects in facial recognition and their dependence on image acquisition: An evaluation of eleven commercial systems. *IEEE Transactions on Biometrics, Behavior and Identity Science*, *1*(1), 32-41.
Google Scholar↗

[11] Nakamura, T., Goverdovsky, V., & Mandic, D. P. (2017). In-ear EEG biometrics for feasible and readily collectable real-world person authentication. *IEEE Transactions on Information Forensics and Security*, *13*(3), 648-661.
Google Scholar↗

[12] Tripathi, K. P. (2011). A comparative study of biometric technologies with reference to human interface. *International Journal of Computer Applications*, *14*(5), 10-15.
Google Scholar↗

[13] Mohamed, C., Dan, I., Valeriu, V., & Michel, H. (2008). Biometric System Based on Voice Recognition Using Multiclassifiers. *BIOID 2008*, LNCS 5372, 206–215.
Google Scholar↗

[14] Desai, N., Dhameliya, K., & Desai, V. (2013). Feature Extraction and Classification Techniques for Speech Recognition: A Review. *International Journal of Emerging Technology and Advanced Engineering*, *3*(2), 5-9.
Google Scholar↗

[15] Saliha, B., Youssef, E., & Abdeslam, D. (2019). A Study on Automatic Speech Recognition. *Journal of Information Technology Review*, *10*(3), 77-85.
Google Scholar↗

[16] Gregory, G., & Jean-Luc, G. (2018). Optimization of RNN-Based Speech Activity Detection. *IEEE/ACM Transactions on Audio, Speech, and Language Processing*, *26*(3), 8-12.
Google Scholar↗

[17] Suzuki, H., et al. (2003). Speech recognition using voice characteristic- dependent acoustic models. *Acoustics, Speech, and Signal Processing, 2003. Proceedings.* (ICASSP'03). IEEE International Conference on. 2003. IEEE.
Google Scholar↗

[18] Revathi, A. and Y. Venkataramani (2011). Speaker independent continuous speech and isolated digit recognition using VQ and HMM. *Communications and Signal Processing (ICCSP)*, 2011 International Conference on. 2011. IEEE.
Google Scholar↗

[19] Dua, M., Aggarwal, R. K., Kadyan, V., & Dua, S. (2012). Punjabi automatic speech recognition using HTK. *International Journal of Computer Science Issues (IJCSI)*, *9*(4), 359-364.

Google Scholar↗

[20] Hughes, G. W., Jacobsen, H. J., Engel, A. I., & Halle, M. (1956). *Speech Analysis*. Research Laboratory of Electronics (RLE) at the Massachusetts Institute of Technology (MIT), pp- 109-117.
Google Scholar↗

[21] Monrose, F., Reiter, M., Li, Q., Lopresti, D. P., & Shih, C. (2002). Toward {Speech-Generated} Cryptographic Keys on {Resource-Constrained} Devices. In *11th USENIX Security Symposium (USENIX Security 02)*.
Google Scholar↗

[22] Carrara, B., & Adams, C. (2010, August). You are the key: generating cryptographic keys from voice biometrics. In *2010 Eighth International Conference on Privacy, Security and Trust* (pp. 213-222). IEEE.
Google Scholar↗

[23] Ballard, L., Kamara, S., Monrose, F., & Reiter, M. K. (2008, October). Towards practical biometric key generation with randomized biometric templates. In *Proceedings of the 15th ACM conference on Computer and communications security* (pp. 235-244).
Google Scholar↗

[24] Vijayalakshmi, A. Jimmy, M., Nair, M. (2015). A Study on Automated Speech Recognition Technique. *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*, *4*(3), 614–617.
Google Scholar↗

[25] Karpagavalli, S., Chandra, E. (2016). A Review on Automatic Speech Recognition Architecture and Approaches. *International Journal of Signal Processing, Image Processing and Pattern Recognition*, *9*(4), 393–404.
Google Scholar↗

[26] Saini, P. Kaur, P. (2013). Automatic Speech Recognition: A Review, *International Journal of Engineering Trends and Technology*, *4*(3), 132–136.
Google Scholar↗

[27] Ghai, W., Singh, N. (2012). Analysis of Automatic Speech Recognition Systems for Indo-Aryan Languages: Punjabi A Case Study, *International Journal of Soft Computing and Engineering (IJSCE)*, *2*(1), 379–385.
Google Scholar↗

[28] Sharma, N., & Sardana, S. (2016, September). A real time speech to text conversion system using bidirectional Kalman filter in Matlab. In *2016 International conference on advances in computing, communications and informatics (ICACCI)* (pp. 2353-2357). IEEE.
Google Scholar↗

[29] Kounoudes, A., Kekatos, V. and Mavromoustakos, S. (2006). Voice Biometric Authentication for Enhancing Internet Service Security. 2nd International Conference on Information & Communication Technologies, 2006, pp. 1020-1025.
Google Scholar↗

[30] Duraibi, S. (2020). Voice biometric identity authentication model for IoT devices. *International Journal of Security, Privacy and Trust Management (IJSPTM)*, *9*(1/2), 1-10.
Google Scholar↗

[31] Singh, N., Agrawal, A., & Khan, R. A. (2018). Voice biometric: A technology for voice-based authentication. *Advanced Science, Engineering and Medicine*, *10*(7-8), 754-759.
Google Scholar↗

[32] Dovydaitis, L., Rasymas, T., & Rudžionis, V. (2016, July). Speaker authentication system based on voice biometrics and speech recognition. In *International Conference on Business Information Systems* (pp. 79-84). Springer, Cham.
Google Scholar↗

[33] Soltane, M., Doghmane, N., & Guersi, N. (2010). Face and speech based multi-modal biometric authentication. *International Journal of Advanced Science and Technology*, *21*(6), 41-56.
Google Scholar↗

[34] Zhang, X., Xiong, Q., Dai, Y., & Xu, X. (2018, December). Voice biometric identity authentication system based on android smart phone. In *2018 IEEE 4th International Conference on Computer and Communications (ICCC)* (pp. 1440-1444). IEEE.
Google Scholar↗

[35 Kataria, A. N., Adhyaru, D. M., Sharma, A. K., & Zaveri, T. H. (2013, November). A survey of automated biometric authentication techniques. In *2013 Nirma university international conference on engineering (NUiCONE)* (pp. 1-6). IEEE.
Google Scholar↗

[36] Gałka, J., Masior, M., & Salasa, M. (2014). Voice authentication embedded solution for secured access control. *IEEE transactions on consumer electronics*, *60*(4), 653-661.
Google Scholar↗

[37] Abozaid, A., Haggag, A., Kasban, H., & Eltokhy, M. (2019). Multimodal biometric scheme for human authentication technique based on voice and face recognition fusion. *Multimedia Tools and Applications*, *78*(12), 16345-16361.
Google Scholar↗

[38] Khitrov, M. (2013). Talking passwords: voice biometrics for data access and security. *Biometric Technology Today*, *2013*(2), 9-11.
Google Scholar↗

[39] Shradha, T., Chourasia, J. N., & Chourasia, V. S. (2015). A Review of Advancement in Biometric Systems. *International Journal of Innovative Research in Advanced Engineering*, *2*(1), 22-26.
Google Scholar↗

[40] Gursimarpreet, K. & Chander, K. V. (2014). Comparative Analysis of Biometric Modalities. *International Journal of Advanced Research in Computer Science and Software Engineering. 4*(5), 10-16.
Google Scholar↗

[41] Hagai Aronowitz, Ron Hoory, Jason Pelecanos, David Nahamoo, (2011). New Developments in Voice Biometrics for User Authentication, INTERSPEECH, 28-31 August 2011, Florence, Italy.
Google Scholar↗

[42] Ahmad Tasnim Siddiqui, Biometrics to Control ATM Scams: A Study, 2014 International Conference on Circuit, Power and Computing Technologies [ICCPCT], 978-1-4799-2397-7/14/$31.00 ©2014 IEEE.
Google Scholar↗

[43] Singh, N. and Khan, R. A. (2015). Extraction and representation of prosodic features for automatic speaker recognition technology, Advanced in Engineering and Technology, Published by: Mc Graw Hill Education (2015), pp.1–7, ISBN-10:93-85965-79-4.

[44] Jeong, S., Hahn, M. (2001). Speech quality and recognition rate improvement in car noise environments. *Electron. Lett.*, *37*(12), 800–802.
Google Scholar↗

[45] Sonali Goyal and Neera Batra, (2017). Issues and Challenges of Voice Recognition in Pervasive Environment. *Indian Journal of Science and Technology*, *10*(30), DOI: 10.17485/ijst/2017/v10i30/115518, August 2017.
Google Scholar↗

[46] Patil, R. P., Mulla, M. R. (2015). A Review Design and Implementation of Image Acquisition and Voice Based Security System. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, *4*(3), 1–6.
Google Scholar↗

[47] Swamy S, Ramakrishnan K. V. (2013). An Efficient Speech Recognition System. *Computer Science and Engineering an International Journal*, *3*(4), 1–7.
Google Scholar↗

[48] Nearey, T. M. (1997). Speech perception as pattern recognition. *J Acoust Soc Am.*, *101*(6), 3241–3254.
Google Scholar ↗

[49] Rashid, R. A., Mahalin, N. H., Sarijari, M. A., & Aziz, A. A. A. (2008, May). Security system using biometric technology: Design and implementation of Voice Recognition System (VRS). In *2008 international conference on computer and communication engineering* (pp. 898-902). IEEE.
Google Scholar↗

[50] de Krom G. (1994). Consistency and reliability of voice quality ratings for different types of speech fragments. *J Speech Lang Hear Res.*, *37*(1), 985–1000.
Google Scholar↗

[51] Tanwar, R., Singh, K., & Malhotra, S. (2019). An Approach to Ensure Security using Voice Authentication System. *International Journal of Recent Technology and Engineering (IJRTE)*, *7*(5), 161-165.
Google Scholar↗

[52] Markowitz, J. A. (2000). Voice biometrics. *Communications of the ACM*, *43*(9), 66-73.
Google Scholar↗

[53] Miller, D., & Fauve, B. (2012). Mobile e-commerce to drive voice-based authentication. *Biometric Technology Today*, *2012*(2), 5-8.
Google Scholar↗

[54] Ferrag, M. A., Maglaras, L., & Derhab, A. (2019). Authentication and authorization for mobile IoT devices using biofeatures: Recent advances and future trends. *Security and Communication Networks*, *2019*(1), 1-20.
Google Scholar↗

[55] Khamis, M., Alt, F., Hassib, M., von Zezschwitz, E., Hasholzner, R., & Bulling, A. (2016, May). Gazetouchpass: Multimodal authentication using gaze and touch on mobile devices. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (pp. 2156-2164).
Google Scholar↗

[56] Yassine, A., Singh, S., Hossain, M. S., & Muhammad, G. (2019). IoT big data analytics for smart homes with fog and cloud computing. *Future Generation Computer Systems*, *91*, 563-573.
Google Scholar↗

[57] Ren, Y., Fang, Z., Liu, D., & Chen, C. (2019). Replay attack detection based on distortion by loudspeaker for voice authentication. *Multimedia Tools and Applications*, *78*(7), 8383-8396.
Google Scholar↗

[58] Gupta, S., & Chatterjee, S. (2012). Text dependent voice based biometric authentication system using spectrum analysis and image acquisition. In *Advances in Computer Science, Engineering & Applications* (pp. 61-70). Springer, Berlin, Heidelberg.
Google Scholar↗

****