

Comparative Analysis of Biometric Recognition Techniques

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Abstract – This research paper discusses a person's different biometrics modalities that are used for personal recognition and identification system. Advantages and disadvantage have also been discussed for many biometrics modalities. Biometrics provide a reliable authentication to determine the identity of a person in contrast to IDs and passwords. There are lots of applications now a days which are using biometrics for their systems like ATMs, attendance systems, mobile phones, electronic banking, access to secure places etc. In this paper a survey of all biometrics is presented that are presently in use or under development or still in the research pipeline. Further, a comparative analysis of the biometric techniques is summarized in a Table which provides their cost, uniqueness, accuracy and their additional requirements. Furthermore, application, pros and cons are also discussed for each technique.

Index Terms – Biometric, Identification, Verification, Recognition, Unimodal, Bimodal

I. INTRODUCTION

BIOMETRICS is a term used to describe a physiological or behavioral characteristic of human that can be used for automated recognition systems. Other authentication methods like passwords and IDs are used to get access to secure systems but these methods can easily be broken. Biometric modalities cannot be stolen, forgotten, borrowed or forged.

These modalities have the capability to reliably distinguish between an authorized person and an imposter. A standard approach to biometric based recognition system can be divided into five major phases: 1) A sensor is used to capture biometric data and store it in digital form. 2) Digital signal processing techniques are used to refine sensor input, preprocess the captured data, remove noise and develop biometric template. 3) The template is stored in a data storage module that is compared to novel input during testing phase. 4) A trained machine learning model is used to recognize new biometric data by finding its closest match in the data store. 5) In the end, a decision process is used to retrieve the best match and make a system-level decision. Some known biometric senses are face, iris, fingerprint, voice, signature and hand geometry etc. which are being used in present biometric recognition systems.

This paper surveys all biometric recognition techniques available in the literature and provides a comprehensive

analysis on such techniques. Moreover, multimodal approach is used to check multiple features of the same individual. This approach provides more secure environment against evaders and attackers. Multimodal systems use multiple sensors for capturing various biometric techniques. Various algorithms and approaches are used in biometrics identification and verification techniques. The major approaches include optimized neighborhood averaging, zero crossing detection, clustering technique and vector quantization etc. [1]. Each modality has its own pros and cons according to scenario and no one is best for all implementations.

II. DENTAL RADIOGRAPHY

Dental radiography is a technique that can be used for both living and non-living people and provides very unique features for identification of a person's teeth diseases like tooth contours, crown, filling etc.

Dental data first used for identification of victims of disaster in Paris. After this, it gains attention by Forensic Dentistry and accepted currently globally [2].

Its identification System consists of Dental Radiography, preprocessing, feature extraction and matching [3]. Three types of dental radiography used for acquisition Bitewing X-Ray, Periapical X-Ray and Panoramic X-Ray [2, 4, 5]. After the acquisition, stored radiography selected from the database and preprocessed [6]. Feature extraction can be done by using morphological operation, image cropping operation and Thresholding [7-10]. Matching can be done with histogram features Skewness, kurtosis and mean [3]. It is used in Forensic identification [11, 12].

III. EAR BONE PATTERN

Ear bone pattern lobes features make the biometric technique for identification of the person Structure of the ear is stable with time but go through to predictable variation. The credit goes to Alfred Iannarelli [13] who developed this technique and introduced a system for ear biometric identification system in 1949.

The Image acquisition process works in such a way that the camera captures the side poses of person head. After image acquisition, system separate ear from hair, clothes and face. Many algorithms have been proposed to account the problem of acquisition, extraction and interpretation. Among them some approaches like adjacency graph [14], force field feature extraction [15], sparse representation [16], capture 3D images as well as utilized Iterative Closed Point [17], 3D ear detection by utilizing local surface descriptor as well as ICP [18] and system based on acoustic attributes [19, 106].

It is used in forensic and for identification of people's in the victim of natural disasters.

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IV. FINGERPRINT

Fingerprint recognition is one of the old biometric technique which has been commercially used because of its low cost, small template size and high accuracy. It can be used for person identification as well as verification. It consists of ridges and valleys pattern which are upper and lower skin portion of fingerprint respectively.

Fingerprinting dates back to ancient times. In 1892, Galton develops a classification of fingerprints [20] after that, Henry develops a fingerprint classification system in 1896 [21] which was deployed in NY state prison for criminal identification. After Hughes publication in 1963 [22], interest in automating finger print based biometric recognition was increased [23]. The development and improvement process is still on its way.

The matching techniques that are used for fingerprint consists of Minutia Point based [24], ridge characteristics based [25], correlation based [26], gradient based [27] and wavelet based [28]. Minutia point based matching system, is mostly used in these studies as a matching technique, but it is very sensitive to environmental elements like noise and deformation [29]. Ridge based method work against when minutia feature based method hands off. Lines on the surface of fingerprint are called Ridges that can be of different patterns [30] but poor line segmentation makes this technique less effective [31]. With co-relation we can combine two fingerprint pattern images and make distinct aligning [26]. Directly or indirectly, among these techniques are affected by different sensitivity factors [32]. In gradient based techniques, minutiae point's neighbor divided into different regions to calculate align gradient histogram, and then textual data separated across each minutiae point's [27]. On the other hand wavelet based feature work in such sense that, core point identified by means of hybrid approach then on the similar region near core point, wavelet is applied [28]. A little while back, proposed [33] fingerprint texture feature of discrimination in personal identification.

It is used as authorization of person in different domains like monetary, room entry, access control etc. It is also a part of CNIC for individual identification.

V. IRIS

Iris is the most prominent, highly accurate and most reliable technique today. Inside our eye, iris muscles regulate pupil size, which is responsible for how much amount of light needs to be entered inside of our eye. Due to melatonin pigment, Iris structure, color or pattern is different in every individual, even in twin [34].

Initially in 1936, iris recognition method was proposed for the identification of a person [35], and then idea of two irises was introduced in 1985 [35]. The improvement in results demonstrated by later approach causes increased interest in iris recognition system. First automated iris recognition system was introduced in [36] and then many different automated Iris recognition algorithms were proposed [37].

Many people proposed different methods for iris recognition system like 1D wavelet based [38], representation method [39], 2D Haar wavelet based [40], symmetric filters [41], multi-channel Gabor filters [42], directional filter [43], correlation filters [44], improved version that use key local variation [45], moment-based [46], Daugman's 2D Gabor filter [47] and 1D local texture [48].

It can be used in forensic practices, authentication system, banks etc.

VI. KNUCKLE CREASE

Finger-knuckle structure and surface makes it unique biometric technique [49]. The bending pattern of finger-knuckle makes it unique for everyone.

With the passage of time, people proposed many methods. [49] Proposed a method but not efficient with outer finger. To overcome this, [50, 51] proposed authentication based on 2D finger-back. After that [52, 53] proposed identification based on finger knuckle orientation features.[54, 106] Proposed classification method that depends upon line features and location. Then principal component analysis (PCA) introduced to transform capture images to lower dimensional [55].

It is used in online client identification.

VII. LIPS FEATURES

Lip grooves, rouge color and labial wrinkles are the features used for identification of a person by using lips print. The outline of the lip has a high possibility of acceptance in identification [56]. Lip pattern of an individual can be captured through non-invasive means and have progressive stability [57]. It has both behavioral and physiological data which is quite useful for identification purposes.[58] Used lip shape and color for recognition purposes. Lips print resembles with fingerprint as well as varies from one person to another. A combination of upper and lower lip is commonly used for identification in postmortem records.

Local feature extractions by using SIFT and SURF from grayscale images of lip are commonly used as low-level features by recognition systems. By using SIFT and SURF in [58] the proposed system was able to achieve accuracy greater than 90%. Lips outline acquisition is possible from color images. After that it can be transformed into a Grayscale image using Huang and Novak transformation, which can be then converted into binary form by using Ridler and Caviar threshold. Lip outline has hit ratio reported in [56] is 96.9%.

It used in forensic and criminal applications.

VIII. MOUSE DYNAMICS

Mouse dynamics fall into behavioral biometric categorization. In mouse dynamics, an individual is recognized on the basis of its behavioral characteristics of interacting with mice like movement speed, distance, double clicking speed, acceleration in each direction etc.

Traore [59] introduced an approach with a combination of mouse and keystroke dynamics. Bradley and Pusara [60] studied about re-authentication by using mouse dynamics.

Zheng [61] presented an approach to monitor user mouse movement passively; extraction of angle based metrics and for verification uses Support Vector Machine (SVM). Their main focus was on mouse movements by using angle-based metrics. These are quite unique to each individual and independent of computing platform.

It can be used where you can see more uncertainties in behavior of user for identification and in digital forensics practices [108].

IX. RETINA

Retina blood vein at the back of eye to each person is unique. This technique is more accurate, not easily forgettable [62], having low error rate and most secure. But it is expensive to use, not user friendly and glasses can affect the results. Cones and rods differentiate between different colors of light. Most of the times it is used for verification. Retina and iris seems to be same, but they are distinct in functionality and form [62].

Goldstein and Simon discovered uniqueness of the retina vascular pattern for recognition of a person while researching on eye disease in 1935 [63]. In contribution, Paul [64] founded that retina vascular pattern unique even in identical twins.

Retina vascular pattern recognition system consists of four phase's [65]. Firstly, the retina blood vein pattern is acquired by using a low-intensity beam (either visible light or infrared) into the target person's eyes. Then the retina is scanned for image acquisition. A person needs to be focused while retina scanning is in process. After acquisition it preprocessed the colored image. Secondly, retina vascular pattern image enhanced by using 2D wavelet and extracted using adaptive threshold. Thirdly and important step is features extraction and filtration. And in last feature matching with template.

Retina biometric used where you cannot compromise with security like in a bank, top secret agencies etc.

X. SCLERA RECOGNITION

Sclera recognition is a new technique and has accuracy as close as to iris recognition. It's the white outer protective area surrounded by eye. The structure of sclera blood vessels is unique to every person. With aging factor, blood vessels don't degenerate [66-69]. Sclera vein pattern can be easily captured in the visible light.

There are many methods developed so far on the basis of sclera several layers, tissues [67], [68] like Conjunctiva blood vessels pattern recognition [69-72]. [73] Proposed a new method for sclera segmentation of both grayscale and color images. For improvement and feature extraction, [73] used Gabor wavelet based method and line descriptor respectively.

XI. BODY SALINITY

In this technique, we measure the natural level of salinity by using electric fields. This is done by passing approximately one-billionth of an amp. As human body already possess natural current but the current we are passing is relatively less than the human body already possess. 400,000 bits of data are claimed to be transferred. The applications by using body salinity could be the interaction between watches, pagers and mobile phones as these devices human body already contain normally. Other applications could include the awakening of appliances by entering into the room.

XII. DNA

Deoxyribonucleic acid is a type of macromolecule, present in every human. It is a genetic code that is unique for each individual except for the identical twins as they share same DNA pattern. DNA is located in the nucleus of the cells as well as the mitochondria. DNA code comprised of purine and pyrimidine bases. Purine bases are adenine and guanine while the pyrimidine bases are thymine and cytosine. These bases combined in a specific sequence to determine the forms and functions of the organisms. Human body possesses about 3 million bases out of which only 1 percent is unique to each individual, which is used as the DNA biometric identification. As these bases are large in number, therefore scientists use a small number of sequences of DNA (short tandem repeats). Before STR has been introduced, Variable Number Tandem Repeats (VNTR) have been used as the basic DNA verification or identification procedure, but as it has recognition problem with degraded DNA samples due to its large size. Therefore Short Tandem Repeats (STR) procedure has been introduced as it is shorter in size, which has reduced the sample size as well as problems with degraded samples [74]. PCR (Polymerase Chain Reaction) technique is used for amplification of DNA samples [74, 75]. DNA based recognition has been used in forensics and paternity testing. The main advantage of this system is that it is very accurate and it is not possible to forge it. The disadvantage of DNA based recognition is that it cannot distinguish between identical twins. Its matching is still not done in real time.

XIII. GAIT

Gait based recognition techniques use person's walk style for recognition. It is not that distinctive as compared to other biometrics. It's a relatively new field and a challenging research area. The major advantage of gait based biometric methods is that we don't need the consent of a person for identification as it can identify a person at a distance and at low resolution as well [76]. It's a behavioral biometric so might change after some time. It can also be affected by pregnancy, illness and even drunkenness. The gait based recognition is normally divided into 2-D and 3-D based recognition technique [77]. In 3-D based approach features are extracted from 3-D limb movement. While in 2-D based

approach the features are extracted from the silhouette shape [78] or human body model [79]. The gait recognition can be used at airports where someone is trying to hide his face. The gait recognition was used in the bank robbery investigation at Noerager (Denmark) [80].

XIV. HAND GEOMETRY

Hand geometry is considered to be a cheap and easy to use biometric technique. In this technique we measure different dimensions of hand to make it unique for each individual like overall structure of the hand, shape of the hand, the length of the fingers, the width of the fingers, the width of the palm, and location of joints, etc. some of the approaches like contour-based, Independent Component Analysis and Hausdorff distance of the Hand Contour can also be used for hand geometry verification [81]. Although hand geometry is not that distinctive as compared to other biometric techniques, but would show very impressive results if combined with other biometric techniques like palm print, fingerprint, etc. [82]. Earlier systems for hand geometry used pegs so that the hand will be placed properly [83, 84]. But now different pegs-free techniques have been introduced, which also increases user acceptance [85, 86]. In this technique as we are measuring different features of hands so dirty hands will not be a problem. The advantage of this biometric is its small template size and less complexity [87]. The disadvantage of this biometric are it will not be used for identification purpose, especially in case of large a database as it has very high false acceptance rate. The system also has some limitations regarding the patient suffering with arthritis. Hand geometry based verification achieved around 11% of market share in 2004 [86]. It has also been used at Shearson Hamil on Wall Street for automatic attendance [88].

XV. KEYSTROKE

It has been studied that each person types on a keyboard in a different way and everyone has its own speed, pressure, and time taken to hitting certain keys [89]. The Keystroke technology uses the compatible keyboard with the normal PCs [89].

This technique is not very discriminative but still can provide useful clues for some individuals [90]. It is a type of behavioral biometric. Another issue to think about here is privacy.

Pros

- The advantage of this method is that keystrokes of a person who is using a system could be monitored easily without disturbing him/her.
- If a person is on other place and need to recognize somewhere, then he can recognize from his/her keystroke.

Cons

- Sometimes a person may loss his concentration & doesn't pay attention that might change his keystroke pattern.

If a person is mentally or physically ill that might be a disturb keystroke pattern.

XVI. PALM PRINT RECOGNITION

The region between wrist and the fingers are considered as palm print. Palm print also contains features like ridges and valleys present in finger print. But as the size of the palm is larger than the fingers they are considered to have more information. Palm print systems are of two type high resolution and low resolution. High resolution contains features like singular points, minutia and ridges. Whereas low resolution contains textures, principal lines and wrinkles [91-94]. The algorithms used for extraction of minutia features for fingerprint can also be used for palm print recognition. The history of palm print is very old and it was used in the sales, deeds of Chinese in 16th century [95]. In the early 1990s the first automated palm print system was launched. The FBI is using palm print recognition as the major component for its Next Generation Identification (NGI) system [96]. Palm based recognition is mostly used in forensic, law enforcement agencies and for commercial applications. The advantage of palm print is that it is very accurate and difficult to forge. The disadvantage is its cost, as the size of the scanner is relatively large. It is slower as compared to finger print due to the extra information it got as compared to finger print.

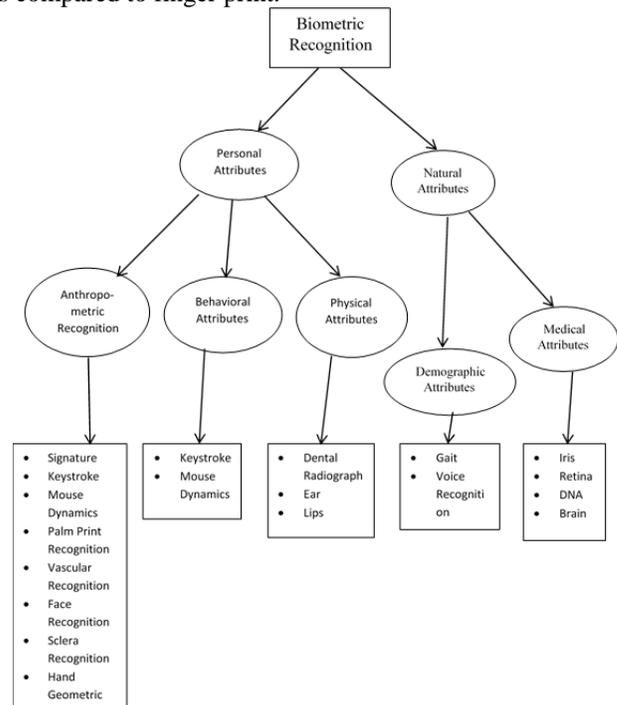


Fig. 1. Biometric attributes and categories.

XVII. VASCULAR RECOGNITION

Vascular recognition also known as veins pattern recognition is a cost effective, accurate and easy to use biometric technique which uses a person back of hand veins

pattern as a unique biometric feature. It is considered to be most secured because veins are beneath the skin of a person's hand so they will not be forged easily.

The matching techniques that are used for vein pattern consists of the thermal-imaged [97], knuckles based [27] fusion based [28], and multimodal based [98]. Thermal-imaged based [97] person verification system using Line Segment Hausdroff Distance (LHD) and tested on a small database of 30 persons. In respect, knuckle based [99] technique, that use minutiae based feature as key to match vein junction point. A Fusion based [100] technique using ordinal code and Hessian phase with Laplacian palm and localized Radon transform. In multimodal based [98] system which uses the combination of palm print and vein pattern images.

In vascular recognition system an infrared diode and high resolution camera are used to capture the vein pattern. As infrared rays fall on the person hands some of it are absorbed in the veins and shows up as a dark region while the rest of the hand appears as white, these captured patterns are then stored in a database as a template. These vascular patterns also contain information about blood vessels branching points, branching angles and vessel thickness. The disadvantage of this biometric is its effect on human health is not clear yet.

XVIII. VOICE RECOGNITION

The Automated voice recognition is old as the other biometric techniques. The first research was started in 1936 when the AT&T's laboratories produced the electronic speech synthesizer called the Voder, and it was developed for the transmission of voice on copper wires and for encryption of voice. In 1939 the experts enhanced that technology with the keyboard and foot pedals to play the machine and to emit voice.

In 1960's after a lot of research by the John Pierce of Bell Laboratories said that the recognition of voice requires the artificial intelligence, so that moved the research in new directions. A dragon system was founded by the Jim and Janet Baker in the 1980's that was a new innovation in voice recognition & it was released on 1st of Jan 1995 to the consumers, & it also got the attention by the IBM and Kurzweil few months later.

So in 1998 voice recognition took a better place in biometrics techniques, and many big companies such as (Microsoft, Lernout & Hauspie, IBM, Apple) are interested to work in voice recognition. Lernout & Hauspie bought Kurzweil and after it Microsoft invested \$45 million in Lernout & Hauspie to make partnership so that will allow Microsoft to use that speech recognition technology in their system. In 2003 Scan Soft introduced a new technology in voice recognition but they deals with the IBM to distribute and support their via-voice desktop products. After ScanSoft in 2007 SIRI Inc. introduced the SIR (Speech Interpretation and Recognition Interface) that can also be used to recognize natural human voice & to answer it, but at the same time that technology was acquired by the Apple Inc. to use as an integrated application in their Apple iOS. So with a lot of

Research in voice Recognition Today it has many more advanced & reliable than the past time.

Pros

Voice Recognition is faster than typing.

- It is totally contact less & even a consent less because people may not be known that they are recognized by their voice.
- It does not move in different areas & it is easy to manage so that's why it is non-invasive.
- Distinctive in terms of vocal chords, vocal tract, sinuses, and mouth tissues
- Vocal tract is not affected by a cold.
- It can be used with Mobile & telephones.
- Low invasiveness

Cons

- Voice recognition is much more expensive than the typing.
- A voice easily corrupted with noise, so may not be suitable for use in public places.
- Probability of High false rates (positive and negative) due to physical ailments (cold & cough, sinus problems, etc.)
- Age is also a big factor that affects the voice recognition. High rate of non-matching ratio.

XIX. BRAIN/EEG

Brain /EEG (electroencephalogram) is a new approach in biometrics [1]. Brain/ EEG (electroencephalogram) signals are an electrical activity of the brain. It contains the useful information about the brain state which is very difficult to get information from these signals directly in the time domain just by observing them. The non-linear and non-stationary in nature makes it difficult to collect information from it. But the important features can be extracted for the diagnosis of different diseases using some advanced signal processing techniques.

In 1999, a research was made by the Poulos and he proposed to model the Electroencephalogram signal using autoregressive models and use the Kohonen's vector Quantizer for the classification [101].

Research in this approach was continued by the Paranjape and he introduced the discriminant analysis (DA) to perform classification [101].

However, fuzzy neural network and the most recent (Gaussian mixture and Posteriori model adaptation) was proposed to enhance and to get more feasible results. But today still it needs lots of research for the better results [101, 107].

EEG as an important tool for localizing brain tumors.

XX. FACE RECOGNITION

Today Face Recognition is one of the best biometric Technique that is being in used to Identify Individuals by their facial features [102]. Research in face recognition was

started 30 years ago, and as a result, today it is much more advanced in technology & measurements.

Automated face recognition is a newly concept, but it was 1960's when the first Semi-Automated Face Recognition system was developed, & it needed an administrator to Identify facial features such as (Eyes , Ears, Nose , and Mouth) on the images to calculate and measure facial feature and to compare with reference data [31, 102]. So after 10 years in 1970's Goldstein, Harmon, and Lesk Introduced a 21 facial features like hair color and lip thickness to make the face recognition automated [103]. But both of these techniques were failing because the measurements and locations were manually computed.

In 1988 it was a great achievement by the Kirby and Sirovich who introduced the PCA (principal component analysis). It was a standard linear algebra technique that can be used to recognize faces. In that technique, it only needs less than a hundred values to accurately code a suitably aligned and normalized face image [102, 103].

PCA was not enough to recognize face so in 1991, Turk and Pentland discovered that while using the Eigen-Faces techniques the missing information (residual error) could be used to detect faces in images that makes it reliable in real time automated face recognition [1,2]. So after a lot of research it took the public's attention from the media in January 2001 Super Bowl, which takes target images, and compared them to a database of a digital mug shots. So with that technology, it initiated a number of analyses how to use technology on different places to support national needs & interest while being without contact with the public's social and privacy concerns.

Like other biometric techniques face takes the best place in personal identification, because it is much more unique and more reliable than the other techniques [102, 109]. A face involves many features such as hair, forehead, eyebrows, nose, lips, and chin. And these all features are different in every person if they are not twins. The person's facial structure varies from each other while other techniques it may have a few things to match & to identify the person correctly, but face involve many things such as (hair, forehead, eyebrows, nose, lips, and chin) that can be used to recognize person accurately.

In other biometric techniques people may have to contact with biometric devices, but face recognition is fully consenting & contactless because it only requires the image/video from a camera in a real time to recognize a person without disturbing them.

XXI. ODOR

Body odor recognition is not old, as the other biometrics, it's a contactless physical biometric technique that is used to identify a person by his/her body smell. Like finger print & Irish every person has different body smell [104, 105].

In Odor recognition, a smell is captured by the sensors that are capable to obtain the odor from the non-intrusive parts of the body such as the back of the hand [104, 105]. For this purpose a sensor is developed by the University of Cambridge which is capable of capturing any human body

scent, where the Machine uses the perfumes and deodorant to recognize any person.

One other Methods of capturing a person's smell are being explored by Mastiff Electronic Systems [105] but this technology is not applicable yet & it requires a lot of research on it. Each human smell is made up of chemicals known as volatiles. They are extracted by the system and converted into a string of data & develop a template.

The use of body odor sensors brings up the privacy issue as the body odor carries a significant Amount of sensitive personal information. It is possible to diagnose some diseases or activities

In the last hours (like sex, for example) By analyzing the body odor [105].

XXII. SIGNATURE RECOGNITION

Today dynamic signature is one of the most common techniques that are being used for the personal identification & it depends upon the behavioral characteristics of individuals when he or she sign for recognition purpose.

The first signature recognition system was developed in 1965. So after some years in research, the researchers continued research & they focus on the use of static or geometric characteristics rather than the dynamic characteristics of a signature. Static or Geometric characteristics means what the signature look like & the dynamic means how the signature was made. The interest in dynamic signature was becoming more attractive when the scientist introduced the touch sensitive technology.

Uniqueness

Like any other techniques, signature recognition is also different from other because every person has its own hand structure & style to write so that's making it different from others. The Signature recognition system measures the physical activity of signing involves the order of stroke, pressure & speed applied by the person, but in some systems it uses to compare visual images of signatures.

Pros

- While it is easy to copy the image a signature, it is extremely difficult to mimic the behavior of signing.
- Low False Acceptance Rates (FAR).
- People are used to sign documents, so signature recognition systems are not perceived to be invasive

Cons

- People may not always sign in a consistent manner.

Applications of Biometric Signatures

- This technique is very helpful in order to restrict duplicate signature frauds.
- It can also be in such organizations where paperless procedures are involved such as online transactions.
- Patient medical records and prescriptions can also be made secure using this biometric technique.

- To prevent the unauthorized access to sensitive data in highly sensitive organizations, this technique is very effective.
- It can also act as a password to computers to protect against illegitimate access.

A most recent application of this approach is its use in cell phones to prevent unauthorized access when phone is lost.

XXIII. ANALYSIS AND DISCUSSION

There are multiple aspects to consider before selecting any biometric technique to use for an application. Factors like acceptability, cost, uniqueness, accuracy and hardware requirement etc. are very important. Table 1, illustrates the dependability of biometric modality on these factors. It is pertinent to mention here that a single modality is not suitable for most situations. Table I helps us to decide the best one according to the situation. Further, Table I shows that face recognition has high level of acceptability and accuracy.

TABLE I BIOMETRICS MODALITIES COMPARATIVE ANALYSIS

| Biometrics | Acceptable | Cost | Uniqueness | Accuracy | Experts Requirement | Add. Hardware |
|--------------------|------------|--------|------------|----------|---------------------|---------------|
| Dental Radiography | High | Low | Medium | Medium | Medium | Low |
| Ear | Medium | Low | Medium | High | Medium | Medium |
| Iris/Retina | High | High | High | High | High | High |
| Fingerprint | Medium | High | Medium | High | Low | Medium |
| Knuckle Crease | Medium | Medium | High | Medium | Medium | Medium |
| Body Salinity | Low | Low | Low | Low | Low | Low |
| Lips | Medium | Medium | Medium | High | Low | Low |
| Gait | Medium | Low | Medium | High | Low | Low |
| Face Recognition | High | Low | High | High | Low | Low |
| Voice Recognition | High | Low | Medium | Low | Low | Low |
| DNA | High | High | High | High | High | High |
| Brain | High | High | High | High | High | High |
| Keystroke | Low | Low | Medium | Low | Low | Low |
| Signature | High | Low | High | Medium | Low | Low |

A survey has been conducted by "Findbiometrics.com" in 2018. Fig. 2. Shows the latest trends followed by industries and corporate sector in the mentioned year. Biggest share occupied by face recognition with 37%. The other single modality who took the second share of market is none other than the finger print, which was the market leader in previous years. Biometrics industry leaders and security experts are of the opinion that the future lies in multimodal biometrics and this the strongest approach to security [110].

XXIV. CONCLUSION

Biometric based recognition technology is quickly becoming a useful security measure for verification and authentication due to its convenience and cost effectiveness. The biometric recognition systems have been proved to be accurate and very effective in various applications. Although

this is used for many applications but further development and assessment is required to improve the quality and utility.

For instance fingerprint is the most widely used modality in the industry and corporate due to its suitability and acceptability. With the rapid developments in biometrics and sensor technology, multimodal biometrics have a bright future. The future of biometric based recognition systems lies in multi modal biometric recognition systems coupled with image-based biometrics. Such systems can integrate information at various levels and provides better recognition accuracy by utilizing information from more than one sources. Different biometric modalities are defined here, these are compared on the bases of multiple perspectives. We can say Iris is the most accurate biometric technique which may be used largely in future, although it will be more expensive and will require more software and hardware resources.

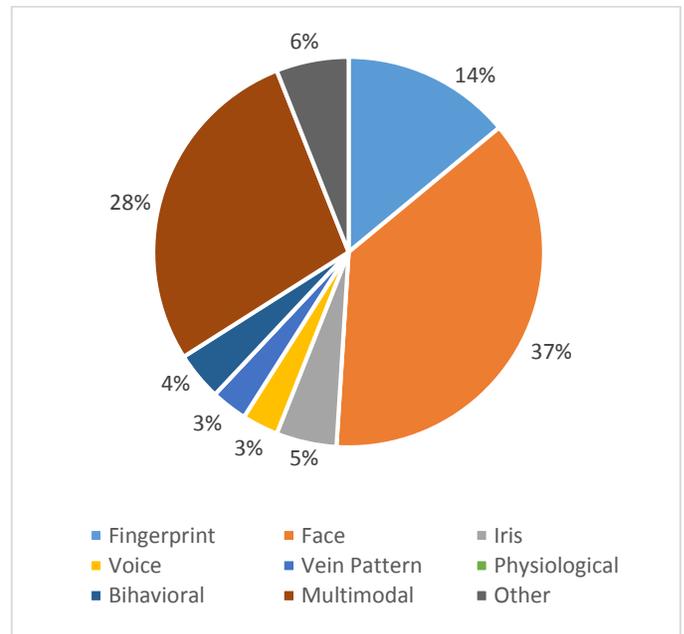


Fig. 2 Latest trends of biometric modalities in 2018 [110]

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