An Analysis on Biometric Traits Recognition

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Abstract: Biometric traits are inherent and unique to each individual such as fingerprints, face, iris, gait etc. Therefore, biometric security systems gain a vital role in wide security applications due to its ability to verify an individual's identity with high accuracy and reliability since biometric traits are part of the individual's being. This paper aims at introduce a full review of biometric traits recognition including the general framework, the criteria of choosing a proper biometric trait for specific application, along with the critical problems and challenges of this field of study. In addition, its evolution in term of historical development is offered. An extensive discussion of an important problems are presented in this paper in order to highlighting and presenting the gaps which make a right directions for improvement and development.

Index Terms: Biometric Recognition, Distinctiveness, FMR, FNMR, FPIR, FNIR.

I. INTRODUCTION

Biometric recognition defined as an automated recognition for individuals based on their own characteristics that may are biological such as fingerprint, iris, face, veins,… etc, or behavioral characteristics such as voice, signature, walking,…etc. [1].

Recognition of persons depend on their own biological and/or behavioral characteristics is called as biometric recognition. Face detection, fingerprint, palm print, iris, palm veins, finger veins, and voice are a successful of biometric characteristics. However, the first scientific publication of biometric recognition was in the fingerprint matching, by Mitchell Trauring in the journal Nature, in 1963.

Generally, the biometric traits are inherent to the person, so, there is a permanent link between the person and his/her own traits. Thus, personal identification can be done using one or more of biometric traits. The logical process can be done through surveillance operations, where recognition is required to acquire their identity for store it, and then use the stored data to identify the person as it needed. Moreover, in current identification systems, the limitations that present in the use of passwords and tokens are eliminated by using biometric systems, where the system require the person himself/herself to present his/her characteristics which is cannot present by others.

Biometrics systems are in continuous improvement, and in the result of usability of performance from day to day. So, the biometric recognition evaluation is an ongoing process which has more interesting as a result of its serviceability.

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Therefore, this paper aims at providing a comprehensive review of the existing biometric traits system along the current challenges and such unsolved problems. The rest of the current paper is organized as follow. Biometric recognition framework is offered in Section 2.Section 3 provides the biometric trait choosing criteria. Major Research Challenges in Biometric are provided in section 4. Section 5 presents an Evolution of Biometric Recognition. Discussion and Interpretation of Unsolved problems is offered in section 6. Finally, conclusion is drawn in section 7.

II. BIOMETRIC RECOGNITION FRAMEWORK

As a matter of fact, the framework of biometric recognition system includes two stages which can be shown in fig. 1 and described as follows:

A. Enrolment Stage

- Acquiring the subject
- Feature extracting, i.e. salient have to be extracted.
- Storing these features in the database.

B. Recognition stage

- Acquiring the subject (biometric trait) from the person.
- Feature extracting (with the use of the same extractor in the enrollment stage).
- Matching, which compare the feature set against the features of every individuals on the database (in order to determine the matching rate or to verify a claimed identity).

However, in acquiring a biometric trait, biometric signals suffers from set of obstacles that may be created by the person or the sensor which in general leads to quality reduction and inaccurate recognition rate. As shown in fig. 1, the signal does not stable across measurement. Nevertheless, the major obstacles might be called as a sources of intra-subject variation such as sensor limitations (η_s), intrinsic aging of the biometric trait (η_a), variation in user interaction (η_v), acquisition environment (η_e),and other factors effects (η_o) [1].

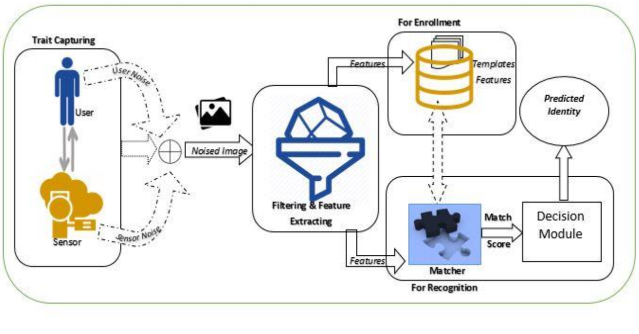

Fig. 1 Framework of biometric system

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III. BIOMETRIC TRAIT CHOOSING CRITERIA

For designing any biometric system, the determination of biometric trait as well as desired features must be taken in to the account. Therefore, an expected question is raised "How to choose a biometric trait?" which may considered as one of the challenges on the biometric systems designing. The answer depends on the usage of the system that may desired, even though, there is absolutely distinguishes/ distinctiveness or uniqueness approved completely in the biometric traits, looking for highest rate of unquietly /distinguishing the biometric traits for personal identification. However, as it shown in the figure below, there are set of characteristics or properties that may satisfy the requirements of a designing system, such as uniqueness or distinguishes/distinctiveness, performance, collectability, universality, user acceptance, invulnerability, integration, accuracy, throughputs, cost, Return on Investment (ROI), template size, user experience, resistance of spoof and template attacks, and ease of system interaction.

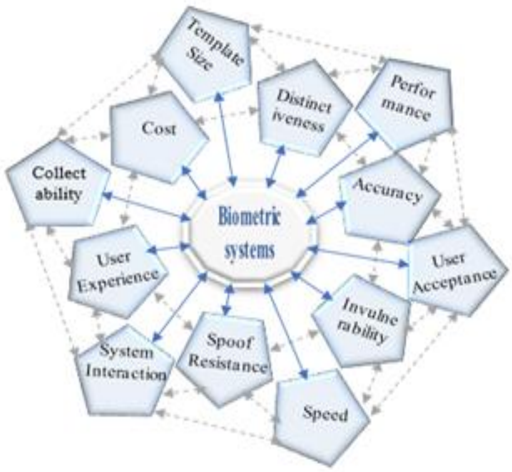

Fig. 2 Biometric systems and its objectives

In addition, Biometric traits can be grouped under four categories of applications depend on its usability and its own degree/rate of distinctiveness and permanence for the person as:

1. In the law enforcement and forensic application, palmprint and DNA mostly used.
2. In the commercial and security applications (verification and authentication tools), the preferred traits to use are signature, voice, hand geometry, and vascular patterns(like palm veins, hand veins, or/and finger veins).
3. In the person recognition (in niche applications), ear, retina/sclera, gait, keystroke dynamic, electrocardiogram ECG, electroencephalogram EEG signals are commonly used.
4. In Security management, fingerprint, iris, and face recognition are mostly used.

Because of the biometric applications divers nature, there is no even single biometric trait has been to be an optimal to satisfy the major requirements of all applications. So that, the idea of combination or fusion of two or more of biometric traits may score the desired performance level. Commonly such systems are called as multi-biometric systems [3].

IV. MAJOR RESEARCH CHALLENGES IN BIOMETRIC SYSTEMS

The main biometric systems objective is to recognizing the individuals accurately, which may means that the biometric system has to reduce the error recognition rate whereas the best system should have lowest rate of errors recognition. However, such metrics are used by researchers for error rate measurement as FMR- False Match Rate, FNMR- False Non-Match Rate, FPIR- False Positive Identification Rate, and FNIR- False Negative Identification Rate.

For gaining an optimal results of the above measurements, a biometric system should have an appropriate: 1) Sensor, 2) Feature representation scheme, and 3) Similarity matcher. Two conditions should be met so as to minimizing the recognition errors:

1- Intra-subject similarity have to increase as possible. Which is the similarity between different samples for the same biometric trait acquired of the same subject.

2- Inter-subject similarity have to reduce as possible. Which is the similarity between different samples of a biometric trait acquired from different subjects.

On the light of what have been discussed, the most important point, that there is no even one universally representation scheme or matcher such that can be applied for all biometric traits. Additionally, similarity between related individuals (twins, father and son) may leads to lack the distinctiveness of some biometric traits.

V. EVOLUTION OF BIOMETRIC RECOGNITION

The current section offers a historical evolution of some important traits such as fingerprint, face, iris, palmprint, gait, hand geometry, and periocular in term of development.

A. Historical Development in Fingerprint

"Perhaps the most beautiful and characteristic of all superficial marks (on human body) are the small furrows with the intervening ridges and their pores that are disposed in a singularly complex yet even order on the under surfaces of the hands and feet."–Sir Francis Galton, Nature, June 28, 1888.

Basically, the classification of fingerprint images can be: Rolled/full, Plain/flat, and Latent which is something present but hidden, and may develop to become noticeable in the future. Rolled and plain finger print images can be obtained using live-scan fingerprint sensor. Fingerprint features can be categorized into three levels are: i) Level1: features capture microscopic details of the fingerprint. Such as ridge flow, ridge frequency, pattern type, and singular point (e.g. core and delta), ii) Level2: features refers to minutia. Such as ridge bifurcations and endings, and iii) Level3: features captures the dimensional attributes of the ridge and include extended features. Such as ridge path deviation, width, shape, pores edge contour, incipient ridge, breaks, creases, scars, and other permanent details.

The approached used in the fingerprint are: a) correlation of image, b) ridge features matching, and c) matching of minutia (most common used).Minutia-based matching, is the

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mostly techniques used in fingerprint because of two reasons are: 1) minutia has been successfully for fingerprint comparison by forensic examiners for more than 100 years ago, and 2) storage efficient to represent minutiae [1].

B. Historic Development of the Face Recognition

"This (face) acknowledgment issue is made troublesome by the extraordinary changeability in head pivot and tilt, lighting intensity and angle, outward appearance, maturing, and so on."–Woodrow Bledsoe, 1966.

The coordinating of face matching was done consequently dependent on 20 standardized separations got from the facial landmarks (for example width of mouth, width of the eyes… and so forth.). In 1973, such framework purposed to concentrate such facial landmarks, which have been displayed the primary completely mechanized face acknowledgment framework.

C. Historical Development in the Iris Recognition

"For motivations behind quick and dependable individual ID, it is difficult to envision (one of a kind identifier) more qualified than a secured, unchanging, inner organ of the eye (iris), that is promptly unmistakable remotely and that uncovers irregular morphogenesis of high statistical complexity."–JohnDaugman,IEEETransactionsonPAMI,1993.

Iris texture and color utilized as a strategy for recognizing individuals and proposed by Bertillon. Factually, iris considered as one of the best biometric traits for such security applications. However, in iris recognition system, set of steps must be included as image normalization, feature extraction and classifier [11].

In 1936, Frank Burch also proposed utilizing iris designs for human identifications. The first patent for an iris recognition system was established at 1985 by Flom and Safir [4]. Which consist of three main stages are image capture, feature extracting, and matching. While the first working iris recognition framework was created and applied by John Daugman in 1990. Where he considered as a first one who develop: 1) Camera to capture the iris image, 2) Image processing algorithm to process the eye image and extract the iris region, and 3) The well-known iris Code representation to describe the iris images as a binary code.

UAE border control system considered as the primary significant organizations of iris recognition at 2001. In 2003, the utilization of iris recognition to simplify immigration control for regular travelers at Amsterdam Schipolairport. Additionally, an iris recognition based immigration system was functioning at main airport in the UK for about 10 years, before it was withdrawing from service in 2013. Between the US and Canada, iris-based border control system used to accelerate immigration approval for pre-affirmed travelers. Likewise, iris recognition was widely utilized by the US military for field tasks in Afghanistan and Iraq [5]. Besides, Mexico national ID program, Indonesia's e-ktp program, and AADHAR ID in India. All of them are instances of accomplishment and worked systems utilized iris.

D. Historical Development in the Palmprint Recognition

Palmprint utilized for human identification follows back to Chinese activities for sale in the sixteenth century. At 1684 [2], Grew presented dermatoglyphics, an investigation of the epidermal ridges and their arrangement on the palm surface. The main deliberate capturing of hand, finger and palm pictures for distinguishing proof was functioned by Herschel in 1858[14]. Galton [15,2] discussed the basis of contemporary fingerprint science, and introduced palmar ridges and creases. He suggested that the ridges on the finger tips, palms and soles are persistent and unique. Galton defined the peculiarities in the ridges as minutiae and introduced several different minutiae types. The first reported use of palmprints in a criminal case occurred in a British court in 1931. The first automated palmprint identification system became available in the early 1990s [16,2].

E. Historical Development in the Ear Recognition

Appearance, structure, and morphology of the human ear has been studied as a biometric trait, which is provides several changes like: 1) Stable structure despite aging, especially after 4th age, 2) Affected by changes in facial expression, and 3) Image capturing does not include obvious contact with the sensor.

Albeit a few algorithms for ear detection and matching suggested in the previous studies, there is no substantial scale public evaluation of ear recognition algorithm conducted. The performance of ear recognition algorithms has been tested in some standard ear dataset, which is result in good recognition accuracy under controlled conditions. In any case, the execution of ear recognition techniques on a non-ideal image got under various illumination and occlusion situations is yet to be set up. Numerous difficulties must be defeated to make this conceivable [1].

F. Historical Development in the Gait Recognition

For human identification at distance, especially for clandestinely recognizing people in unconstrained conditions with an uncooperative subject. In such a situation the subject/individual of interest, may not be cooperating with the biometric system in a deliberate way. In contrast to fingerprint and iris, gait must be perceived in remain off separation of the biometric system which may can only with significant effort be captured/acquired at an extensive remain off separation [1, 6].

Subsequently, gait-based human recognition has gotten some enthusiasm for biometric recognition at a distance [6]. Gait is characterized as pattern of locomotion in creatures. Human gait is the way in which individuals walk. While the formal meaning of gait pertaining to human movement, practical algorithm for gait recognition contain both dynamic and statistic features of the human body moving [1].

Gait considered as an appealing solution for distance based recognizable proof for various reasons as: i) human gait has been seen to have some individual particular characteristics, ii) gait biometric can be captured passively, and iii) discriminately features of human gait can be extracted in low resolution image [1].

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G. Historical Development in the Hand Geometry Recognition

Hand geometry, refers to the geometric structure of the hand [7,8], which can verify the individuals using of width of fingers at various locations, width of palm, thickness of the palm, length of the fingers, contour of the palm,… etc.

Hand geometry measurement is non-intrusive and the verification include a basic preparing of the extracted features. Not at all like palmprint which does not include extraction of definite features of the hand lie wrinkles in the skin.

Since 1970, hand geometry-based verification systems are accessible, when the earliest previous studies on the hand geometry biometrics is as patent or application-situated depictions. In these applications, the biometric system works as a verification approach. Along these lines, comparatively of hand geometry for a subset of people, the identification accuracy might be low. Besides, the shape of the hand changes with time or getting old (aging). However, more recent researches explored the use of hand geometry in conjunction with fingerprint and low-resolution palmprint in multibiometric configuration for improved accuracy [1].

H. Historical Development in the Periocular Recognition

Periocular is the region around the eyes. It dominatingly comprise of skin eyebrow, and eye. As a biometric, the periocular region represent a good trade-off between the entire face region or using only the iris for recognition [9]. When the entire face captured from the distance (typically more than one meter), the iris information has been low resolution, this is means poor matching result.

Particular image can be captured in the INR spectrum to minimize illumination variation compared to visible spectrum. The advantages of using the periocular biometric trait are:

1. In the iris, when the image of iris cannot to be clear, or there is low resolution, the surrounding region (periocular) may be used.
2. The periocular region can offer data about eye shape that may helpful as a delicate biometric.
3. When the parts of the face relating to the mouth and nose are impeded, the periocular district can be utilized to decide the personality.

No need to design new scanner.

VI. DISCUSSION AND INTERPRETATION OF UNSOLVED PROBLEMS

Because of distinctiveness problem, permanence problem, lack of extraction and matching schemes, and some application specific problems. The biometric recognition issues can be divided into two categories, which is fundamental related to design of the recognition system, and specific problems which are related to the applications that use biometric recognition. In the other words, there are two main unsolved issues on biometric recognition:

a) Techniques to shield a biometric system from ill-disposed assaults/attacks and supply assurances on user privacy.

b) Techniques to assess the convenience of biometric systems and estimate the return to investment.

Basically, in the case of resolving these problems, the new applications of biometric recognition will open up [1]. In the following, such challenges and unsolved problems are briefly discussed and interpreted:

A. Distinctiveness

Determining the level of information at which the individuality should be measured, is considered as a basic issue in estimating the biometric trait individuality. Individuality can be defined based on:

a) The biological trait(I(Y:B))

b) The sensed samples/images which are recorded from the subject (I(Y:M))

c) The feature extracted from the sensed samples (I(Y:X))

Along these lines, by and large, it is difficult to quantify the peculiarity of the biological trait, since we rely upon the sensed samples which are accessible for investigation, and consist of diverse kinds of noises mixed with the biometric trait information. Moreover, the subject recognition will be in the eventually/completely dependent on the features extracted from the sensed images.

The lack of robust statistical models which characterize the intra- and inter- subject variations accurately, is esteem as the foremost difficulties in estimating the individuality in the biometric trait based on its features representation. In this way, approximating the entropy functions H(X), H(X|Y), or H(Y|X) turns into a difficult duty. The vast majority of the efforts made those far to evaluate the individuality of biometric traits needed to make simplifying expectations so as to keep the issue tractable [10].

At long last, the capacity of the biometric system to accomplish very low error rates, can be considered as proof of high independence of the underlying biometric trait. This is on the grounds that $H(Y|\hat{y})$ can be considered as an upper bound on $H(Y|X)$, where $H(Y|\hat{y})$ is a component of the error rates of a biometric system. The estimation of distinction dependent on an observational system has a few demerits, for example:

1. Since error rates depend on the database, it is not easy to extrapolate them when the population size increases in large numbers or when the trait of the population change.
2. The resulting estimate is just a loose minimum on real individuality [12].

B. Persistence of Biometric Traits

Biometric trait Persistence is correlated to the aging which is referred to the modification in the biometric trait over a period range, so it can conceivably affect the precision of the biometric system. Nevertheless, there are two kinds of aging: trait aging, and template aging. Trait aging belongs to the natural change in the trait itself over an individual's lifetime, and the template aging belongs to changes in an individual's biometric template after some time. While the template aging is absolutely identified with trait aging, the features extracted from a biometric trait can alleviate the effect of characteristic aging in template aging.

In spite of the fact that the determination of biometric trait differs from person to another, in this manner, an inquiry "is it conceivable to measure/predict the level of change which certain trait or template is required to encounter over person's lifetime?". An answer needs to systematically build a system at times and to check and refresh the biometric template of a client so as to gather and quantify the age-related changes[1,13].

C. Unconstrained Biometric Sensing Environment

A biometric trait acquiring is a difficult job in the most of the applications of person recognition. The way of sensing, user acceptance, distance, rotations, and occlusion are critical issues that face the acquisition process to obtain the subject image.

However, table 1 provides a quick overview of the existing biometric traits recognition systems evolution.

Table. 1 Historical Development of the Crucial Biometric Traits

Year	Biometric trait	Development description	By
AD 600	Fingerprint	Fingerprint to seal contract and legal document.	China
16th century	Palmprint	Used for human identification traces back to Chinese deeds for sale.	China
1684	Palmprint	Introduced the dermatoglyphics	Grew
1858	Palmprint	The first systematic capture of hand, finger and palm images for identification purposes.	Herschel
1880	Fingerprint	Article in fingerprint published in Nature	Henry Faulds
1892	Fingerprint	Use ink and paper for fingerprint	Juan Vocetich
1893	Fingerprint	First use of fingerprint as forensic evidence	Argentina
1901	Fingerprint	Adopted Galton/Henry system of classification	Scotland Yard
1915	Face	35mm still camera	
1924	Fingerprint	Fingerprint identification division of FBI	FBI, USA
1931	Palmprint	The first reported use of palmprints in a criminal case.	British court
1936	Iris	Concept of using iris recognition pattern for human identification.	Frank Burch
1963	Fingerprint	First paper in automatic fingerprint matching	Mitchell Trauring
1964	Face	Automated face recognition (FAR)	Wwdrow Bledsoe
1970	Fingerprint	Initiation of AFIS	FBI
1973	Face	First Automated face recognition (FAR) thesis	Takeo Kanade
1985	Iris	First iris recognition patent	Flom and Safir
1989	Iris	First iris camera	John Daugman
1990	Face	Surveillance camera 480p@30fps	
	Fingerprint	Optical sensor and capacitive sensor	
	Palmprint	The first automated palmprint identification system.	NSTC
1991	Iris	Iris recognition patent	John Daugman
	Face	Digital camera 1024p	Kodak
	Face	Eigen face	Turk &Pentland
1995	Iris	One of the earliest commercial iris camera	IrisScanner system
1996	Face	Local feature analysis	Penev&Atick
1997	Face	Elastic Bunch Graph Matching	Wiscott et al.
	Fingerprint	First swipe sensor	Thomson-CSF
2000	Face	First camera phone 320p	Sharp
2001	Iris	Developed iris recognition system for border crossing control	UAE
	Face	Face detector	Viola & Jones
2002	Iris	Using of iris recognition in field operation	USA
2003	Iris	Immigration clearance in the Schiphol airport	Amesterdam, Netherlands
2004	Iris	Portable iris recognition device	Securi Metrics
	Fingerprint	DHS US-VISIT	
2005	Fingerprint	Touchless 3D sensor	TBS
2006	Iris	Iris recognition device in the move.	Sarnoff
	Face	Local binary pattern (LBP)	Ahonen et al.
2007	Fingerprint	Slap sensor for rapid ten-print capture	US-VISIT
2008	Fingerprint	NGI	FBI
2009	Iris	Using iris in the biggest database for AADHAR ID	India
	Face	Sparse representation	Wright et al.
	Fingerprint	India started issuing 12-digit UID number to its residents	UIDAI
2010	Iris	National ID including the iris trait	Maxico
	Face	RGB-D camera Microsoft Kinect 480p@30fps, with depth accuracy: ~ 2mm @ 1m distance.	Microsoft Kinect
2011	Iris	Patent expired	John Daugman
	Iris	National ID including the iris trait	Indonesia
	Face	Galaxy nexus, face unlock for smart phone	Samsung
2013	Iris	Smart phone application and device for iris recognition	AOptix
	Iris	Smart phone application and device for iris recognition	DeltaID
	Face	Wearable camera Google glass 720p@30fps	Google glass
2014	Face	Deep network library caffe	Jia et al.
	Fingerprint	2-factor authentication	Apple Pay
	Fingerprint	Touchless swipe sensor	SAFRAN
	Fingerprint	TouchID sensor in iPhone-5s	Apple
2015	Face	Smart phone REG-D camera	Google & Intel
	Face	Body camera used by NYPD & Chicago PD	

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VII. CONCLUSION

An extensive review of biometric traits recognition is provided in this paper. The historical development of different biometric traits such as fingerprint face, iris, palmprint, gait, hand geometry, and periocular are deeply covered. Due to presenting the critical challenges and problems of the field of biometric traits recognition, new applications and research development and improvement of biometric recognition will open up. Introducing the full information and discussion of unsolved problems of this field can be considered a contribution of this paper through which one can select a proper biometric traits for specific application and also researchers can find out a real problems for new researches. The future work is to combine a multi traits for developing a multimodal recognition system.

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