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Survey
Multimodal Biometric Algorithm: A Survey

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Abstract

Identifying a person automatically based on a physiological or behavioral characteristics become a challenge when the data getting larger. These data have many problems which included noisy data, spoof attacks, an unacceptable error rates and others. In this study, current and new multimodal biometric algorithms are studied comparatively. Unimodal biometric used only a single sample of physiological traits while multimodal system combine at least two physiological traits. Results from the latter system proved that combination of more than one sample of biometric traits solved noisy data problem. It was found that multimodal biometric algorithm is the best solution to solve bulk data problems and to improve the accuracy, efficiency and applicability of the problems. The results of various techniques such as combination of face biometric system and iris, speech and face recognition systems proved to solve the problems in spoof attacks. It also includes processing biometric modalities sequentially until an acceptable match is identified. This study presents a review of existing and current studies and suggest a direction for future developments in multimodal system. This study will focus more on the combination among the biological traits for the purpose of automatic personal recognition.

Key words: Algorithm, multimodal biometrics, biological traits, 2D iris, face recognition, finger prints identification

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INTRODUCTION

Recent developments in the field of security awareness, have led to a renewed interest in biometric systems. In Malaysia, current biometric systems used unimodal system especially in government agencies for example immigration department which used fingerprint identification systems at the airport and most bank e.g., Tabung Haji, CIMB bank, bank Muamalat, bank Islam, HSBC and others used similar systems for identification purposes when withdrawal money at their counters. Many places in the world have also applied unimodal biometric systems such as The Schiphol Privium scheme at the Amsterdam airport, which employs iris scan cards to speed up the passport and visa control procedures[1]. Other countries which also employed the same system included Japan at Narita airport, Japan and immigration department, France which make use of iris and face biometric system for getting entrance into the countries. The list is expanding on its own pace.

Biometric systems are technologies that use human body by measuring and analyzing its characteristics such as fingerprints, hand measurement, DNA etc. for authentication purposes. Most system that have been used in the market employed unimodal biometric system.

Unimodal system is based on single source of information while multimodal system used combination of multiple types of biometrics such as a fusion of a subject's fingerprints, irises, faceand voice. Mishra[2] identifies the following disadvantages of unimodal biometric:

- Biometric sensors are susceptible to noise which lead to inaccurate matching. Noisy data can cause false rejection
- It is prone to interclass similarities within large population groups. For example, in case of identical twins, facial feature leads to inaccurate matching
- Unimodal biometrics is also open to spoofing where data can be imitated or forged e.g., rubber fingerprints can be used for spoofing therefore real time tests are required

These problems can be solved by deploying biometric multimodal system that makes decision from incorporation of information of many modalities. The researcher provides in-depth analysis of the work on multimodal biometrics systems. Multimodal system is intrinsically more secure than unimodal system since it is more dif cult to spoof two or more biometric marker than a single one. There have been several studies in the literature reporting the success of multimodal biometric system compared with the traditional system.

BIOMETRIC ALGORITHMS

Biometric systems are essentially a pattern recognition system that operates by acquiring biometric data from an individual, extracting a feature set from the acquired data and comparing this feature against the template set in the database[3].

Biometric personal identification is the science of distinguishing an individual based on physiological traits of a person such as iris, face, thumbprint and others[4]. In normal approach of biometrics, a single sample from a biometric source is taken from a person and then processed to obtain a recognition result. This approach has been widely accepted in face recognition and iris recognition. Types of biometrics algorithms have been discussed and mentioned the earlier section which consists of unimodal biometric which make uses of single or one biometric traits and multimodal biometrics use combination of biometric traits.

The biometrics solutions available in the market are based on unimodal biometric system. These systems rely on single source of biometric data i.e., fingerprint, iris or face but not both. The existing systems have to deal with variety of problems with the usage of single data such as a fingerprint image with a scar or poor illumination of the subject in face recognition system[5].

The problems caused by unimodal biometrics system can be overcome by applying multimodal techniques. Multimodal techniques use a system where multiple biometric data are used to authenticate a person. These systems can significantly improve the recognition performance with addition to improving population coverage, deterring spoof attacks, increasing the degrees of freedom and reducing the failure-to-enroll rate.

Commonly, there are two types of biometric traits: Physiological and behavioral traits which can be referred to Fig. 1. Physiological biometrics (iris, fingerprint, retina, face, hand geometry, hand vein, ear, odor, DNA and palm print) take measurements from human body while behavioral biometrics (signature, keystrokes, voice, typing recognition and gait) take dynamics values based on human actions[6].

In accordance with the advance in technology, biometric systems have a bright future in the industry e.g., for authentication and security. A generic biometric system has a sensor module, a feature extraction module and a matching module which is shown in Fig. 2.

In the capture section (Image acquisition/sensor module), a suitable sensor is used to capture raw biometric data. Copy of images will be stored in the database. The next stage is

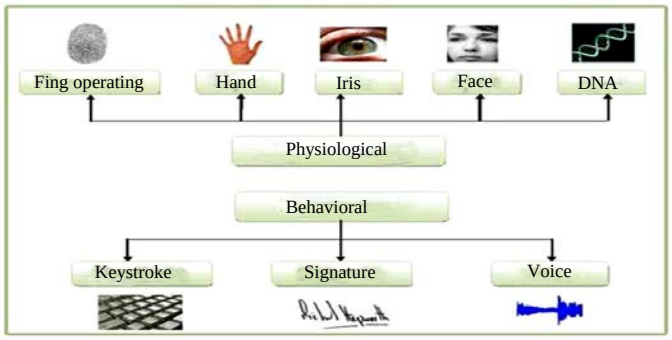

Fig. 1: Categories of biometric sources

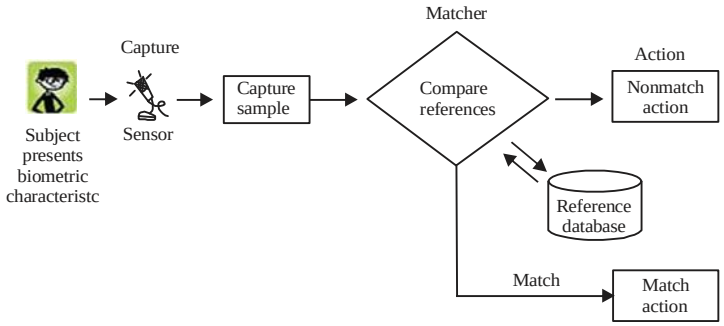

Fig. 2: A generic biometric system, which consist of sensor module, feature extraction module and matching module

where feature extraction is applied together with enhancement algorithm to improve the quality of the images. The matcher section (matching module) is where all captured image is matched with the stored images to generate match score. The performance of a biometric system is highly affected by the reliability of the sensor used and the degrees of freedom offered by the features extracted from the sensed image.

BIOMETRIC WORK MODE

Depending on the use of the biometric systems, it can work in two situations: Identification and verification process.

Verification/Authentication: Through this mode, the system verifies the identity by comparing the enrolled biometric trait by a stored biometric template in the system (1:1). This approach is used for positive recognition and aims to prevent the multiple individuals from using the same identity[7].

Identification: In this mode, an attempt is made to establish the identity of an individual. The biometric system performs a one-to-many comparison or search process where a biometric traits set against all or part of the database to find biometric references with a specified degree of similarity[6].

Requirements: A biometric system should meet the following requirements:

- **Availability:** Where each person should have the characteristic. This is measured by the "failure to enrol' rate
- **Distinctiveness:** Where any two persons should sufficiently have different characteristics and measured by the False Match Rate (FMR), known as type II error
- **Permanence (Robustness):** The characteristics should be stable over a period of time which means the stability over age

There are many requirements listing for this system but these are the minimal requirements for a biometric systems to have.

MULTI-BIOMETRIC

Multi-biometric combine two or more different biometric sources of a person and sensed by different sensors. This system relies on the evidence presented by multiple sources of biometric information. Therefore, it can be classified into the following categories:

Table 1: Previous multimodal biometric system

Years	Traits combine	Feature extraction method
1999	Fingerprint, face+speech[10]	Cryptographic algorithm
2003	Hand-geometry, finger+palm-print[11]	Not available. Match score level fusion
2005	Face+speech[12]	Not available. Decision level fusion
2007	Two fingerprints[13]	Not available
2008	Iris+palm print[14]	Not available
2009	Face+ear+signature[15]	Not available. Rank level fusion
2011	Fingerprint+iris[16]	Fast fourier transform, concatenation and euclidean matching
2013	3D ear+face[17]	PCA to the nearest
2014	Face+fingerprint+iris[18]	Gabor and FOCC

- **Multi-sample:** In this system, a single sensor can be used to acquire multiple samples of the same biometric sources in order to account for the variations that can occur in the trait. One of the main issues in this system is in determining the number of samples that have to be acquired from a person[8]
- **Multi-algorithm:** Multi-algorithm systems combine the output of multiple feature extraction algorithms or multiple matchers or other algorithms operating on the same set of images or traits. Since it uses the same sensor are cost effective
- **Multi-instance system:** For this type of system, multiple instances of the same body sources are used which is also known as multi-unit systems. It can be cost effective if single sensor is used
- **Multi-modal system:** This is the current biometric systems researchers are working which involved two or more biometric traits being used for user identification. It can be expensive because more sensors are used
- **Multi-sensor system:** Data from the same biometric recorded from different sensors are linked together. These are then integrated at fusion level
- **Hybrid:** This is a system which merge more than one of the above multi-biometric systems

Study have found that multi-biometrics improved better than a unimodal biometric in terms of increasing the security level. This boost the level of confidence for people to use and trust the system. Multi-biometric has a history of more than 30 years. Each biometric traits has its own strengths and weaknesses and the choice typically depends on the application.

MULTIMODAL BIOMETRIC SYSTEM

Multimodal biometric systems are more reliable because of the many, independent biometric traits. Due to this it has higher accuracy in identifying an individual. The system is universal in nature because it can take other form of biometric traits for identification purpose. It also has liveness detection which protect from spoofing or hackers.

Multimodal biometric system can perform in three different ways[9]:

- **Serial mode (cascade mode):** Each trait is examined before the next trait is investigated. The overall recognition duration can be decreased, as the total number of possible identities before using the next trait could be reduced
- **Parallel mode:** Sensed or captured image from multiple traits are used in concurrent way to perform recognition. Final decision is taken from the combined results
- **Hierarchical mode:** Individual classifiers are joint together in a hierarchy-tree-like-structure. This mode is preferred when a large number of classifiers are expected

Studies of previous multimodal biometric systems have been made and shown in Table 1. It provide the summaries of multimodal biometric systems that have been done (the lists are expanding) and where possible, the type of feature extraction used for each systems.

Recently, there has been a gradual increase in the research on multimodal biometric systems and the list keep on expanding with new interest and new options of biometric combinations.

FUSION

The use of the various types of biometric data or methods of processing to improve the performance of biometric system is known as biometric fusion. It is a special case of combining multiple classifiers in pattern recognition. Application of biometric fusion to the system gives an enhancement to the biometric system. There are many fusion methods available and can be applied at various levels.

Decision to determine at which level of fusions should be done is not easy to determine. Nevertheless, consider only what type of information that should be fused and the

selection of method for fusion. The objective of fusion is to create an appropriate function that can maximally combines the information presented by the biometric subsystems[7].

In multi-modal biometric systems, there are six levels of fusion:

- **Sensor level:** This level of fusion involves the consolidation of evidence presented by multiple sources of raw data before they are subjected to feature extraction. This fusion is suitable for multi-sample systems which capture multiple snapshots of the same traits which gives multiple results. It is also known as data level or image level fusion
- **Feature level:** Feature level fusion merges the feature sets acquired from different multiple biometric algorithms into one feature set
- **Score level:** In this level, the match scores output by multiple biometric matchers are combined and compared with the templates in the database to generate a new match score. It is also known as confidence or measurement level. When these outputs are taken from different biometric matchers and combined, then fusion is done at the match score level
- **Decision level:** Also known as abstract level where only final decisions are available. The final decision for a multimodal biometric systems is developed from getting individually separate decision of different biometric modalities using different techniques
- **Rank level:** This is a new fusion method where each classifier links a rank with each enrolled trait to the system (a higher rank indicating a good match). It merges multiple unimodal biometric matcher outputs and determine a new rank that would help in estimating the final decision. This is more useful for the identification, with the working concept: The identity with the lowest score is the correct identified
- **Opinion level:** It is also known as confidence level. This level of fusion consists of the combination of the scores provided by each matcher. The matcher just provides a distance measure or a similarity measure between the input features and the models stored on the database

Among the best and popular fusion level is the score or match level, which is due to the factor of easier to access and consolidate matching scores. Fusion can be applied at various levels in a biometric system.

CONCLUSION

Multimodal biometrics are gaining its popularity in the current technological world. These systems are expected to improve the recognition accuracy of a personal authentication system by combining the evidence presented by multiple sources of information. There has been evidence that this type of system is better than applying unimodal biometric systems and can overcome the problems in the previous system.

In this study, current and previous multimodal biometric systems are summarized and presented. The level of fusions that can be applied is also presented. The list is expanding and becoming longer as there are still many combination of biometric traits have not been explored e.g., face and iris, speech and iris, 2D fingerprint and 2D iris.

Multimodal biometric systems is gaining its popularity and becoming reality application in the world of verification and identification for the purpose of integrity, safety and security.

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