MULTIMODAL BIOMETRICS SCHEME BASED ON DISCRETIZED EIGEN FEATURE FUSION FOR IDENTICAL TWINS IDENTIFICATION

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DEDICATION

Thanks to my beloved mother and husband for your kind support and sacrifices. To my children's for praying to me. To my supervisor, nice knowing you and thanks for the understanding and encouragement. Special thanks to PROF. DR. SITI MARIAM BINTI SHAMSUDDIN for her advising and encouragement.

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ABSTRACT

The subject of twins multimodal biometrics identification (TMBI) has consistently been an interesting and also a valuable area of study. Considering high dependency and acceptance, TMBI greatly contributes to the domain of twins identification in biometrics traits. The variation of features resulting from the process of multimodal biometrics feature extraction determines the distinctive characteristics possessed by a twin. However, these features are deemed as inessential as they cause the increase in the search space size and also the difficulty in the generalization process. In this regard, the key challenge is to single out features that are deemed most salient with the ability to accurately recognize the twins using multimodal biometrics. In identification of twins, effective designs of methodology and fusion process are important in assuring its success. These processes could be used in the management and integration of vital information including highly selective biometrics characteristic possessed by any of the twins. In the multimodal biometrics twins identification domain, exemplification of the best features from multiple traits of twins and biometrics fusion process remain to be completely resolved. This research attempts to design a new scheme and more effective multimodal biometrics twins identification by introducing the Dis-Eigen feature-based fusion with the capacity in generating a uni-representation and distinctive features of numerous modalities of twins. First, Aspect United Moment Invariant (AUMI) was used as global feature in the extraction of features obtained from the twins handwriting-fingerprint shape and style. Then, the feature-based fusion was examined in terms of its generalization. Next, to achieve better classification accuracy, the Dis-Eigen feature-based fusion algorithm was used. A total of eight distinctive classifiers were used in executing four different training and testing of environment settings. Accordingly, the most salient features of Dis-Eigen feature-based fusion were trained and tested to determine the accuracy of the classification, particularly in terms of performance. The results show that the identification of twins improved as the error of similarity for intra-class decreased while at the same time, the error of similarity for inter-class increased. Hence, with the application of diverse classifiers, the identification rate was improved reaching more than 93%. It can be concluded from the experimental outcomes that the proposed method using Receiver Operation Characteristics (ROC) considerably increases the twins handwriting-fingerprint identification process with 90.25% rate of identification when False Acceptance Rate (FAR) is at 0.01%. It is also indicated that 93.15% identification rate is achieved when FAR is at 0.5% and 98.69% when FAR is at 1.00%. The new proposed solution gives a promising alternative to twins identification application

ABSTRAK

Pengecaman biometriks pelbagai cara untuk kembar (TMBI) secara konsisten menjadi subjek yang menarik serta bermanfaat untuk dikaji. Memandangkan subjek ini memerlukan kadar kesalinghubungan dan penerimaan yang tinggi, TMBI sesuai digunakan dalam kajian untuk mengenal pasti kembar menggunakan ciri-ciri biometriks. Ciri berbeza yang diperoleh daripada proses pengekstrakan ciri-ciri biometriks pelbagai cara menentukan ciri unik yang dimiliki oleh kembar. Walau bagaimanapun, ciri-ciri ini tidak begitu penting kerana ia mengakibatkan peningkatan saiz ruang carian serta menyukarkan proses generalisasi. Dalam hal ini, cabaran utama adalah untuk menentukan ciri-ciri terpenting yang berupaya untuk mengenali kembar dengan tepat menggunakan biometriks pelbagai cara. Dalam pengecaman kembar, kaedah yang efektif dan proses gabungan adalah penting untuk memastikan kejayaan penghasilan biometriks pelbagai cara. Proses ini boleh digunakan dalam pengurusan dan integrasi maklumat penting termasuklah sifat biometriks tertentu yang dimiliki oleh seseorang kembar. Dalam bidang pengecaman kembar menggunakan biometriks pelbagai cara, pemberian contoh ciri-ciri terbaik seseorang kembar serta proses penggabungan biometriks adalah sangat penting. Kajian ini mencadangkan proses pengecaman biometriks pelbagai cara ang lebih berkesan untuk kembar dengan menggunakan penggabungan ciri Dis-Eigen yang berupaya untuk menjana perwakilan cara tunggal serta ciri-ciri unik seseorang kembar. Pertama, *Aspect United Moment Invariant* (AUMI) digunakan sebagai global untuk mengekstrak ciri-ciri yang diperoleh dari bentuk dan gaya dari tulisan-cap jari kembar. Kemudian, gabungan ciri-ciri ini diperiksa dari segi generalisasinya. Seterusnya, untuk mencapai ketepatan klasifikasi yang lebih tepat, algoritma penggabungan ciri Dis-Eigen telah digunakan. Sejumlah lapan pengelasan berbeza digunakan untuk menjalankan empat proses latihan dan ujian persekitaran. Sehubungan itu, ciri-ciri yang paling penting dari gabungan Dis-Eigen telah dilatih dan diuji untuk menentukan ketepatan klasifikasi terutamanya dari segi prestasi. Keputusan menunjukkan, pengenalan kembar bertambah baik kerana ralat kesamaan untuk intra-kelas menurun sementara pada masa yang sama, kesilapan kesamaan untuk antara-kelas meningkat. Oleh itu, dengan penggunaan pengelasan pelbagai yang berbeza, kadar pengecaman meningkat kepada lebih 93%. Dapat disimpulkan dari dapatan kajian bahawa kaedah yang dicadangkan menggunakan *Receiver Operation Characteristics* (ROC) berjaya meningkatkan proses pengecaman tulisan-cap jari kembar dengan kadar pengesahan 90.25% apabila Kadar Penerimaan Palsu (FAR) berada pada 0.01%. selanjutnya, kadar pengecaman 93.15% diperoleh apabila FAR bersamaan 0.01%, dan 98.69% kadar pengecaman dicapai apabila FAR bersamaan 1.00%. Kaedah yang dicadangkan ini sangat sesuai untuk digunakan dalam proses pengecaman kembar.

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THFI	-	Twins handwriting-fingerprint Identification
ANN	-	Artificial Neural Network
ASI	-	Aspect Scale Invariant
CV	-	Cross Validation
MAE	-	Mean Absolute Error
SD	-	Standard Deviation
UMI	-	United Moment Invariant
BI	-	Biometric Identification
AUMI	-	Aspect United Moment Invariant
GMI	-	Geometric Moment Invariant
CSM	-	Contour Sequence Moment
WI	-	Writer Identification
IMI	-	Improved Moment Invariant
GMF	-	Global Moment Function
TMBI	-	twins multimodal biometrics identification
TI	-	Twins Identification
T	-	Twins
MF	-	Moment Function
GFE	-	Geometrical-based feature extraction
MFE	-	macro feature extraction
GEF	-	global extracted feature
NF	-	Nero-Fuzzy
GAR	-	Genuine Acceptance Rat
ROC	-	Receiver operation characteristics

FAR	-	false acceptance rate
FRR	-	false rejection rate

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CHAPTER 1

INTRODUCTION

1.1 Overview

As articulated by several researchers (Koda et al., 2016; Karahan et al., 2016; Hamid and Karim , 2013), biometric-based identification and verification systems are set to be a main technology that is equipped with applications for crucial activities including reducing falsified transactions in electronic commerce, control of access to computers and buildings, and deter illegitimate immigration.

For personal identification, among the commonly used system is the token-based or knowledge-based system that requires the use of ID, magnetic or smart cards to represent user identity. However, this system is flawed because tokens can be stolen, misplaced, shared or used by the non-owners, which allows them to disguise themselves from their actual identity using fake or duplicate identification which compromises the entire security of the systems. As expressed by Mjolsnes (2012), this system is easily compromised via the use of social engineering software by criminals, or as reported by Narayanan and Shmatikov (2005), via dictionary attacks as well as password-cracking tools. As such, the token- or knowledge-based system on its own is insufficient, and this is particularly true for cases involving the identification of identical twin. As such, to counter this inadequacy, the existing knowledge-based and token-based mechanisms should be equipped with an additional level of biometric procedure. This can be achieved via the use of two or three layers of identification process at the start or at the end of a system. Such system is known as the biometrics-based identification and it should be noted that the different layers actually accentuate each other.

“Biometrics” is created from two Greek words, ‘bio’ and ‘metrics’, and according to Xiao (2007), it means “life measurement”. As such, biometrics

technology means the technique that dependably employs computable physiological or behavioral characteristics for differentiating one individual from another. Faces, DNA, irises, ear shape, fingerprints, hand geometry, handwriting, keystrokes patterns on a keyboard, signature and speech are among the popular biometrics currently under study (Umair et al., 2009; Nain et al., 2008; Hamid & Karim, 2013). Every biometrics system possesses both strengths and weaknesses. As such, Jain et al. (2004) and Phillips et al. (1998) stated that an effective biometrics system should contain four properties: (1) universality, which means that every identified population member possesses the biometrics characteristics; (2) uniqueness, which means that every identified population member possesses biometrics signature that is different from that of others; (3) invariance, which means that the signature should be invariant under the conditions that it will be gathered; and (4) resistance, which means that the biometrics should be able to resist possible counter measures. Biometrics system is also considered as a system of security that covers the recognition of pattern domain for measuring and analyzing human body's biological data, taking out a feature set from the obtained data and making comparison between the obtained set and the template sets in the database. As explained by Wang et al. (2013), biometrics systems that identify a user with only one biometrics trait, either behavioral or physical, are called the unimodal biometrics systems. These biometrics systems have in fact been successfully used in many real-world applications. Nonetheless, different biometrics traits necessitate different biometrics technology. As such, a single biometrics technology that dominates all areas within the biometrics industry may not exist. Therefore, in the context of identical twin, a fully successful biometrics system is yet to be created.

Intrinsically, faces, irises, ears and fingerprints, are image-based. As such, their implementation will necessitate the techniques of image processing, pattern recognition, and computer vision. On the other hand, keystrokes, hand geometry, speech and signature belong to the category of pattern recognition and signal processing. There have been scholarly works that attempted to combine multiple biometrics (Bigun et al., 1997; Hong et al., 1998) including faces-fingerprints and audio-video.

As indicated by the literature, works on the history of biometrics system were mostly focusing on unimodal biometrics identification for identical twins. This is because it is more challenging to perform such process particularly in terms of uniqueness that leads to a weak recognition system with high error rates. As recognized, identical twins possess similar biometrics shapes, sizes and features, making unimodal systems inadequate, so new algorithms should be studied and considered in order to deal with the high similarities in case of identical twins. As for this study, it will employ the multimodal biometrics that could replace biometrics-based identification among identical twins. This will generate a unique representation of individual features for identical twins' identification.

Table 1.1 presents the summary of the strengths, weaknesses, applications and usability of multiple biometrics systems according to six parameters: universality, uniqueness, permanence, collectability, performance and acceptability.

Accuracy, scalability and usability including security and privacy are among the common issues contributing to the complexity of the biometrics mechanisms (Jain et al., 2005). As such, the solutions to the issues relating to the unimodal biometrics system include the design of sensors adaptable to more than one biometrics trait of an individual (physical or behavioral), the creation of algorithms capable of combining evidence from numerous biometrics sources to deal with the limitations of the individual source and the extension of superior mechanisms of feature representation and efficient matching algorithms of biometrics system (Kaur & Kaur, 2013). Such system is called the multimodal biometrics system (MBS) and it employs physiological traits of individuals including vein, face, iris and hand geometry, and/or behavioral properties including speech, signature and handwriting for identification of a person.

Table 1.1 Comparison of numerous aspects of biometrics according to researchers' view

Biometrics aspect	Strengths	Weaknesses	Parameters						Applications
			Universality	Uniqueness	Permanence	Collectability	Performance	Acceptability	
Signature	*High user acceptance *Minimal training	*Unstable over time *Weighted summation signal variability *Changes with illness, stress or injury *Enrollment takes times	L	L	L	H	L	H	*Portable devices with stylus input *Applications where a "wet signature" ordinarily would be used
Voice	*Good user acceptance *Low training *Microphone can be built into PC or mobile device	*Unstable over time *Changes with time, illness, stress or injury *Different microphones generate different samples *Large template unsuitable for recognition	M	L	L	M	L	M	*Mobile phones *Telephone banking and other automated call centers
Face	*Universally present	*Cannot distinguish identical siblings *Religious or cultural prohibition	H	L	M	H	L	H	*Physical access control
Fingerprint	*Small template (approximately 10 bytes) *Low failure to enroll rate *Unaffected by skin condition	*Physical size of acquisition device *Physical contact required *Juvenile finger growth *Hampered by temporary physical injury	M	M	H	M	H	M	*Physical access control *Time and attendance
Hand geometry	*Easy to capture *Highly stable over adult lifespan	*Requires training *Not sufficient for identification over large databases	M	M	M	H	M	M	*Physical access control *Public justice and safety (i.e., county courthouses use for ID systems)
Iris	*Protected internal organ; less prone to injury *Highly stable over adult lifespan	*Easily obscured by eyes-lashes, lens, etc. *Requires more training and attentiveness than other biometrics systems	H	H	H	M	H	L	*Access control *Identity verifications including time and attendance
Retina	*Stable time *Uniqueness	*Requires user training and cooperation *High user resistance *Slow read time *Dependent on a single vendor's technology	H	H	M	L	H	L	*IS access control, especially for high security government agencies *Physical access control (same as IS access control)

*High, Medium and Low are denoted by H, M and L, respectively.

1.2 Problem Background

Medical reports point out that the current rate of twin births in many industrialized countries is around 3% (Hengyi Zhang et al., 2014). Twins can be classified into two types, dizygotic and monozygotic. Dizygotic twins evolved from two different fertilized eggs and have different DNA sequences. Monozygotic twins, also called identical twins, are from a single fertilized egg splitting into two individual cells, which finally develop into two individuals. Thus, identical twins have the same DNA sequence. DNA contains all genetic information required to create an organ of a species. The mapping from DNA to an organ is very complex. The final products are influenced by not only genetic information, but also other factors, such as living styles, diets and climate. In spite of this, some biometrics traits of identical twins are still very similar (Mahta et al., 2019). Studying biometrics traits of identical twins is an important topic because they are expected to have maximum similarity. If there is no or only limited extra similarity between them, and the corresponding biometrics trait is believed to be highly unique. In addition, if the biometrics traits are used for criminal and victim verification in legal cases involving identical twins, their genetic dependence has to be understood completely. Genetic dependence of many biometrics traits, including fingerprints, faces, irises, and palm prints, have been studied by several researchers (Sun et al., 2010; Kong et al., 2006).

In fact, in certain circumstances, twins biometrics identification mechanism is the method that allows the discovery a unique pattern of a person's biometrics (Jeffrey et al., 2014; Hengyi Zhang et al., 2014; Nisha et al., 2013; Bayan & S.M. Shamsuddin, 2012; Srihariet et al., 2008; Ayman et al., 2017). In relation to this, the unimodal biometrics identification for identifying identical twins has been considerably improved in terms of accuracy and reliability, with certain traits demonstrating sound performance. Nonetheless, until today, biometrics traits are still facing issues no matter how superior they are because some of these issues are embedded to the technology itself. A unimodal biometrics system is typically made of four key elements: sensor, feature extraction, matching and decision making elements.

Past works on the identification or verification of identical twins utilizing the unimodal biometrics system include analysis of DNA by Rubocki et al. (2001), face detection based on facial mark by Sh.Eliabeth et al. (2015), vein patterns of identical twins by Hengyi Zhang et al. (2014), discriminability between fingerprints of twins by Jain, Prabhakar and Pankanti (2002), computational discriminability analysis on fingerprints of twins by Yu Liu and Srihari (2009), 3D face recognition used for distinguishing identical twins' face by Vipin et al. (2011), identification of identical twins from ear images by Hossein et al. (2012), analysis of facial marks to distinguish between identical twins by Nisha et al. (2012), differentiating identical twins by face recognition by Jeffrey et al. (2014) and demonstration of coefficient values in individual sets as a form of unique code for the face of a person by Rychlik, Stankiewicz and Morzynski (2009). All these research are physiological in nature and as such, change is unlikely (Bayan & Shamsuddin, 2012, Monireh et al., 2018).

Identical twins have identical genetic makeup owing to the fact that they share one zygote. As such it is much more difficult to identify them biometrically due to the vast similarities between them. The usage of more than one biometrics traits is one way to deal with this problem and this method is known as the multimodal biometrics system (Mahta et al., 2019). This system comprises of a combination of multiple sources from different biometrics traits. Using this system, users with no specific biometrics identifier can still enroll and authenticate through the usage of other traits. This solves the problem of enrollment, therefore, this system is universal.

The work on multimodal biometric systems had started as early as 1997 and the focus was on combining at decision level via the merging of the weak classifiers to improve the traditional biometrics system's overall performance (Wang et al., 2013). Kittler et al. (1998) introduced a multimodal system grounded on three biometric traits namely face profile, face and voice. This system encompasses a combination of multiple classifiers including max and sum rule for user verification, and reported that sum rule outperformed other fused classifiers. On the other hand, for personal identification, the mechanism proposed by Hong and Jain (1998) combined face biometrics and fingerprint modalities. Jain et al. (2005) introduced

another fused biometrics system. The system entails the integration of fingerprint minutiae and reference location point classifiers. According to the authors, the fused matcher generates superior results when compared to individual classifier.

Meanwhile, the characteristics resemblance within the styles and patterns of writing and minutiae in twins is the major reason for significant identicalness in the twins' features. The multimodal biometric system analyzes these identical features to enable the extraction of the unique features so that more investigation can be performed on the written texts and patterns of minutiae in comparison to the original ones. There are two stages in this phase namely the individual features analysis stage and the identification and capture of the identical features stage. Then, using the traditional biometrics identification method, both functions are computerized and executed accordingly for quick and accurate results. In general, the applications of biometrics identification include the extraction of features and classification or learning scheme (Liu et al., 2003; Liu et al., 2004; Bangy et al., 2009).

The capture and selection of the desired main features are the most important and highly prioritized process in biometrics identification. This is particularly crucial in identical twins' identification. In biometrics identification, there are two major problems. The first major problem occurs in finding the mean of obtaining the key features within numerous styles of biometrics traits or within styles of biometrics traits that bear close resemblance to find the actual person (Bayan and S.M. Shamsuddin, 2012; Xu et al., 2008; Bensefia et al., 2005a; Schlapbach and Bunke, 2004b; Kun et al., 2004; He and Tang, 2004; Srihari et al., 2002; Michael et al., 2017) and obtaining the meaningful features in making comparison between the biometrics traits of a pair of twins. The second major problem occurs in categorizing the features chosen from the numerous styles of biometrics traits and the styles of biometrics traits of twins into the classes in which the features belong to.

Irrespective of the degree of similarity, or how difficult the identification process is, there is individuality in biometrics traits even among twins (Bayan & Shamsuddin, 2012; Yu Liu and Srihari, 2009; Srihari, 2010; Srihari et al., 2006; Zhang and Srihari, 2003; Srihari et al., 2002; Srihari et al., 2001b; Marti et al., 2001;

Yong et al., 2000). As such, much effort is needed in generalizing certain features in unimodal biometrics traits as individual ones to assure the accurate representation a person's individuality. Many scholars have attempted to preserve the unimodal biometrics features. As such, previous studies have primarily focused on the local features such as local graphemes features for handwriting of twins (Bayan & S.M. Shamsuddin, 2012; Srihari et al., 2002). Meanwhile, for biometrics traits, most research were focusing on friction ridge (for fingerprints) (Yu Liu and Srihari, 2009), vein (Hengyi Zhang et al., 2014) and face (Sh.Eliabeth et al., 2015), and resulted to high similarities between identical twins. Somehow, the global (holistic) features from the cursive words or shapes as one complete object for any identical twins biometrics have not been sufficiently studied. Azah Kamilah et al. (2010) were among the few that focused on this subject on writer identification.

A strong method is necessary in manual multimodal biometrics identification. This will allow users to ascertain the uniqueness of individual features in identification of twins. Identical twins have similar features in their biometrics traits. Therefore, the process of identifying them can be challenging. As such, a robust method is necessary to enable observation, comparison and evaluation of the similar features so that different unique features from a given biometrics can be. This phase comprises of two key processes. In the first phase, multimodal biometrics is used and the individual features are observed. In the second phase, the different features are identified. Then, the traditional procedures of biometrics system which are feature extraction and classification will be performed after the two mentioned processes are properly modified to fit into a computerized system. Most of the previous research studied concrete unimodal biometrics traits for identical twins. In contrast, Cajote and Guevara (2004), Morita (2003) and Madvanath and Govindaraju (2001) indicated that the use of global approach for extraction of features in biometrics of twins does not result in additional lexicon into the database. Unimodal biometrics trait also results in the identical representations of a pair of twins' biometrics identification. This contributes to existence of low variation for inter-class (both in a pair) and large variation between features for intra-class (one in a pair). In classification, both intra-class and inter-class variations are integral. As such, this study will fully focus on multimodal biometrics and the global features for identification of identical twins.

It is important that features of multimodal biometrics are classified to ascertain the person and his or her unique features. Therefore, the task of classification is crucial in the identification of an actual person in a pair of twins. In relation to this, two types of classes should be considered in the comparison of the multimodal biometrics: intra-class (one in a pair) and inter-class (both in a pair). In biometrics identification, the variation of intra-class must be lower than that of the inter-class (Bayan and S.M. Shamsuddin, 2012; Nisha et al., 2012; Hoang et al., 2012; Felix and Marios, 2013; Paone et al., 2014, He et al., 2008; Leedham and Chachra, 2003; Srihari et al., 2001b; Zois and Anastassopoulos, 2000).

Eventually, this echoes the individuality in the concept of multimodal biometrics in identical twins. Here, low intra-class variation demonstrates a high probability that the multimodal biometrics goes to the exact person twin. On the other hand, large variation in intra-class and low variation in inter-class result in a poor identification performance. This is caused by the similar features that represent twins. The motivation of the study in the identification of biometrics of identical twins is shown in Figure 1.1.

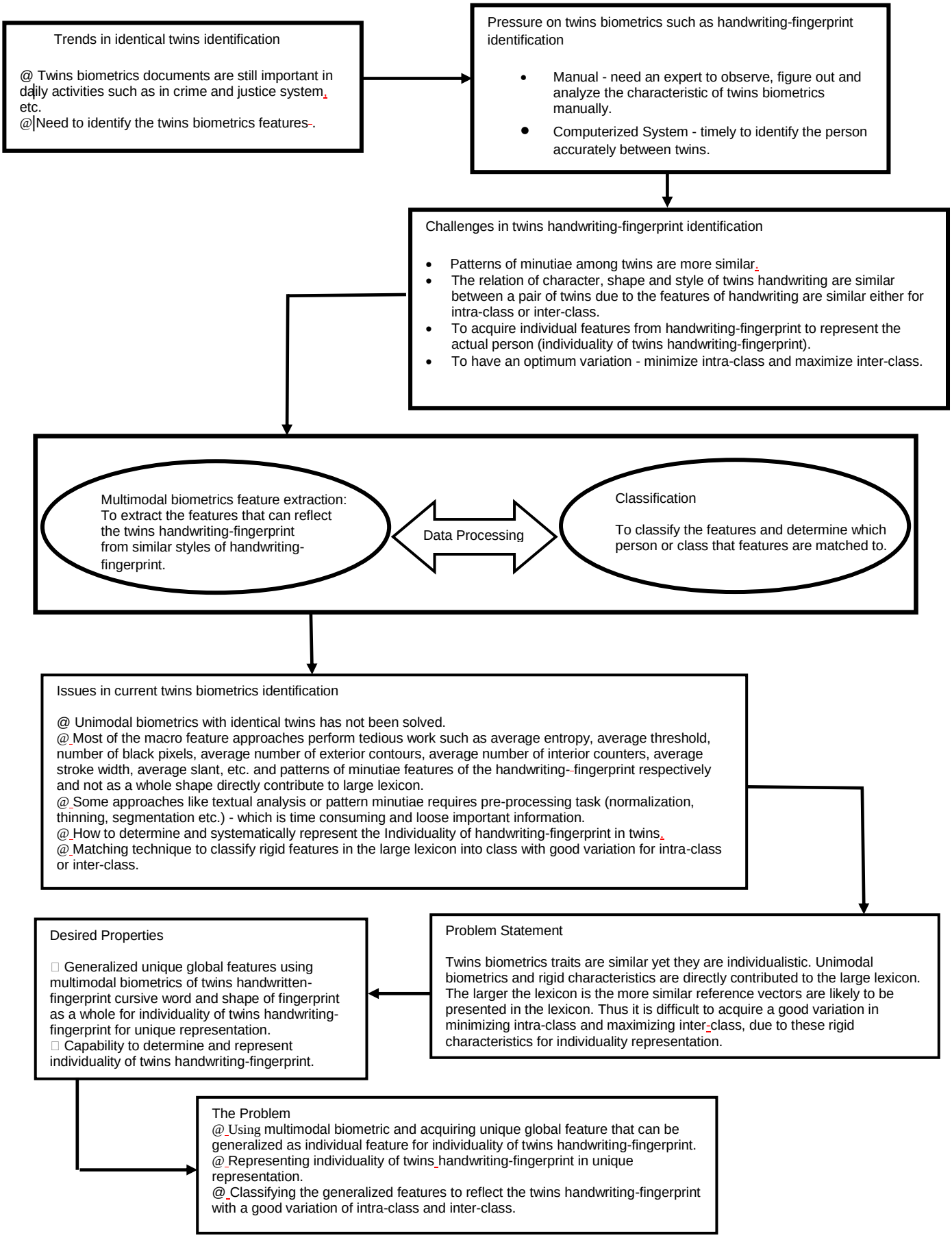

Figure 1.1 Motivation for the study

1.3 Problem Statement

Today the need for the presence of biometric systems, recognition and security of information are becoming more tangible than before. Tools like passwords and other old methods have lost their effectiveness against secured and accurate biometric systems. On the other hand, technology of unimodal biometrics systems comprises an all-inclusive usage of numerous biological characteristics of biometrics technology that is consistently developed (Kauba et al., 2016; Easwaramoorthy et al. 2016; Patil et al. 2016). Nonetheless, as indicated by Ali et al. (2019), unimodal biometrics systems face a number of issues including non-universal applicability, background noise, intra-class variations and inter-class similarities. These issues are impacted by overlapping features resulting from incorrect interaction problems especially with identical twins because twins similarities increase the possibility of misleading in case of biometrics systems' absent. So it's better to use a multi-biometric system. Multimodal biometrics techniques emerge as times require. The multimodal biometrics recognition technology carries three primary advantages: higher reliability, wider applicability and stronger security (Wang et al., 2013). Owing to its crucial theoretical research value as well as its possibility of implementation in the market, the domain of multimodal biometrics is now a crucial direction for research in biometrics recognition. Also, there are now an increasing number of domestic and international research groups that are focusing in this domain.

Identical twins share similarities in terms of the style and shape of their biometrics traits. However, the biometrics traits style and shape can differ from time to time. As such, obtaining minimum variation in same one in a pair and maximum variation between a pair using such huge reference vectors is difficult. This difficulty is contributed by rigid characteristics and numerous representations for unimodal biometrics. A person is only recognizable if a feature from the document given fits with rigid characteristic in the database. However, the identical styles and shape of biometrics traits and large lexicon result in very slim matching likelihood. As lexicon grows in number, the identification task will become more challenging owing to the possible existence of more identical reference vectors inside the lexicon.

Nonetheless, each individual twin in a pair possesses their specific styles and shapes of biometrics traits. With respect to the entire biometrics shape, this reflects more on individuality. This individuality characteristic is generalizable as individual features and is representable for demonstrating the twins biometrics system's individuality. As such, there should be an approach that can extract global features from multimodal biometrics. This allows the preservation of the individuality of twins biometrics in representation of data. Hence, this study attempts to answer the following primary question:

"How to acquire unique, discriminative, reliable, informative representation of twins features to give better biometrics identification and how it can be classified in order to identify the handwritten-fingerprint authorship in twins?"

The primary question is complemented by the secondary research questions as listed below:

1. How to apply the multimodal biometrics trait with Aspect United Moment Invariant to proof the individuality of twins' handwriting-fingerprint in biometrics identification?
2. How effective is the proposed Dis-Eigen feature based fusion algorithm in representing the individual global features of individuality of twins handwriting-fingerprint in biometrics identification?
3. How to combine features in systematic and uni-representation in twins to get the best classification?

1.4 Research Goal

The goal of this research is to propose a new scheme in order to extract the individual global features and also to enhance the performance of identical twins multimodal identification process. This can be done by extracting the individual global features by using Aspect United Moment Invariant (AUMI). Extracted features are then validated for individuality of twin handwriting-fingerprint prior to the identification process using feature based fusion method. The validated features

are further discretized and fused with the proposed Dis-Eigen feature based fusion before it can be identified for twins handwriting-fingerprint identification.

1.5 Research Objectives

The following objectives are to be met by this research:

1) To propose a new scheme that determines the significant identical twin identification global features based on AUMI.

2) To propose Dis-Eigen feature based fusion algorithm that represents the individual features for individuality of handwriting-fingerprint in identical twins identification.

3) To evaluate the best classifier to get the individuality of twins handwriting-fingerprint biometrics identification process.

1.6 Theoretical Framework

In general, the problem solving approach in the area of unimodal biometrics identification for identical twins is grounded on the technique of image processing and pattern recognition (Paone et al., 2014). Figure 1.2 presents a common framework of pattern recognition for unimodal biometrics identification for identical twins.

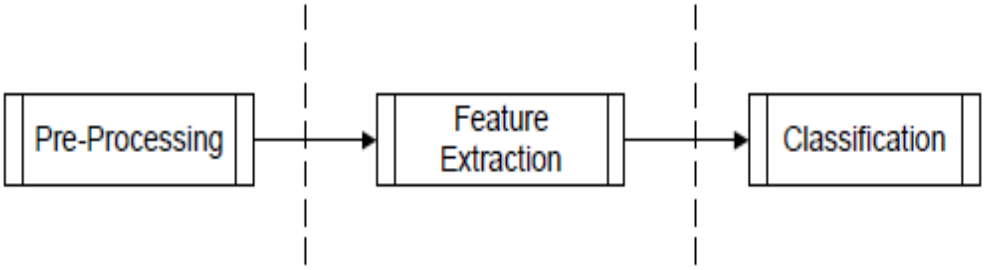

Figure 1.2 A traditional framework of unimodal biometrics identification for identical twins

The framework presented above is also adopted in this study except that this study omits the pre-processing tasks owing to loss of some original and crucial image

information during the pre-processing stage. It should be noted that the pre-processing stage can increase the rate of text recognition. However, it can also reduce the performance of identification in the domain of biometrics identification.

The extraction of word and shape image is performed using AUMI (Azah & Shamsuddin, 2010), and AUMI employs the modalities of multimodal biometrics. In order to exemplify the individual features, the extracted invariant features are combined with Dis-Eigen feature based fusion algorithm. This is done via the discernment of the extracted features into category. This process basically represents multimodal biometrics features as the individual feature of each twin using a single Eigen representation. It acquires attributes, for both biometrics decision values for approximation value of each feature from the individual's handwriting-fingerprint, in the process of Dis-Eigen algorithm. These approximation values enable the classification of a new feature intone interval using a single Eigen representation called the Dis-Eigen feature based fusion vector, the generalized individual features. Using these Dis-Eigen features, the process of classification called the identification task is done for identifying the twins' handwritten-fingerprint authorship in the domain of multimodal biometrics identification. The identification task employs K-NN, SVM, Neuro-Fuzzy, Artificial Neural Network (ANN), J48 Decision Tree, Random Forest, Random Tree and Naïve Bayes (NB) algorithms.

Pattern recognition, a crucial application of neural networks, is employed using a properly trained feed-forward neural network. This network is trained to link outputs with input patterns. Using this network, the input pattern is identified and tries to output the associated output pattern. The neural networks emerge when a pattern with no linked output is given as an input. Here, the network provides the output that matches up to a taught input pattern that is least different from the specified pattern. Here, ANN, K-NN, SVM, Neuro-Fuzzy were selected due to its capacity and J48 Decision Tree, Random Forest, Random Tree and Naïve Bayes (NB).

1.7 Importance of the Research

This research is of value to the theoretical knowledge and also the actual life application. First of all, the domain of multimodal biometrics identification has the objective of identifying identical twins handwriting-fingerprint. This is particularly crucial in the system of criminal justice with vast exploration in the analysis of forensic documents (Bayan and Shamsuddin, 2012; Bayan and Shamsuddin, 2011; Yu Liu et al., 2009; Srihari et al., 2006; Bensefia et al., 2005a; Srihari et al., 2002).

Further, an expert in multimodal biometrics identification analysis (graphologist) is necessitated in running the manual identical twins biometrics identification in finding out the uniqueness of twins' handwriting-fingerprint known as individual features. The unique features obtained from the twins' handwriting-fingerprint that can represent the person have to be observed in the method. The use of computerized system for twins handwriting-fingerprint identification can ease the manual process.

The past works that obtained features from the unimodal twins biometrics have concentrated on the extraction of rigid characteristics of twins biometrics. Such method is closely linked to the large lexicon. As such, global features are proposed in this research as they can provide solution to the issue of local features in the area of twins handwriting-fingerprint identification.

On the other hand, individuality of twins biometrics traits is a crucial success factor of multimodal biometrics identification application. Majority of past works have concentrated on the way to extract the individual features from unimodal biometrics trait that fulfills the individuality of twins biometrics, in which the variance between features for intra-class is smaller than that of the inter-class. Also, this study demonstrates additional improvement on the individuality of twins multimodal biometrics with global features as well as feature based fusion. Also, individual features are methodically represented to demonstrate the individual features. Directly, this enhances the performance of identification of twins handwriting-fingerprint, paving the way for fresh perspective of research in the

domain of multimodal biometrics identification with global features and feature based fusion.

1.8 Research Methodology

This section briefly introduces the research methodology implemented in this study. The detailed discussion of research methodology is presented in Chapter 3. It contains four main tasks:

1. Review and investigation of a conventional biometrics identification process for identical twins; a basic based pattern recognition system to understand the general processes, issues, requirements, methods and interactions with others.
2. Application of the Aspect United Moment Invariant algorithm.
3. Proposing a novel identical twin identification scheme with multimodal biometrics identification for multiple modalities by expanding an existing identification scheme with Dis-Eigen as feature based fusion.
4. Examination of existing extraction, the proposed Dis-Eigen feature based fusion in order to represent and illustrate the individual features into uni-representations for individuality of twin handwriting-fingerprint in biometrics identification domain.
5. Finally, perform similarity measurement of features for testing data set and training data set. ANN, K-NN, SVM, Neuro-Fuzzy, J48 Decision Tree, Random Forest, Random Tree and Naïve Bayes (NB) are adopted into this identification task as classifiers.

1.9 Contribution of the Research

In order to assure success in identifying identical twins using multimodal biometrics, it is crucial to have effective organization of methodology because the study has to have the capacity to integrate and deal with integral information including individual's distinguishing characteristics in a pair of twins. The distinct characteristics of a person are unique to biometrics identification and this is

particularly relevant in the forensic domain. This study mainly contributes to the usage of feature representation grounded on multiple biometrics images, global features and Dis-Eigen feature based fusion algorithm. This enhances identical twins identification in terms of its performance. The twins' multimodal biometrics based forensic authentication is a capable and good model in assisting forensic investigation which could be of value to both academia and industry. Forensics, security, financial activities and archeology are among the domains that could reap benefits from this proposed system. This research has a number of contributions as presented below:

i. A novel scheme of twins multimodal biometrics identification. This research proposed a novel scheme of twins multimodal biometrics identification with holistic approach that presumes one word or shape as one whole entity that cannot be broken down. This approach does not split the word or shape into sub-units. The non-existence of sub-unit features can directly decrease the large size of lexicons. Then, these modalities are extracted as features vector and are represented informative feature set based on region and contour based representation. The novel multimodal biometrics identification scheme is workable and gives a significantly better performance than existing schemes.

ii. The improved design of global features from geometrical function. Aspect United Moment Invariant (AUMI) algorithm has been selected for feature extraction due to its capability to select individual features for feature extraction process. The proposed scheme is unique because it can minimize MAE for intra-class and maximize MAE for inter-class.

iii. The proposed Dis-Eigen feature based fusion algorithm. A novel way of dealing with the feature fusion process and representing the individual features by eliminating features that have a strong correlation between them and also to reduce over-fitting features. Here, a single multimodal biometrics feature based AUMI is created for the twins multimodal biometric features. After concatenation twins handwriting-fingerprint features, dealing with Eigenvector process and compute med value for each discrete in Eigenvector, then Start with mapping process between

med value and mean value that comes from both multimodal biometric twins handwriting-fingerprint features, and finds the best Eigen discriminatory features of each individuals twins biometric modality. This research addresses new structure of twins multimodal biometrics fusion.

Lastly, the concept of generalization of affinity binding in ANN, K-NN, SVM, Nero-Fuzzy, J48 Decision Tree, Random Forest, Random Tree and Naïve Bayes (NB) has also been used in the process of classification.

1.10 Scope of the Research

This research's scope is bound by a number of factors, namely:

i. Offline twins handwriting-fingerprint was obtained from Kurdistan in Iraq, comprising of 100 twins (200 authors) amounting to 1600 data of cursive word shape and fingerprint.
ii. The proposed method is based on offline data format of the twins handwriting-fingerprint from the database.
iii. Emotions are not taken into account in this study although it is noted that writing styles and fingerprint shapes are affected by them.
iv. The development tool that is used in this study includes MATLAB for feature extraction purposes and classification while WEKA toolkit is used for experimentation and validation of training and testing purposes as well.

1.11 Thesis Organization

Chapter 1 presents the introduction of the research. Chapter 2 provides the literature and information of related areas that lead to the problem statement and solution of the study. Chapter 3 describes the research methodology and justification for the solution approach. It is then followed by Chapter 4 and Chapter 5 which are the objective of the research that is outlined in Chapter 1. Each chapter will discuss

and demonstrate the development phases of proposed solution for each objective. Chapter 6 discusses the overall research findings and contributions of the research as well as proposed future research and conclusion.

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