A NEW DIGITAL MESHED POLYGON METHOD FOR DEMONSTRATING INDIVIDUALITY IN FINGERPRINTS FROM DIFFERENT INDIVIDUALS

BY

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE (HONOURS) (FORENSIC SCIENCE)

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JUNE 2016

ACKNOWLEDGEMENT

All praise be to Allah. I would like to thank my supervisor Dr. P. T. Jayaprakash for giving me this research opportunity and for all his patience, hard work and guidance throughout this research. I learned a lot from him throughout the journey of this research. I also thank our course coordinator Dr. Haslindawaty binti Abd Rashid for her advice, concern and determination in keeping us on track for this whole semester. To all those wonderful persons I have met in Pusat Pengajian Sains Kesihatan and Universiti Sains Malaysia as a whole for making my time here meaningful and rewarding.

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ABSTRAK

Cap jari menghasilkan corak tekstur berpaksi yang mewakili simbol individualiti. Hingga kini, individualiti masih tidak dapat dibuktikan secara saintifik, sungguhpun begitu, tiada satu pun yang mampu untuk memberi bukti yang bertentangan bagu menolak teori tersebut. Samada secara kebarangkalian, statistik atau pengiraan matematik. Kajian ini bertujuan untuk menetapkan kaedah baru bagi pengecaman individualiti. Kajian ini merupakan kajian rintis dan kajian kolerasi secara amnya. Perisian Adobe® Photoshop® digunakan untuk menganalisa cap jari. Untuk setiap cap jari dan setiap teraan, 12 tanda titik khusus telah dikenal pasti, kemudian setiap tanda titik akan disambung untuk menghasilkan satu bentuk poligon. Bentuk poligon bagi teraan tinggi dan normal akan ditindan menghasilkan bentuk poligon yang bertindan daripada sumber jari yang sama. Bagi membuktikan individualiti cap jari, 20 poligon yang terhasil daripada teraan normal akan ditindih tepatkan. Hasil kajian menunjukkan bahawa bentuk yang dihasilkan jaringan poligon dari sumber jari yang sama selepas ditindih tepatkan mempunyai bentuk poligon yang sama tetapi berlainan dari segi saiz. Perbezaan didapati dalam ukuran ketinggian, kelebaran dan keluasan maksimum. Majoriti perbezaan ketinggian maksimum dan kelebaran maksimum berukuran antara 0 sehingga 0.05 cm sahaja dan tidak melebihi 0.07 cm. Manakala, untuk penindih tepatan 20 jari daripada sumber yang berlainan, menunjukkan tiada satu poligon yang mempunyai bentuk poligon yang sama. Untuk menunjukkan keunikan corak cap jari, bukti visual berdasarkan konsep morfologi melalui penghasilan jaringan poligon memenuhi keperluan dalam menghasilkan kaedah untuk mengukuhkan elemen individualiti.

ABSTRACT

A fingerprint produces an oriented texture pattern which represent a symbol of individuality. Until today, individuality remains scientifically unprovable and yet, none have ever been able to provide a contradicted proof to ban the theory. Be it probabilistic, statistic or mathematic. This study aims to propose a novel method to demonstrate fingerprint individuality. This is a pilot study design and a correlational study as a whole. Adobe® Photoshop® software was used to analyse fingerprint samples. For each fingerprint impression, 12 precise points were located upon the minutiae, each point was connected to construct a polygon which had produced a meshed polygon. The shape of the meshed polygon for high impression and normal impression were superimposed from a common source finger. Whereas, for meshed polygon originating from different source fingers, 20 meshed polygons from each finger type were superimposed. The result shows that for the superimposition of high impression print and normal impression print from common source finger, the shapes remained the same but differ in size, the variations are in the measurement of maximum height, breadth and area. Majority of the difference in maximum height and breadth had a range of 0 0.05 cm only, in which, none had exceeded the threshold value 0.07 cm. Whereas, the 20 superimposed meshed polygon outlines for each finger type, had showed that none of 20 the meshed polygon outlines produced a 'match'. Hence, in order to demonstrate the individuality of fingerprint, visual evidence based on the morphology basis was shown through the constructed meshed polygons had fulfilled the requirements in producing a method to enhanced the element of individuality.

CHAPTER 1 INTRODUCTION

1.1 Overview

Fingerprint is one of the most exquisite biometric feature used for recognizing an individual based on his or her physical trait (Jain et al., 2006). It plays an important role not only in providing a personal identification for law enforcement purpose but also serves as a forensic evidence since the second half of nineteenth century (Kobus et al., 2016). Fingerprint identification is also a type of pattern identification (Evett, 1993) where the pattern produced by the epidermal ridges on the surfaces of our body parts (Adebisi, 2008) are utilized for comparison and identification. The use of specific number of points on the fingerprints which are also known as minutiae was introduced and is progressively being practiced (Champod et al., 2004).

However, the uniqueness of fingerprint in the patterns of fingerprint that is the basis for individualization identification is not fully demonstrated when solely relying on a specific number of minutiae. Hence, a new method based on the lines connecting the minutiae, 12 in number, which will form a meshed polygon is proposed in this research since such a polygon will form a visual basis to convey the morphological similarity indicating the element of uniqueness while interpreting match among two fingerprints thereby offering a more significant, transparent and reliable method for demonstrating the individuality of fingerprints.

1.2 Research Background

Forensic science is a profession that aids in criminal investigation by establishing facts through the analysis of physical evidence (Inman and Rudin, 2000). Identification and individualization are the two fundamental physical evidence based activities that have been utilized in forensic science (Saferstein, 2004). For more than a century, source attribution through physical matching or pattern matching such as fingerprints have remained extremely reliable methods for individualization (Jayaprakash, 2013). Thus, individualization remains a fundamental tenet of forensic science (Jayaprakash, 2013).

In the field of fingerprint comparison, the details in the ridges form the basis of identification (Egli Anthonioz and Champod, 2014). The distribution of these details, known as minutiae, is considered unique for a given fingerprint. By convention, experts rely on a specific number of minutiae for concluding identification and the number is seen to vary across countries. Although a fingerprint is assumed unique, the use of a given number of minutiae for identification has prompted treating the match on a statistical basis. Consequently, the concept of morphological basis for comparison, although well agreed to among practicing experts, is not conveyed while interpreting the match when it is based on a given number of minutiae.

Despite the general proposition which prescribes that every natural pattern is unique (Vanderkolk, 2009), there is still considerable controversy in accepting the uniqueness of fingerprints consequent to the recent Daubert court ruling. The insistence on quantifying any match similar to DNA profile match is increasing (Lynch, 2003). Alongside, the criticisms on the uniqueness and individualization concepts in forensic science are being amplified culminating in the suggestion that individualization is not required for forensic science practice (Page et al., 2011). On the other hand, the practical relevance of pattern matching based on morphological comparison such as those in physical matching of broken edges that are complementary or among fingerprints has also been stressed recently (Jayaprakash, 2014).

However, the practice of relying on a specific number of minutiae, for example 12 in Malaysia, for comparing fingerprints is seen to have eclipsed the reality that the match concluded by the expert is indeed on a morphological basis. Despite, the tolerance ranges or levels fashioned during the analysis phase of fingerprint comparison, different decisions among examiners, or differences in the examination protocol carried out, a spectrum of clarity and distortion factors need to be weighed to make the required decision of correspondence (Cedric Neumann et al., 2013). Therefore, there is a need for forensic scientists to prescribe methods that would convey the correspondence in pattern matching on a morphological basis and yet preserve the element of individuality in a clear and transparent manner during fingerprint comparison for rendering it demonstrable and acceptable to courts

One solution would be devising a method to convey the uniqueness in two matching fingerprints on a morphological basis which will offer convincing visual evidence on a match. This research proposed the similarity in the morphology of meshed polygons created in two fingerprints from the same source as the basis for concluding 'match'. In addition, the polygon offers measurable parameters which can also be utilized for interpreting the match offering due allowance for the inevitable expansion of pattern due to expansion of the finger surface consequent to pressure variation during contact. The same minutiae that serve as elementary morphological elements (Pradhan and Ghose, 2012) during comparison also serve as the basis for the variations in the shape of the polygons that are created in this research.

1.3 Problem Statement

i. The concept of morphological basis for comparison of fingerprints, although well agreed to among practicing experts, is not conveyed while interpreting the match when it is based on a given number of minutiae.

ii. The practical relevance of pattern matching based on morphological comparison has been questioned.

iii. There is a need for forensic scientist to prescribe methods that would convey the element of individuality in the fingerprint comparison on a morphological basis as well as in a manner demonstrable and acceptable to courts.

1.4 Research Objectives

Main objective: To formulate a method for classifying face image.

Specific Objectives:

i. To demonstrate the use of digital meshed polygon method for differentiating inked fingerprints obtained from different source fingers.

ii. To demonstrate the use of digital polygon meshed method for matching inked fingerprints from the same source finger obtained using different pressures.

1.5 Research Hypotheses

Null Hypothesis:

i. The shape of the meshed polygon generated by joining 12 minutiae would not remain stable for the same fingerprint from the same source finger.

ii. The shape of the meshed polygon method generated by joining 12 minutiae would not differ for different fingerprint from different source fingers.

Alternative Hypothesis:

i. The shape of the meshed polygon generated by joining 12 minutiae would remain stable for the same fingerprint from the same source finger.

ii. The shape of the meshed polygon method generated by joining 12 minutiae would differ for different fingerprint from different source fingers.

1.6 Research Significance

To prescribe a method that would convey the element of individuality in the fingerprint comparison on a morphological basis and in a manner demonstrable and acceptable to courts.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

In general, fingerprint is an impression produced by the pattern of the epidermal ridges (Adebisi, 2008) on the surface of the palm of the hands and fingers, and the soles of the feet and the toes (Kucken and Newell, 2005b, Kaushal, 2009, Andrew and Julie, 2004, Adebisi, 2008). It is a two-dimensional pattern (Amery et al., 2004) created by series of ridges and valleys and have a core commonly at the centre of the fingertip (Chaudhari et al., 2014) which believed to form in the embryo from around the thirteenth week of gestation (Tilstone et al., 2006a). The fingerprint feasibility, accuracy, reliability, acceptability, (Ravi et al., 2009), uniqueness (Su and Srihari, 2010) distinctiveness, persistency ease of acquisition, and high matching rates are the primary factors which contribute on why fingerprint based authentication system dominate the biometric market with over 52% of the total authentication system based on biometrics traits (Maltoni et al., 2009).

2.2 History of Fingerprint

It was in the 16th century that, the uniqueness in the characteristics of human fingerprints were recognized by many scholars in different scientific disciplines. Dr. Nehemiah Grew, a botanist was the first person to document the details of his findings about the superficial features of ridges. Marcello Malpighi (1628-1694), an anatomist explored the formation of the ridge in order to understand the functions of the skin. Next, Thomas Bewick (1753-1828), a noted wood engraver, reproduced fingerprints in his engraving which was conjectured to be his own fingerprints. John Evangelist Purkinje (1797-1869), a Professor of

Physiology presented a thesis describing the patterns formed by the ridges on the fingers and divided them into nine groups (Lambourne, 1977).

As time revolved, the pattern ridges present on the bulbs of the human fingers have drawn the attention of Sir William Herschel, a British officer in India to initiate the application of fingerprint as a form of personal identification. He used fingerprints and handprints as signatures on native contracts in order to prevent fraud. The first fingerprint identification in history was recorded by a Scottish physician working in Japan, Dr. Henry Faulds. He conducted the contemporary method of recording and comparing fingerprints using black printer's ink producing inked impression and by comparing it with a greasy fingerprints found on a piece of glassware (Kaushal, 2009).

Nowadays, methods that use fingerprints can be divided into two categories,- identification and verification (Patel and Sharma, 2013). The identification method of fingerprint pertains to the traditional domain of criminal fingerprint matching which also is termed, one-to-many matching (Lawrence, 1996). It is a combination of anatomical and behavioural characteristics as primary characteristics of fingerprints are anatomical in nature while the method by which prints are left and retrieved using input devices depending on the person's behavioural (Chaudhari et al., 2014). While, verification is the one-to-one comparison of a claimant's fingerprint against an enrolleed fingerprint of the same individual usually available in a reference database of known fingerprints (Lawrence, 1996). In short, verification is a process of accepting or rejecting a user's claimed identity (Jain et al., 2000).

2.3 Fingerprint as Forensic Evidence

Fingerprint evidence is routinely encountered in forensic laboratories and identification units around the world (Pankanti et al., 2002). Forensics and law enforcement agencies across

the globe to apprehend and convict criminals (Choi et al., 2011) and become one of the most precious clue obtained in the field of investigation. Notably in homicide or suicide cases, mass disaster incidents and combat casualties from wars in Iraq and Afghanistan. Criminals often do leave identifying "signatures" in the form of fingerprint which serve as a unique and highly individualistic traits as no two people, not even twins, have ever been shown to have exactly the same pattern of raised, curved lines on their fingertips (Kaushal, 2009).

Fingerprint is known as a trace evidence. Fingerprint traces left at the scene of a crime can be three kinds which are moulded impressions, visible impressions, and latent impression and all these impressions vary depending on the nature of object surface touched and the material coating the fingers at the time of contact (Edwin, 1940). The study of the research will only involve one type of fingerprint trace which is the visible fingerprint. It is the result of fingers being coated with a substance that deposits and forms a fingerprint when a surface is touched (Kobus et al., 2016).

2.4 Fingerprint Identification

The heart of fingerprints identification is the belief and confidence of an examiner that there is a sufficient number of common ridge characteristic present (Epstein, 2002) in order to establish an identity by fingerprint. Due to the fact that the path of friction ridges is unique to that area of friction skin, it has become a fundamental basis for the identification process of fingerprint (Champod et al., 2004). An average human fingerprint contains 75 to 175 minute ridges characteristic, called minutiae, (Epstein, 2002) which allow a total of 8 minutiae, the minimum standard number required for fingerprint identification process, to be easily detected. Eventually, making fingerprints emerging across the globe as the most common and reliable biometric for personal identification (Yager and Amin, 2004).

2.4.1 The Basic Premises of Fingerprint Identification

Fingerprints have been denoted as the gold standard for the fact that they form an infallible tool for personal identification within the forensic community (Kaushal and Kaushal, 2011). The basis of fingerprints that has remodel a means of personal identification comprises of three essential aspects (Giannelli, 2006). Primarily is the stability or permanency of human fingerprints (Giannelli, 2006, Andrew and Julie, 2004). Unlike face and voice patterns, fingerprint patters are persistent with age and remain stable as they do not easily change (Rani and Sharma, 2014). Moreover, fingerprints of an individual remains unchanged and its pattern endures throughout life even if it may be marred, for example, by deep scarring.

Secondly, the uniqueness of fingerprints as there are no two fingerprints are identical, even those of identical twins (Giannelli, 2006, Andrew and Julie, 2004). Sir Francis Galton demonstrated that the odds against two individual fingerprints being exactly the same was 64 billion to 1 and to date, up till now no two fingerprints have yet been found to be the same (Andrew and Julie, 2004). Fingerprint is also unique because each ridge is characterized by numerous minute peculiarities known as minutiae (Rani and Sharma, 2014) which comprise of various distinctive features such as ridges, and pores (Chen and Jain, 2009) making it immutable and lead to a strong mark for identity (Babatunde, 2015).

Thirdly, the transferability of an impression of the friction ridge skin to another surface (Giannelli, 2006). The Locard's Exchange Principle, also known as Locard's Theory states that every contact leaves a trace is the foundation of investigative science including fingerprints (Ramsland, 2012). One of the main function and morphology of the friction skin is as a tactile organ (Ashbaugh). Those minute ridges on our fingertips provide frictions upon any contacted surfaces and allow grasping activity to take place without slipping away easily. Every object

that our fingers come into contact with will certainly leave traces of ridge pattern and these traces do not alter when deposited on a surface unless other disturbance come into contact afterwards (Tilstone et al., 2006a). All these three premises have fashioned fingerprints as an excellent, popular and effective means for identification of an individual and used as a forensic evidence (Chaudhari et al., 2014).

2.5 Individuality of Fingerprint

Individuality in a fingerprint refers to the distinctiveness of fingerprints originating from different source of fingertips (Chen and Moon, 2007). For achieving fingerprint individualization, it is compulsory to capture some invariant features of the fingerprints in order to reliably establish whether two prints came from the same source (Acharya, 2015). The most widely prevailing fingerprint features used by forensic experts to match two fingerprints are minutiae of the ridges (Chaudhari et al., 2014) which are also known as local ridge anomalies (Jain et al., 2000) that interrupt otherwise smooth flow of ridges (Ambadiyil et al., 2015). Attempts have been made to quantitatively measure the uniqueness or individuality of fingerprints but have failed as they could not exploit completely the information contained in minutiae features (Chen and Jain, 2009). In reality, experts consider the relative location of point rather than the number of minutiae although a minimum number of minutiae have grained popular acceptance.

2.5.1 Uniqueness of Minutiae-Based Methods

Fingerprint minutiae are the most unique, durable and reliable features mostly utilized because forensic examiners have successfully relied on minutiae to match fingerprints that have remained admissible in court of law (Babatunde, 2015). However, the exact random process governing minutiae formation is still unknown as there are very little research available to

articulate more precisely the stochastic process of minutiae generation (Champod et al., 2004). Minutiae comprise of different types of elementary morphological element contributing to different types of morphological features (Pradhan and Ghose, 2012). Furthermore, each minutiae has some coordinate characteristics, type, and direction (Zhu et al., 2005) making it predominantly a local landmark (Jain et al., 2000). Figure 1 shows some of the various types of minutiae including ridge endings, bifurcations or forks, islands, cross-overs, short ridges, spurs, deltas, and cores.

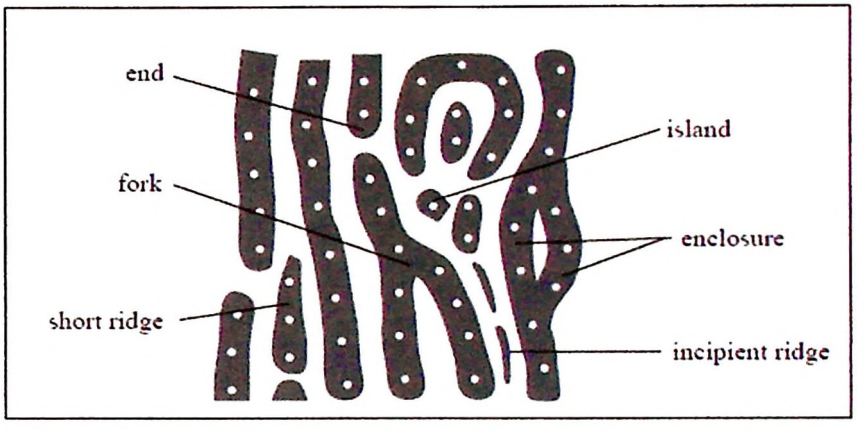

Figure 2-1: Example of minutiae
(Kucken and Newell, 2005a).

Matching method is one of the techniques in fingerprint identification. There are a few techniques currently being practiced and mainly classified into four sets: minutiae based methods, ridge based method, texture based methods and neural based methods. The matching involving two fingerprints originating from the same source finger is known as homologous matching. Whereas, the matching between two fingerprints originated from different source finger is known as heterologous matching. Consequent of matching process usually result in match area, where the overlapped area of the two matching fingerprint. Particularly for minutiae based method, extracted minutiae will be the controlled variable to measure the similarity of these two fingerprints (Zhang et al., 2016).

For decades, many countries around the globe have prescribed a minimum number of minutiae that are required for fingerprint experts to make an identification (Kobus et al., 2016, Cole, 1999). For example, Holland, Germany (Evett and Williams, 1995), Malaysia and Australia specify 12 minutiae, United Kingdom requires 16 minutiae, New Scotland Yard specified 10 to 15 minutiae (Kobus et al., 2016). Generally, fingerprint experts well-agree that there must be at least twelve corresponding minutiae in the same relative positions for a positive identification (Edwin, 1940). However, there is no scientific basis for the minimum number of minutiae standard before a conclusion of identity may be reached (Giannelli, 2006) and well-agreed by an expert panel convened by the International Association for Identification reported in 1973 (Tilstone et al., 2006b).

2.5.2 Challenges and Criticisms

Lately, criticisms against individualization in forensic science have been put forth by some authors affecting the reliability in identifying individuals based on biological patterns including those of human fingerprints (Saks and Koehler, 2008, Giannelli, 2006, Fagert and Morris, 2015). These criticisms are mainly based on the inability to offer conclusive evidence to support the claim of uniqueness in fingerprint patterns which forms the basis for declaring match between two (Chen and Jain, 2009). Indeed, the reliability and validity of fingerprint persistency and individuality are being questioned aggressively by a number of authors and some courts too.

It can be argued that the persistency of fingerprint has been successfully validated by the anatomy and morphogenesis of friction ridge details in the skin while the individuality of fingerprint even though generally accepted has not yet been formally tested (Pankanti et al., 2002). Regardless of these critics, the opinions offered on the basis of analysis of fingerprint evidence by fingerprint examiners who are, suitably qualified as "expert" examiners by virtue

of training and experience will continues to sustain the paradigm of individuality in fingerprint identification (Kaye, 2003). It has also been proposed that the pattern in nature, when seen as a whole, provide sufficient features generated by indeterminable combination of factors to support the proposition and as such it appears unreasonable to dismiss uniqueness as irrelevant or banal (Jayaprakash, 2013).

It is seen that the popular use of a specific number of minutiae has prompted statistical application for interpreting match among two fingerprints. It follows that individuality would not be attainable since application of probability does not enable reaching individualization. Thus, the uniqueness in fingerprint patterns is not conveyed when using a prescribed number of minutiae as the basis for the matching and identification. Many fingerprint matching methods were introduced in earlier works (Zhu et al., 2005) such as those that use graph matching method (Isenor and Zaky, 1986), grammar method (Moater and Fu, 1986), optical features integrating with neural network (Wilson et al., 2000), and computation technique of texture features of fingerprint (Jain et al., 2000). While all these methods share the same aspiration to demonstrate the individuality of fingerprint, none has succeeded in demonstrating individuality.