

# An Investigation of Matching Approaches in Fingerprints Identification

Asraful Syifaa' Ahmad, Rohayanti Hassan, Noraini Ibrahim,  
Mohamad Nazir Ahmad and Rohaizan Ramlan

**Abstract** Fingerprints identification is one of the most widely used biometric technologies that can enhance the security for an access to a system. It is known as the most reliable application compared to others. In the framework of fingerprints identification, the most crucial step is the matching phase. Thus, this paper is devoted to identify and review the existing matching approaches in the specialized literature. The literatures that related to the fingerprints matching were searched using all the relevant keywords. Thirty-five studies were selected as primary sources which comprised of 34 journal articles and a book. The overview of the generic processes was provided for each fingerprints matching. Besides, current works for each of the approaches were addressed according to the issues being handled.

**Keywords** Biometrics • Fingerprints identification • Correlation based • Minutiae based • Ridge feature based

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A.S. Ahmad (✉) • R. Hassan • N. Ibrahim • M.N. Ahmad  
Faculty of Computing, Universiti Teknologi Malaysia,  
81310 Johor Bharu, Malaysia  
e-mail: asrafulsyifaa.ahmad@gmail.com

R. Hassan  
e-mail: rohayanti@utm.my

N. Ibrahim  
e-mail: noraini\_ib@utm.my

M.N. Ahmad  
e-mail: mnazir@utm.my

R. Ramlan  
Faculty of Technology and Business Management, Universiti Tun Hussein Onn,  
86400 Parit Raja, Batu Pahat, Johor, Malaysia  
e-mail: rohaizan@uthm.edu.my

## 1 Introduction

Present-day, old security methods that used access card and password are not excellent enough to protect individuals' belongings. Therefore, biometric authentication systems had been introduced to overcome the limitation of the existing methods, as they are unique and cannot be stolen. For example, among the traits from human body part that can be used for recognition process are DNA, iris, retina, face, voice, signature, palm print, hand geometry, and hand vein [1]. Primarily, biometric authentication process collects all the biometrics information and keeps them in a database for verification. However, the procedure was claimed unsecured. Thus, the current methods enroll the biometric template with the newly produced template by using algorithm or mathematical calculations. The aim was to find the similarities between both the templates, and the access will be granted if the pairs match [2].

The key factors of fingerprints usage are the uniqueness of its pattern [3] and the acceptability to people as a comparison trait compared to other biometric modals. Fingerprints are one of the most widely used metrics for identification among all biometrics [4, 5]. The advanced technology of this identification technique had been deeply explored by the law enforcement agencies and positively used for security purposes that include getting access to a control system, passing the country border, and in criminal investigation. Fingerprints identification or dactyloscopy compares two instances of minutiae from human fingers to determine whether both are from the same individual. The uniqueness of fingerprints are the distinct pattern of a series of delta, ridge ending, furrows, and also the characteristic of local ridges.

This paper is organized as follows: Sect. 2 explains the research method used, Sect. 3 describes the fingerprint matching approaches in detail, and lastly, Sect. 4 reviewed the current issues related to approaches.

## 2 Research Method

Following the recommendation by Achimugu et al. [6], the review protocols consist of four main phases as follows: map out the research questions, designing the search strategy, study the evaluation results, and lastly interpretation and synthesis of data. The subsequent strategy search designed phases are search terms and resources and search process, while the study evaluation of subsequent phase included scrutiny and assessment of quality criteria.

## **2.1 Research Questions**

The aim of this review was to understand and summarize the properties of matching approaches used in fingerprints identification and to identify the possible area for further research in order to complement the performance of existing technique. The following three research questions were simultaneously explored and interlaced to achieve this aim:

- What are the existing techniques in matching approaches used for fingerprints identification?
- What are the generic process and limitations for matching approaches?
- What are the current issues in fingerprint matching?

## **2.2 Research Strategies**

The search strategies used in this research that included the searching by terms and resources were explained in this section. Specifically, the search terms focused on the selected domain of the research and were created by using the following steps [6]:

- (1) Derive the major terms from the research questions and identify the synonyms.
- (2) Integrate the alternative spellings and synonyms, using the Boolean.
- (3) Link the major term using the Boolean AND.

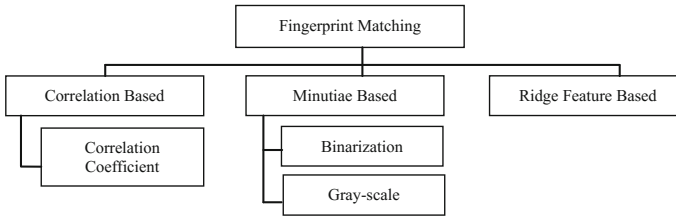
Four mega electronic resources were used as main references including Springer, IEEE Explorer, Science Direct, and Google Scholar. For published journal, papers, title, abstract, and conclusion were used as the parameters. Thereafter, 175 potential studies were realized. By using study selection and scrutiny, only 24 papers were able to provide the answers to the research questions formulated.

# **3 Fingerprints Matching Approaches**

## **3.1 Taxonomy of the Study**

The large numbers of fingerprints matching approaches have been mainly classified into three types which are minutiae based, ridge feature based, and correlation based. Three main taxonomies of fingerprints matching have been shown in Fig. 1.

The correlation-based matching calculates different alignments using the correlation between the corresponding pixels of two superimposed fingerprints images and need to be applied to all possible alignment as the rotation and also displacement are unknown. The minutiae-based matching finds the minutiae alignment



**Fig. 1** Taxonomy of fingerprint matching study

between the two fingerprints to find the maximum number of similarities. Another type of matching is ridge feature based that is also known as non-minutiae feature based. The difference of this approach is the usage of feature extracted from the ridge pattern.

### 3.2 *Generic Process of Three Main Types of Fingerprints Matching*

Fingerprints matching is a crucial step in both identification and recognition [7]. Basically, fingerprints matching techniques compare and calculate the similarity score between both the input and the template image. Both fingerprints images are called genuine if they obtain a high similarity score and called as impostor if the images were different. The most apparent differences between these three approaches are the input parameter and also the algorithm.

Correlation-based matching used the entire fingerprints structure as its input and all the possible alignments are need to be compared in order to obtain a high matching score [8]. Then, both images are rotated using estimated rotation [9], followed by applying image transform technique to correlate both the template and the input fingerprints images at different rotational and translational alignments before calculating the matching score.

Minutiae-based matching is the most popular approach among others as it includes finding the best alignment in between the image template and the input. In this approach, brute-force algorithm is used in order to find all the possible similar minutiae [10]. After the minutiae extraction phase, the coordinate type of minutiae (ridge ends or bifurcation) is determined. A track of 10 pixels wide is created [11], while any minutiae located in that track are recorded to calculate the matching score.

Ridge feature-based matching utilized the characteristic of fingerprints which are ridges. Local ridge frequency and also local ridge orientation are used to create a set of features that symbolize the individuals' fingerprints [8].

4 Current Issues of the Matching Approaches

This section presents and compares the related work of existing fingerprints matching approaches according to their issue being handled (Table 1). Fingerprints computing can be used to solve noisy and low-quality image, while robustness issues were comprised of the accuracy and precision of the techniques.

Table 1 Comparison of fingerprint matching approaches

Issues	Correlation based	Minutiae based	Ridge feature based
Low-quality image	<ul style="list-style-type: none"><li>• Apply correlation coefficient on low-quality input image yet achieve higher matching result [12]</li><li>• Manipulate the phase-only correlation function that comprises of both global and local search. Each search has its own aim to ensure the matching success [13]</li></ul>	<ul style="list-style-type: none"><li>• Implement global distortion correction as preprocessing step that considering texture characteristic of fingerprints image [14]</li><li>• Apply NCC method for low-quality images and implement normalized cross-correlation method in matching phase [15]</li><li>• Put different weights on reliable and unreliable minutiae points to calculate similarity score [16]</li></ul>	<ul style="list-style-type: none"><li>• Apply this method to find the initial minutiae pair. First implement the ridge matching process. Finally, calculate the matching score [17]</li><li>• Manipulate hierarchical matching method that employs Level 3 features. The methods performed well and being test on both the high-quality and low-quality images [18]</li></ul>
Robustness	<ul style="list-style-type: none"><li>• Apply correlation mapping and discriminative–generative classifier scheme to decide either the input fingerprint is from live person or not. The scheme is based on GMM, Gaussian copula, SVM, and QDA [19]</li><li>• Design three-step matching phase using the correlation coefficient. First is alignment, next is extraction of common region, and last is calculation of similarity degree [20]</li></ul>	<ul style="list-style-type: none"><li>• Included nearest-neighbor matching strategy using different condition of fingerprint image as follows; unaligned, aligned, partial distortion, and occlusion fingerprints [21]</li><li>• The confidence level of minutiae pair based on the consistency of other pair is considered [22]</li></ul>	<ul style="list-style-type: none"><li>• Apply additional dynamic anisotropic pore model (DAPM) pore extraction method to increase the confidence of the matching [23]</li><li>• Incorporate both minutiae information and ridge features to obtain the similarity score. It also defeats distortion problems in referenced method [24]</li></ul>

**Acknowledgements** This research is funded by GUP Grant and Universiti Teknologi Malaysia under Vote No: 11H84.

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Recent Developments in Intelligent Computing,  
Communication and Devices

Proceedings of ICCD 2016

Patnaik, S.; Popentiu Vladicescu, F. (Eds.)

2017, XVIII, 164 p. 68 illus., Softcover

ISBN: 978-981-10-3778-8