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An efficient slap fingerprint segmentation and hand classification algorithm

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ABSTRACT

This paper proposes an efficient algorithm to segment all fingertips from a slap-image and to identify them into their corresponding indices *i.e.* index, middle, ring or little finger of left/right hand. Geometrical and spatial properties have been used to identify these fingertips. The proposed algorithm can handle various challenges like the presence of dull prints, large rotational angles of the hand, small variation in the orientation of the fingertips and non-elliptical shape of components. It has been tested on a database of 6732 images of 1122 subjects. Experimental results reveal the segmentation of all fingertips from slap-images with an accuracy of 99.02%.

1. Introduction

Fingerprint consists of the patterns of ridges and valleys on the surface of a fingertip. It is one of the most extensively studied biometric traits and is considered as a proof of evidence in courts of law or in forensics because it exhibits all necessary characteristics such as uniqueness, permanence and difficult to forge. But the use of fingerprint in automatic personal identification is somehow limited due to many factors such as (i) environment (which causes wet/dry prints), (ii) cuts and bruises on fingertip, (iii) sensor's condition (presence of dirt, latent print, etc.), (iv) occupation or age (which may smoothen the ridge–valley structure) and (v) undue pressure on some parts of a finger (which may introduce shear transformation). However, accuracy of any fingerprint based identification system can be increased if images of multiple fingers, henceforth we refer as *multiple fingerprints*, are used [1]. A slap fingerprint device can capture images of multiple fingers in a hand simultaneously. Fig. 1 shows an example of a slap-image. Though images of multiple fingers can be acquired by capturing fingerprint for each finger but it requires more time and operator intervention as compared to capturing a slap-image instantaneously [2]. The use of a slap-image not only increases the authentication accuracy but can also minimize the problem of spoofing. All these factors have ignited the use of slap fingerprint based personal authentication in the modern era [3].

For slap-image based personal authentication, fingerprint of each finger is segmented from the slap-image and features which are used for authentication are extracted from each of these fingerprints. Extraction of all fingerprint images from slap-image is termed as slap fingerprint segmentation. Fingertip components of a slap-image are shown in Fig. 2. Performance of a slap fingerprint based system depends on its segmentation technique. Hence, there is a need to design an efficient slap fingerprint segmentation algorithm which satisfies the following constraints:

1. *Accurate*: All fingerprints in slap-image are correctly located.
2. *Detecting hand*: It can classify correctly whether the given slap-image is of the right or the left hand.
3. *Finger labeling*: Each segmented fingerprint image should correctly be recognized as one of these four fingers viz., index, middle, ring or little finger.
4. *Real time*: This segmentation is done in near real time.

These constraints are necessary for effective usage of slap fingerprint in a personal authentication system. This paper proposes an algorithm which segments slap fingerprint image accurately, detects hand and fingerprint in near real time. It considers full resolution of images which helps to avoid the problem of merging components lying close to each other. It has detected knuckle line accurately even for dry/wet fingerprints, creases or dull prints. The proposed algorithm works efficiently even for a large angle of rotation, for dull/wet prints in small portion of the image and for non-elliptical shaped fingerprint image.

Initially, a given slap-image is partitioned into multiple segments (which can be a pixel or blocks of pixels) such that each

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segment belongs to the foreground or the background object. Foreground objects for slap-image are the areas belonging to some part of the hand and have sufficient intensity variation as compared to background objects. These segments are merged using neighborhood connectivity and are referred to as "*components*" in the slap-image. For example, fingertip components of Fig. 3(b) are clustered into four classes in such a way that components of a finger belong to a class. In human anatomy, terminal phalanges are the terminal limb bones located at the tip of the fingers which are referred to as fingertips. Hence, corresponding to each class (or finger), a "*fingertip component*" is extracted which lies at the top of the finger. These fingertip components contain fingerprint area. But sometime other parts of the finger (or intermediate phalanges) are also captured in the slap-image and merged with fingertip component at the distal interphalangeal joints which are also referred to as knuckle line. For example, Fig. 3(d) shows all fingertip components of a slap-image and it can be observed that the leftmost fingertip component contains other part of finger except fingerprint. Merging of fingertip with other finger components can hamper the performance of the slap-image based system because it can change the spatial and geometrical properties like center of mass, mean and orientation. This can lead to the wrong finger/hand classification and/or generation of spurious features (like minutiae). Therefore, each of these extracted fingertip components is analyzed to remove the areas that do not belong to fingerprint. Finally each fingerprint is labeled as index, middle, ring or little finger of the left or the right hand.

The paper is organized as follows. Next section discusses some well known slap fingerprint segmentation techniques. Section 3 presents some methods which are used to design our algorithm. Section 4 presents the proposed algorithm to segment fingertips for the slap-images. Experimental results are analyzed in Section 5. Conclusions are given in the last section.

Fig. 1. Slap fingerprint image.

Fig. 2. Segmented fingerprints components for Fig. 1. (a) Index, (b) middle, (c) ring, and (d) little.

2. Literature survey

In [2], a slap fingerprint image segmentation algorithm, NFSEG, has been presented. Each slap-image in NFSEG is binarized and several pairs of parallel lines with equal spacing are drawn on the image at various angles. However, spacings and angles are heuristically determined. Each component belongs to a finger and the pair of parallel lines that can separate these fingers is chosen. The top most component of each class/finger is the fingertip component. This is a multipass algorithm; hence it is computationally expensive. It is designed based on the assumption that all fingers are in one common direction which is the global orientation of hand.

The algorithm presented in [4] uses several hand geometry constraints to obtain the components from the binarized slap-image. In [5], components are extracted using mean-shift algorithm and ellipse-fitting algorithm. Anisotropic measures are used in [6] to extract the components. The hand geometry and the global hand orientation help to put these components into various classes/fingers. It has been improved in [7] by enhancing orientation estimation and detecting knuckle line. Further improvement has been reported in [8] by using some additional constraints. In [9], components are extracted from the binarized slap-image. Since fingerprint lies on the top of hand, four components that lie on the top are marked as fingertip components. But this is not the case with the slap-image having large rotation. This algorithm has been improved in [10] which can handle the problem of rotation. In [10], slap-image has been rotated at various angles (heuristically) and one of these which represents the best possible hand geometry is chosen. This is a multipass algorithm and is also computationally expensive. The algorithm proposed in [11] extracts different components from a slap-image by using local entropy along with 8-neighborhood connectivity. Geometrical

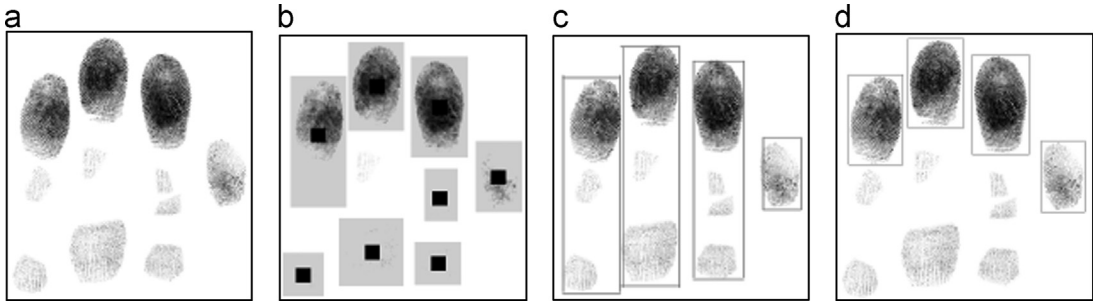

Fig. 3. Extracted fingertips. (a) Slap-image, (b) components, (c) fingers, and (d) fingertips.