On-the-fly fingerprint acquisition method

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***Abstract-* Biometric systems have been gaining widespread popularity in recent years. For example, fingerprint biometrics have been proliferated in many serious applications such as border control. However, despite the current fingerprint identification systems have been proven popular the necessity of physical contact with scanners, in most existing systems and the demand of stationary finger during acquisition, constraint the throughput of tested people. This limitation along with hygienic concerns calls for a system that overcomes these limitations.**

In this paper, we strive to solve some of the existing obstacles by developing a fingerprint acquisition system using a contactless optical scanner. The proposed system is designed to collect the fingerprint information while the user is in motion, a so-called on-the-fly fingerprint extraction. A system has been developed to achieve this objective is introduced. The quality of the fingerprint images acquired has been assessed by using the Verifinger SDK and NFIQ quality measure standards. We show that the proposed system and approach are promising to adopt in contactless fingerprint extraction.

I. INTRODUCTION

Biometric identification has been present for many years [1],[2]. Now it is face recognition [3] and more importantly for us the fingerprint recognition [4] that experiences a rapid spread in our everyday life. There are multiple technologies used for the fingerprint collection such as optical, capacitive and other [5]. Most of these approaches, however, require touching a scanner by fingers. In this paper, we will introduce an on-the-fly (OTF) approach for fingerprint collection from cooperative users. The proposed technique can be embodied in any identification system including the Biometric-Enabled Watchlists Technology [6].

Along with general device requirements to make this method feasible, a setup that meets these parameters was constructed and will be briefly presented. A database has been collected for feasibility and quality assessment. A methodology of fingerprint extraction and enhancement will be discussed, and the results of the assessments will be presented. For the quality assessment, the commercial Verifinger SDK [7] quality metric is used as well as NFIQ standard [8].

II. DATA COLLECTION

The data collection has been conducted in two steps. In the first step, the hand image is acquired using a certain setup that shall be briefly introduced in the following subsection. In the second step, the image needs to be pre-processed in order to detect the global features and the region of interest, where the fingerprint is expected to exist. The acquired image is then saved in a database for fingerprint enhancement and further processing.

A. Experimental device

The full description of the device cannot be provided at the time of releasing this paper and needs to be redacted to a few paragraphs, as the process of patent submission is currently underway. The basic principle is similar to the Automated Non-contact Distance Identity (ANDI®) On The Go (OTG) device presented by the Advanced Optical Systems, Inc. company [9], where a high-speed full-frame camera is used. The camera is triggered by an optical gate to capture a number of images that are subsequently used to extract individual fingerprints. The user has to extend his hand and move it through a rectangle or u-shaped void in a barrier, where the focus of the distant camera and the triggering mechanism; that initiates the acquisition process of the camera.

Figure 1. shows a schematic of the system setup used, indicating the location of the camera, gate and light sources. A commercial Canon EOS 50D with CANON LENS EF 24-70mm f/2.8 has been used to capture colored images with resolution of 4,752×3,168 pixels at 100 cm.

The camera has been set to 70 mm focal length to achieve a spatial resolution of 500 DPI at 100 cm. Due to the non-immediate external trigger of the consumer camera a mirror is placed in the frame to allow for extracting the depth information from the frontal image.

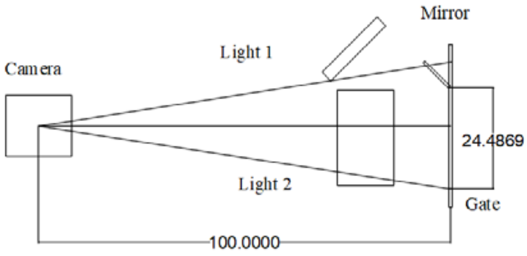

Figure 1. Schematics for laboratory setup for OTF fingerprint extraction, top view

A pair of Amaran H528S light sources illuminating at 4,380 lux is used, to provide the necessary illumination to match the high shutter speed used. Figure 2. shows the actual laboratory setup indicating the camera, gate, and lighting locations.

Figure 2. Laboratory setup for OTF fingerprint extraction

Further details shall be disclosed upon successful patent submission in subsequent publications.

B. *Database collection*

In the collection phase, 82 volunteers have been invited to submit their fingerprint data to be used for algorithms validation. Each volunteer has been briefly instructed on the proper usage of the device, with a single demonstration with the emphasis on the necessity of straightening the fingers, ideal hand position at the place of image capture and ideal movement speed. After the first image collection, if necessary, a user is given feedback to improve the collected image quality i.e. regulating the hand movement speed or adjusting the hand movement path.

In this manner, the volunteers have been instructed to trigger the device at least 10 times. The session resulted in a collection of 908 hand images or up to 4,525 potential fingerprint images. Figure 3. shows the typical format of the acquired image. Observe, the hand position may vary within the space.

Figure 3. Sample image of a user's hand acquisition

III. Image Processing

Two pre-processing steps are needed to allow for good quality fingerprint acquisition. The first step is oriented on hand extraction, while the second step is for finger extraction. The primary objective of this stage is to localize and extract parts of images containing the fingertips of the moving hands. The following steps have been taken.

A. *Hand extraction*

1. Using YCbCr color model, the areas falling within the range of predefined human pigments are segmented. The same method has been used in [10] for face detection, however, the limits have been modified to better fit our data; namely $YCbCr_{Low}$ = [0,133,85] and $YCbCr_{High}$= [255,185,135].

2. To accommodate situations, where the fingers are squeezed together, adaptive thresholding was used to enhance the shadows in the grayscale version of the original image. Binarized images are then combined in a bitwise logical operation to create a single binarized image that contains an easily distinguishable shape of the hand along with additional minor noise. Example can be seen on Figure 4. a).

3. The largest object in the image is detected using the OpenCV tool: *SimpleBlobDetector().*

4. The contour of the binary images, shown in Figure 4. b), is determined by using the OpenCV tool *findContours(skin_region,cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_NONE)* where the skin region is the binarized image.

5. The contour is then smoothed to eliminate jagged edges due to shadows, as shown in Figure 4. c).

B. *Finger extraction*

1. Distance between points of the preceding and upcoming points of the contour are measured to determine the likelihood of the fingertip or in-between point of fingers. Along the contour, we calculate the Euclidean distance between the coordinates A= i-3K and B= i+3K, where K is defined as 1% of the total length of the contour and i is the index in the cycle.
2. By observing the line connecting points A and B, we determine whether the point of highest variability is the fingertip or the in-between point. If it crosses our binarized hand mask, we consider the point as a fingertip and vice versa. Figure 4. d) shows an example of this scenario.
3. The last finger segment is extracted by using points A, B, midpoint C, the position of detected fingertip (F) and distance between fingertip and in-between finger point *d*. The region of interest is then defined by the rectangle of width equal to the distance between points A and B and Length equal to 0.5d for thumb and 0.35d for all other fingers. The orientation of the rectangle is determined by the angle between the line connecting points F and C, and the x-axis.
4. The rotated and extracted finger segments are saved for fingerprint enhancement.

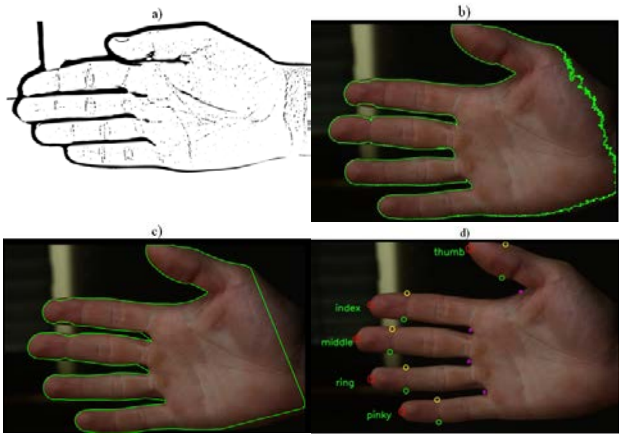

Figure 4. Chosen steps of image preprocessing. a) Adaptive thresholding to separate touching fingers b) raw contour of biggest object c) smoother contour d) significant points identified

C. *Fingerprint enhancement*

Image enhancement is necessary to improve the classification accuracy. Image enhancement is an active area of research as reported in K. Han [11] and Y. Tang [12]. A comprehensive survey of the enhancement techniques is depicted in [13].

In our research, we use an approach that is heavily inspired by a method described in [14]. However, we modified this method to suit our system to deal with the effect of direct light source and resultant shadows. To eliminate the illumination variance due to the depth of the object, we used local adaptive normalization, CLAHE [15], with block size of 8×8, while in [14] they used global normalization. Image orientation is used to compute the Gabor filters of size 7×7 with Gaussian envelope having a standard deviation of 4. Figure 5. shows two examples of the original fingertip images and the corresponding ridge extraction after enhancement and binarization. Figure 6. shows the block diagram of the individual steps taken during the enhancement process. The dotted line denotes an optional path to follow in case the results from the first iteration are not satisfactory.

Figure 5. Examples of fingerprint enhancement

D. *Fingerprint quality evaluation*

After pre-processing, there is 3,610 images of individual fingerprints availabe. Verifinger SDK has been used for the evaluation of the quality of the fingerprints. The quality scale of the default measurement goes from 0-100; 0 being the worse quality and 100 being the highest. NFIQ quality measure has also been used for evaluation, where the scale varies between 1 (best) and 5 (worse).

TABLE I summarises the quality results, where the mean post-enhancement result is 68 for Verifinger SDK quality evaluation, and 1.85 for NFIQ standard. Figure 7. shows the quality distribution for both prior and after the enhancement. NFIQ prior to the enhancement has not been shown as the grayscale images prior the enhancement are mostly not readable and thus the graphical representation is not informative. On the Verifinger SDK pre-enhancement quality, SDK failed to identify a significant number of images as fingerprints; resulting in score of 0. This is likely caused by insufficient contrast of individual papillary lines. After the enhancement, the number of uunrecognised fingerprints has decreased significantly. Overall, the measured quality of fingerprints has increased.

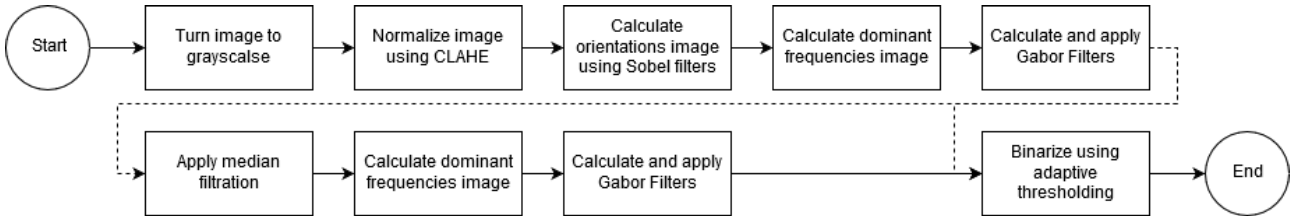

Figure 6. Steps taken to enhance fingerprint

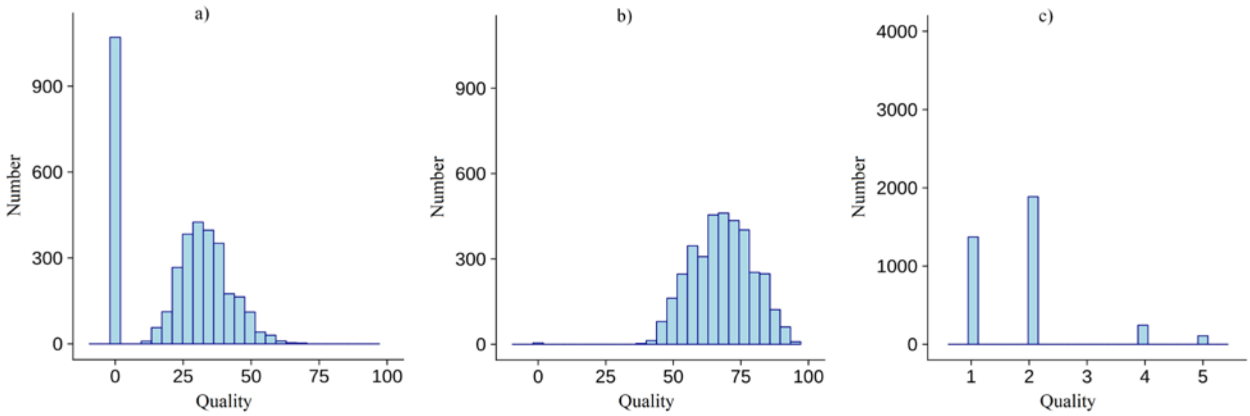

Figure 7. Verifinger SDK quality of the fingerprints a) pre-enhancement b) post-enhancement c) post-enhancement using NFIQ rating

TABLE I. QUALITY OF FINGERPRINTS BEFORE AND AFTER ENHANCEMENT

Quality standard	Pre-enhancement	Post-enhancement
Verifinger SDK	23.18	68.00
NFIQ	4.89	1.85

III. CONCLUSION

In this paper, an on-the-fly system of acquiring fingerprint has been presented along with a laboratory setup that presents its validity. A database has been collected using this system. From individual images, areas including fingerprints have been extracted in a way that allows for a high background variability. Enhancement algorithms have been applied onto these sub-images and the quality of the resultant fingerprint images has been determined. The Verifinger SDK quality scale and NFIQ scale have been used to determine the quality of each fingerprint retrieved by the system before and after the image enhancement. An average fingerprint quality after enhancement has been determined to be 68.00 out of 100.00, using Verifinger SDK scale, and 1.85, using NFIQ scale. Although the image quality is inferior to that found in typical touch-based sensors, the results prove that this approach is a promising mean of the touchless on-the-fly fingerprint extraction technique. Currently this method is being improved through using an industrial-grade camera of similar parameters supported by an improved triggering mechanism.

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