Volume 3, Issue 5, May 2013 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

A Model of Fingerprint Biometrics with Low-cost Sensors and Webcams

Abhishek Shukla *
I.T.Department&RDEC,GZB
India.

Vijay Singh
CSE Department&SRMCEM, LKO
India.

Mithlesh Kr. Mishra
MCADepartment&RDEC,GZB
India.

Chandramani Srivastava
CSE Department&RDEC,GZB
India.

Abstract*— The diffusion of mobile cameras and webcams is rapidly growing. Unfortunately, images produced by these kinds of sensors during the acquisition of human fingertips are very different from the images obtained by dedicated fingerprint sensors, especially as quality is concerned. At the present stage of the research, fingerprint biometrics can be successfully achieved in real-life applications only by using dedicated sensors and scanners. In the literature a paramount quantity of methods which are extremely effective in processing fingerprints obtained by classical sensors and procedures is pre-sented. In this paper, we investigate new techniques to suitably process the camera images of fingertips in order to produce images which are as similar as possible to the ones coming from dedicated sensors. This will allow for directly reusing the large and valuable experience presented in the literature for fingerprint recognition and verification in environments in which mobile cameras and webcams are already or can easily become available and dedicated devices are not required by the desired security level. The proposed technique encompasses a prefiltering step, the segmentation of the fingertip image, a fingertip registration phase, the dedicated processing techniques for the ridge enhancement, and a post-processing phase. In our research we tested the identification capability of the proposed methods by using a state-of-the-art, public software for minutiae extraction and matching. The effects of different registration algorithms on the identification accuracy are also discussed and the final system has been compared with the use of commercial dedicated sensors.

***Keywords*— Biometric,fingerprint,sensors,mobile camera and webcams.**

I. INTRODUCTION

The possibility to obtain fingerprint images by using low-cost cameras and off-the-shelf webcams has a great practical importance since nowadays fingerprint biometrics can be successfully achieved only by using dedicated sensors. The diffusion of general purpose cameras is rapidly growing, and they can be found easily on laptops and cellular phones. Unfortunately, the images of human fingerprints acquired from these kinds of sensors are very different from the images obtained by dedicated fingerprint sensors. In order to exploit the paramount variety of techniques now available in the literature to achieve verification and recognition by fingerprint biometrics it is important to pro-cess the camera image of the fingerprints so that they are as similar as possible to the images produced by dedicated sensors. The approach that we propose aims to allow for using the webcams as an interoperable device for fingerprint biometrics. For example, the proposed approach allows for exploiting a webcam as a fingerprint biometric sensor on a personal computer in case of a dedicated sensor is not available or a dedicated sensor is not required by the desired security level for the envisioned application.

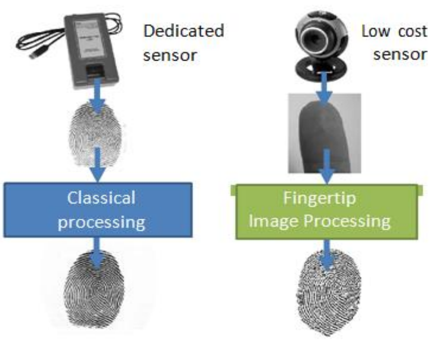

Fig. 1. The classical acquisition technique (left) compared to the proposed approach (right).

Figure 1 shows the presented approach in comparison to the classical one which uses dedicated sensors. The presented method aims to extract the ridge structure from the fingertip image (acquired by the low-cost camera or a webcam) so that it is as similar as possible to the ridge structure derived from the image produced by a dedicated fingerprint sensor for the same finger. Obviously, it not possible to completely emulate the performance of a state-of-the-art fingerprint dedicated sensor, but we aim at providing a method that can produce a reasonable output for a biometric system. In the literature, there are only few works on the usage of low-cost sensor, mainly focused on the ridge structure extraction phases [1], [2]. In this paper, starting from a similar approach, new and ad-hoc preprocessing modules are introduced to cope with common application problems such as defocusing and motion-blur problems. A direct compari-son of the output images with respect to the images produced by dedicated sensors is also provided and discussed. Results indicate that the registration phase of the fingertips images can be critical since many important matching algorithms are not rotation-and-scale invariant in their functioning.

The contribution of this work is twofold: we propose an innovative sequence of modules for image-based fingertip biometrics suited for low-cost acquisition devices (such as webcams), and we present the results by an experimental comparative campaign (*Scenario Evaluation* [6]) where the same individuals has been acquired by using low-cost and dedicated sensors. The paper is structured as follow. In Section II the characteristics of the fingertip images acquired with a low-cost camera are compared with the images obtained with dedicated sensors. Section III describes the proposed approach, by giving the details on how we can design the prefiltering module, the segmentation module of the fingertip image, the processing techniques for the ridges enhancement, and the final preprocessing module. Section IV reports the experimental results, discussing the details concerning the experimental setup.

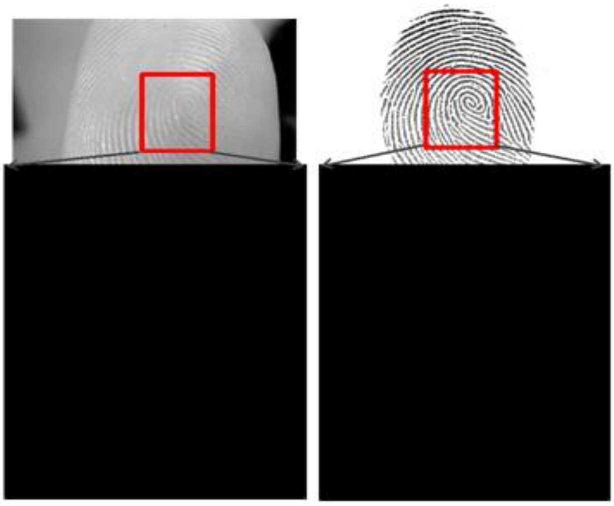

Fig. 2. Comparison of the same portion of the ridge structure image acquired by using a webcam and a dedicated sensor.

Dedicated sensors tend to produce high-contrast image of the ridge structure of the fingertip (Figure 2, right). The background of the image tends to be very flat and continuous, permitting a simple segmentation of the ridge structure. By using a state-of-the-art sensor, the produced image can have a very small noise component, and the presence of artifacts in the final image is rare (presence in the output image of spurious characteristics which are not present on the finger surface, such as false bifurcations or ends of the ridges, as well as deformations of the original ridge structure). With the dedicated sensor the ridge structure is produced by the pressure of the friction ridges of the fingertip on the sensor surface. The noise on the image can be related to dryness or high humidity of the skin, excessive or limited pressure of the fingertip on the sensor and bad condition of the skin surface (e.g., illness, scratches, usage of abrasive material and other particular working conditions). The Failure to Acquire/Enroll ration is considered to be few percents, depending on operational conditions and on the population.

Low-cost sensors and webcams tend to produce color images of the fingertip which are very different from the related fingerprints images (Figure 2, right). The background is composed by two main components. The first one is the image of the surrounding environment. Another component of the background can be considered the finger itself, since we are interested only to the ridge structures lying on the surface of the fingertip. Blurring effects can be present due to errors in the focus of the

lenses and the relative movements of the subject in front of the camera. In addition, it is always present the electronic noise of the specific camera CDD.

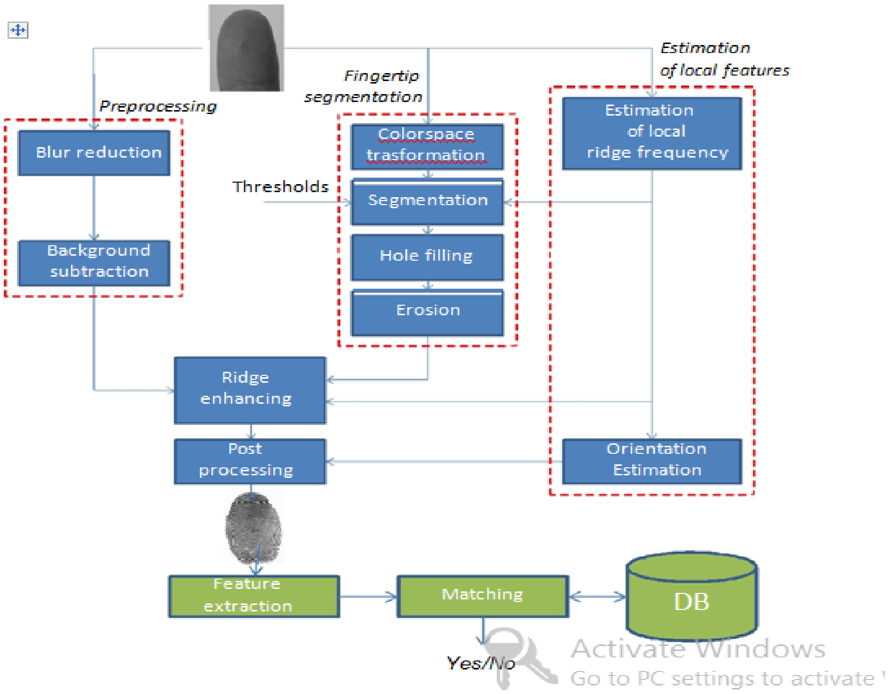

Fig.3. Complete structure of the proposed method.

In this case, the ridge structure is not produced by a mechanical pressure, but the ridge pattern is shown by the creation of the shades and the color variances on the fingertip surface. In particular, the fingertip ridges tend to be paler or even white then the relative valleys. Considered as noise effects, the environmental light can produce different shades along the fingertip due to its intrinsic convex shape.

III. THE PROPOSED METHOD

In the literature, the interest in low-cost sensors is rapidly growing and some preliminary methods have been presented mainly focused on the extraction of the ridge structure [1], [2]. Similar image processing techniques have been exploited to cope with the palm image biometrics [3], [4]. This work aims to contribute in a twofold manner: we propose an innovative complete sequence of modules for image-based fingertip biometrics and we present the results of an experimental campaign (Scenario Evaluation [6]). In our experiments, to compare the proposed approach with the classical solutions, the fingerprints of the same individuals have been acquired by using two sensors: webcam and dedicated sensor.

Figure 3 plots the complete structure of the proposed method. In our method, once the input image is acquired by the low-cost camera, a preprocessing operation is performed in order to reduce the blur effect that can -very commonly-be present in the input image. In addition, a pre filtering operation of background subtraction is executed. In parallel, the segmentation of the fingertip region in the image is performed by identifying the fingerprint Region Of Interest (ROI in the following). The segmentation module exploits the estimation of the local ridge frequency in order to achieve a better localization of the ROI.

By using the estimation of the local features of the finger image, the ridge-enhancing module aims at enhancing the ridge structure in the ROI portion of the pre filtered image. As last step, a post processing of the ridge structure image is performed by taking into the account the estimation of the local orientation of the ridges. In some application cases, this final step can be considered optional. The ridge structure of the fingertip has thus been extracted from the webcam image, and this output image can be used by the classical biometric chains of modules, which encompasses a feature extraction module (e.g., a minutiae extractor) a matching module and a biometric template repository. Let us now detail the presented modules.

A. Preprocessing modules

In the preprocessing phase, the first step is performed by the blur reduction module. Its goal is to recover the input image from the blurring effect. In order to effectively use a webcam or a low-cost camera as a biometric sensor, the finger must be positioned near the objective lens (few centimeters), and the focal length of the lens must be accordingly tuned. Most commercial webcams and cameras allow for tuning the lens in order to correctly focus a near object. But in this particular optical situation, very small variations in the distance of the finger from the objective can easily produce focus problems. In addition, even small relative movements of the fingertip are magnified and, in addition, the motion-blur effects can be present.

The literature on deblurring methods is very wide. In this work we considered the Lucy-Richardson algorithm (LR) [5] and the deconvolution of the input image by using the Wiener filter algorithm (WF) [7]. These methods can restore images that have been degraded by convolution with a point-spread function $P\ SF$ and possibly by additive noise. The blur effect and the camera noise described above can be modeled and corrected under these hypotheses. The main problem is to correctly estimate the $P\ SF$ which corresponds to the specific blur that might happen in the specific application. Section IV will discuss the design of the $P\ SF$. Additional characteristics of the optical system can be used as input parameters to improve the quality of the image restoration. If the blur model is not effective or not known, the Blind Deconvolution method (BD) can be considered [8]. Hence, given the image $I\ (x, y)$ and the estimation of the $P\ SF$, the deblurred image I_{DB} is given by:

$$I_{DB}(x,\ y) = I\ (x,\ y) * G(P\ SD) \qquad (1)$$

where $G(.)$ is the deconvolution operator estimated on the known $P\ SD$.

B. Fingertip segmentation

In [1] a fingertip segmentation approach is presented. The final segmentation output is produced by combining two different segmentations. The first segmentation is based on the fingerprint color model which has been created as a Gaussian PDF estimated by using supervised learning on 200 sample images (manually classified pixel by pixel). This segmentation is combined with another one based on a wavelet decomposition by using the Daubechies' 9/7 filter. In this paper, we propose a simpler approach (Figure 3) which (optionally) combines a color-based segmentation (refined with morphological filters, such as the hole filling operator and the erosion operator) with a ridge frequency estimation map. The basic idea consists of the selection of the image pixels which belong to a color model available in the literature associated to skin types [14], [15]. The color model is estimated by using the color feature components constructed by combinations of the Y, Cr, Cb, Hue, and Saturation channels. Each camera tends to map each pixel in the color space in a different manner, but the results of the proposed method are quite general: the thresholds of the color-space segmentation require only some rapid fine tuning once the experimental setup is fixed. Due to differences in the illumination on the fingertip, the segmented areas should be regularizated by basic morphological ope the segmentation model can be made more robust by combining information coming from the estimation of the ridge frequency [12], [13]. In this case, the ROI will contain only the image regions where there is energy in the spatial frequency associated to the fingertip ridges. In Section IV the remaining modules are further detailed.

C. Fingertip registration

Registration is the operations required to scale and rotate the fingertip image so that the input image is transformed in a standard image having the following characteristics:

1) the center of the fingertip should be placed at the center of the image;

2) the orientation of the fingertip should be horizontal to maximally exploit the CCD rectangular resolution;

3) the fingertip should have fixed area/size in pixels;

4) aberrations of the lens system should be minimized by a proper inversion model.

The registration operations are strongly required since many classical matching algorithms are not rotational-scale invariant. Unfortunately, the use of webcam and low-cost cameras as a biometric sensor (without any additional structure for the finger positioning) produces significant variations of scale, position and rotation of the fingertip among different acquisitions in time. Many techniques are available to perform registration [9] mainly based on affine transformations and the detection of significant points extracted by ad-hoc operators (e.g., corners point detector for general images). Registration of the input images has been performed by processing the binary mask obtained from the color-based segmentation of the fingertip. The centroid of the wider connected object in the mask (the fingertip) has been used to center the fingertip in the registered image. Them the obtained image has been rotated by an angle opposite to the angle of the major axis of the fingertip. This step corresponds to the *horizontal alignment* of the fingertip in the resulting image. The last step of the registration phase is zooming by a factor that normalizes the minor axis of the fingertip to the standard measure of 9/10 of the height of the final image. The choice to normalize the minor axis of the fingertip guarantees the better normalization of the fingertip, since the major axis has a stronger variability during the experimental acquisitions. Similar reasons exclude the possibility to successfully perform any area normalization operations. Experiments showed that the same in dividual can position the fingertip at different distances from the camera thus producing variations in the minor axis up to 40%.

D. Ridge enhancing

The first step in ridge enhancing is background subtrac-tion. The goal is to enhance the ridge structure with respect to the image background. Some a priori knowledge can be profitably exploited for this purpose, for example the high spatial frequencies and the periodicity that are present in the image of the fingertip. The literature on this issue is very rich [10] [11], especially in the specific field of the fingerprint enhancement [12], [13]. Unfortunately, fingertip images are very different from the fingerprint images, hence typical techniques used in fingerprint biometrics are not effective on such a king of images. As described later, these techniques should be instead considered as post-processing techniques that can be used once the ridge structure has been extracted. In Section IV we will describe a possible chain of modules, the choice of the parameters and the results obtained with the collected dataset of fingertip and fingerprint images.

IV. EXPERIMENTAL RESULTS

Experiments has been carried out by using a webcam (Microsoft LifeCam VX-1000 at 640x480 pixels) and by simulating a typical user biometric authentication. Users were sitting in front of the laptop and showing the fingertip to the webcam. During experiments, two simple environments have been tested: one in daylight condition without illumination systems, and one in a dark environment using a common table lamp on the desk.

Reference images have been acquired by using a Cross-match Verifier 300 fingerprint optical scanner. This scanner has been chosen for his great diffusion and accuracy. Fifteen untrained volunteers has been acquired 10 times in 10 different days by using the webcam and the dedicated sensor thus producing the datasets DS1 and DS2, respectively. Each dataset is composed of 150 images.

All algorithms have been implemented in Matlab ver. 7.3 by using the Image Processing toolbox ver.2. Let us now present the experimental results obtained by using the DS1 dataset.

A. Preprocessing modules

The use of the Lucy-Richardson algorithm (LR) and the deconvolution of the input image using the Wiener filter algoritm (WF) is plotted in Figure 4 for an image sample acquired at 640x480 pixels in daylight conditions. The PSD function has been estimated using a rotationally symmetric Gaussian lowpass filter with a squared matrix of 10 pixel.

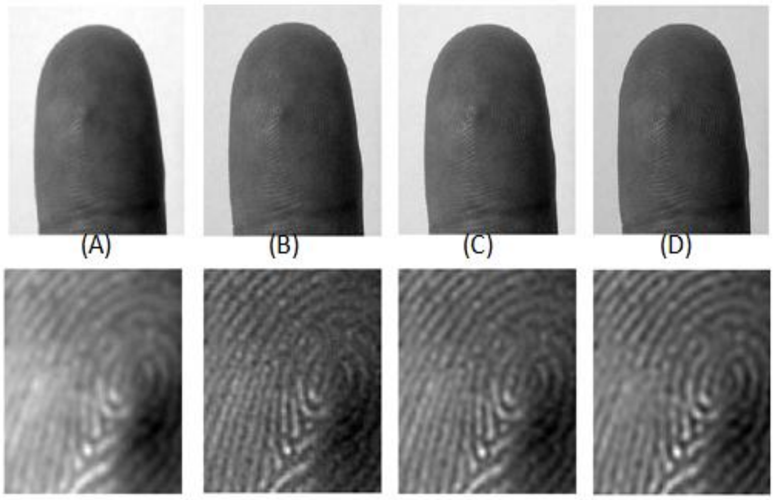

Fig. 4. Comparison of the different prefiltering modules: algorithms LR (B), WF (C), BD (D) are applied to the input image (A). The bottom subplots show a zoom of the central portion.

In our experiments, the best obtained spread of the Gaussian function was equal to 3 pixels for 1Mpixel image. In the case of the LR algorithm, the best results have been obtained with 50 iterations. The fourth column in Figure 4 presents the results of the Blind Deconvolution Method. In the majority of tested images, the FR algorithm showed the best results. In the following we will use the LR algorithm as preprocessing module.

B. Segmentation modules

Let us now detail the ridge structure segmentation algo-rithms. For the color space transformation we used a typical RBG to YUV, while segmentation was processed by using an upper and lower bound for each channel [14]. This approach is very simple and experiments showed good robustness in different acquisition conditions (illuminations, subjects, cameras). Regularization has been applied using two simple morphological filters: first the larger connected object (the fingertip) is selected and its eventual “holes” are filled, then, all the remaining smaller objects are removed. The final step is an erosion operation performed by using a structured element (a circle of 1/50 of the image width). This last step is required to unselect the borders of the fingertip where typically the ridges are not correctly acquired due to the perspective problems. Figure 5 shows the application of the color-based segmentation in different environmental conditions and resolutions (first column: daylight, 340x240 pixels; second column: daylight, 640x480 pixels; third column: dark room using a normal table lamp, 320x240 pixels). Even though the computational complexity is low, the method is effective. The segmentation output can be further processed with the estimation of the local ridge frequency in order to make segmentation more robust.

C. Ridge enhancing and post processing

The background subtraction technique has been imple-mented by using the unsharp filtering approach. A blurred copy of the original image obtained by using a Gaussian filter (square matrix having $L/50$ width with $\sigma = L/100$, where L is equal to the image width) is subtracted to the original input image. Artifacts introduced by the image processing can produce fake

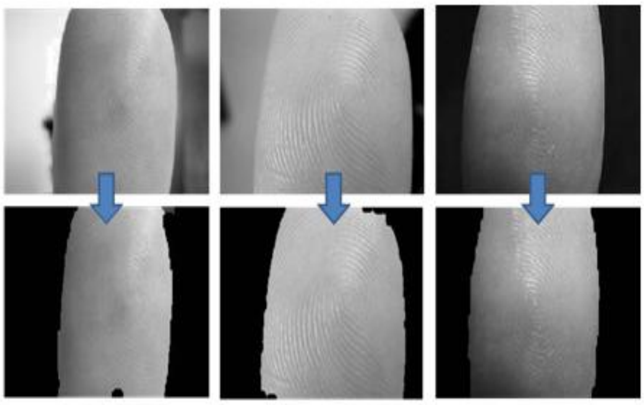

Fig. 5. Fingertip color based segmentation. The input images (top) and the output images (bottom) are shown in different experimental conditions.

Fig. 7. Application of final postprocessing algorithm and the resulting minutiae detection.

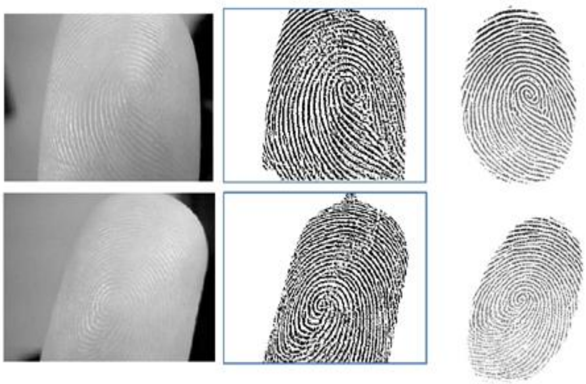

Fig. 6. Application of the ridge enhancing technique (without registration) with different input images at the 640x480 resolution (left). The output (center) can be directly compared to the real fingerprint image taken with the dedicated sensor (right).

TABLE I

RATES OF THE PROPOSED METHODS: EQUAL ERROR RATE (EER) AND FALSE NON-MATCH RATE (FNMR)

	EER	FNMR @ FMR=0.01
Reference	0.040	0.051
Webcam (no registration)	0.047	0.14
Webcam (with registration)	0.042	0.11

minutiae, typically introduced by the ridge-enhancer algorithm when too much noise is present in the webcam image. The accuracy of the proposed system has been tested by using the dataset of fingertips DS1 of webcam image (with different chains of modules). As reference we used the dataset DS2 obtained from the same individuals scanned by the dedicated sensor Crossmatch Verifier L300. Figure 8 shows the results of 22350 fingertip comparisons sum-marized in the ROC curves. The biometric match among fingerprints templates was verified by using the NIST NBIS matcher bozorth3. The performance of the proposed ap-proach is plotted with and without the registration phases discussed in the previous section (Figure 8). The results show that the proposed approach is feasible and that, in a significant region of the ROC curve, the behavior of the low-cost system is comparable in accuracy to the system exploiting the dedicated sensor (False Match Rate FMR>0.01). It should also be noted that the limited dimensions of the tested population does not allow - at this time - for generalizing the results concerning the False Match Rate, FMR, and the False Non-Match Rate, FNMR. More interestingly, the results indicate that the state-of-the-art algorithms for feature extractions and matching can be profitably adopted even in the case of low-cost sensors when a proper image processing system is used to generate their inputs. Results show also that the image registration phase can impact the final accuracy of the system.

V. CONCLUSIONS

This paper presented an innovative composition of tech-niques to extract the fingerprint ridge structure by image processing in images acquired by low-cost cameras and we-bcams. The approach we propose aims for allowing the use of webcams and low-cost cameras as interoperable devices for fingerprint biometrics when these devices are already

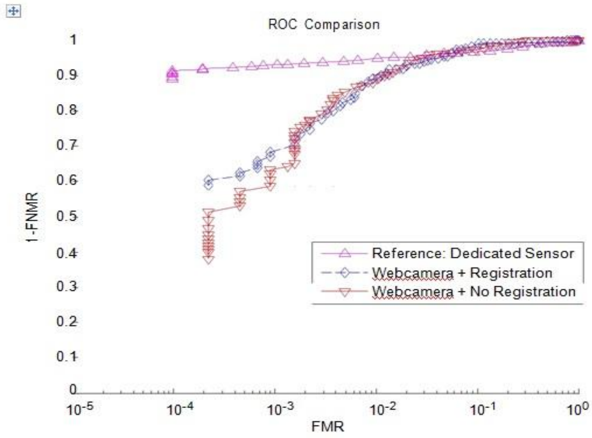

Fig. 8. Comparison of the ROC curves of between the presented techniques and the reference method: the one's complement of the False Non-Match Rate (FNMR) is plotted vs. the False Match Rate (FMR).

or can become easily available while the security level of the envisioned applications does not need the accuracy of dedicated devices. Results are very attractive: even in normal illumination conditions and by using sensors of about 1Mpixel (or above), the ridge structure can be effectively extracted. The limited resolution of current CCDs can produces several artifacts in the extracted ridge structure, but experiments have shown that the presence of artifacts can be reduced by using higher image resolutions. Results show that the registration module should be carefully designed since the registration phase can greatly affect the final system ac curacy.

The method accuracy has been tested by directly compar-ing the extracted ridge structures with the ones extracted by using a state-of-the-art dedicated sensor on the same individuals. This comparison has been done by using a state-of-the-art public minutiae extractor and matcher from the NIST. The presented method is general and can be applied to any CDD sensor. Results presented in this work considered a *scenario evaluation* with a limited number of volunteers: in future work we will study the performances on larger datasets and also in varying operational conditions, as well as the optimization of the proposed modules.

REFERENCES

[1] C. Lee, S. Lee, J. Kim, S. Kim, "Preprocessing of a Fingerprint Image Captured with a Mobile Camera", ICB 2006, pp. 348-355.

[2] D. Lee, W. Jang, D. Park, S. Kim, J. Kim, "A Real-Time Image Selection Algorithm: Fingerprint Recognition Using Mobile Devices with Embedded Camera", AutoID, 2005, pp.166-170.

[3] Xiangqian Wu, David Zhang, Kuanquan Wang, "Palm line extraction and matching for personal authentication", IEEE Transactions on Systems, Man, and Cybernetics, Part A 36(5): 2006, pp. 978-987.

[4] Adams Wai-Kin Kong, David Zhang, Mohamed Kamel, "Palmprint identification using feature-level fusion", Pattern Recognition 39(3), 2006, pp. 478-487.

[5] S. Prasad, "Statistical-information-based performance criteria for Richardson-Lucy image deblurring," J. Opt. Soc. Am. A 19, 2002, pp. 1286-1296.

[6] Biometrics Working Group (BWG), "Best Practices in Testing and Reporting Performance of Biometric Devices", http://www.cesg.gov.uk/biometrics, January 2000.

[7] E. Sekkoa, G. Thomasb, A. Boukrouchea, "A deconvolution technique using optimal Wiener filtering and regularization" Signal Processing, Vol.72, January 1999, pp. 23-32.

[8] Dalong Li Simske, S. Mersereau, R.M.M.,"Blind image deconvolu-tion using constrained variance maximization", Signals, Systems and Computers, Vol. 2, 2004, pp. 1762-1765.

[9] B. Zitova, J. Flusser "Image registration methods: a survey", Image and Vision Computing Volume 21, Elsevier, Issue 11, October 2003, pp. 977-1000.

[10] M. Piccardi, "Background subtraction techniques: a review", IEEE International Conference on Systems, Man and Cybernetics, Vol. 4, Oct. 2004, pp. 3099-3104.

[11] A. Elgammal, D. Harwood, L. Davis, "Non-parametric Model for Background Subtraction", Lecture Notes in Computer Science, Springer, 2000, pp. 751-767.

[12] A. K. Jain and D. Maltoni, Handbook of Fingerprint Recognition. Secaucus, Springer-Verlag New York, 2003.

[13] L. Hong, Y. Wan, A. Jain, "Fingerprint Image Enhancement: Algo-rithm and Performance Evaluation", Transactions on Pattern Analysis and Machine Intelligence, vol. 20, no. 8, 1998, pp. 777-789.

[14] J. Yang, W. Lu, A.Waibel, "Skin-color modeling and adaptation" Pro-ceedings of ACCV'98, Lecture Notes in Computer Science, Springer, 2006, pp. 687-694.

[15] M.J. Jones, J.M. Rehg, "Statistical Color Models with Application to Skin Detection", International Journal of Computer Vision, Volume 46, 2002.

Craig I. Watson, Michael D. Garris, Elham Tabassi, et. al., User's Guide to NIST Biometric Image Software (NBIS), 2007.