On using document scanners for minutiae-based palmprint recognition

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Abstract. The development of forensic palmprint biometric systems has not been as popular as civilian systems until today, because of the high costs of the required capturing devices and the lack of publicly available high-resolution palmprint databases. The feasibility of using low-cost technologies like document scanners to acquire a high-resolution palmprint database is explored in this work. A database was established using a biometric industry standard scanner and an HP document scanner. Experimental results show the potential of using similar inexpensive technologies to develop high-resolution palmprint systems for forensic applications. Advantages and disadvantages of both technologies are highlighted too.

Keywords: High resolution palmprint matching · palmprint recognition · minutiae based recognition · document scanner.

1 Introduction

Palmprint applications are employed for a wide range of scenarios. For civilian applications, palmprint biometrics has been thoroughly explored. Used as a stand-alone biometric or in combination with others, palmprints has proven to be very reliable [3, 4, 6, 23, 24] due to the large area of the palm which contains rich and useful features, hence being highly distinctive. Furthermore, the urgent need for palmprint applications in forensic scenarios has been clearly stated by several studies regarding the number of latent palmprints found in crime scenes as summarize in [11].

Nevertheless, the development of forensic palmprint biometric systems has not been as popular as civilian systems until today. Civilian applications usually employ low-resolution images and extract features from the principal lines or texture information. For forensics, more detailed features like minutiae need to be extracted which require high-resolution images (500 ppi) [17]. Therefore, bigger and more expensive devices are needed to establish a palmprint database for forensic applications. The high cost of these scanners (3000-4000 USD) is one of the main issues refraining the development of palmprint forensic systems. Moreover, the lack of publicly available high-resolution palmprint databases has prevented the research in this area.

This study is the first step towards solving the aforementioned problems. The feasibility of using commercial document scanners for minutiae-based palmprint recognition is explored. Compared to forensics industry standard scanners, document scanners are cheaper and widely distributed [21]. If this type of scanners proves to be feasible for forensic applications, it will open a wide range of possibilities of using similar technologies and therefore, reducing the development cost of forensic palmprint systems. The main contributions of this work are:

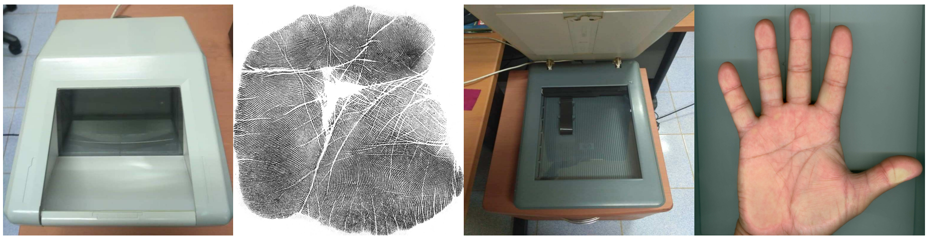
1. A feasibility study of using document scanners for minutiae-based palmprint recognition as the first step to apply similar technologies in forensic applications.
2. A new database of high-resolution palmprint images acquired with two different scanners. This database will be made publicly available to the research community.
3. Evaluating the cross-device recognition performance between a forensic palmprint capturing device and the HP document scanner.

Following, a summary of related works is given. Section 2 will introduce the database structure, acquisition protocol, and the challenges faced. Experimental results are discussed in section 3, and finals conclusions are presented in section 4.

1.1 Related work

In 2006 a set of algorithms to deal with fingerprints acquired using a mobile phone camera was proposed [15]. In order to get rid of fingerprint sensors on mobile phones and thus, to reduce the cost of these devices. The proposed preprocessing algorithms improved the performance of a fingerprint system based on a regular mobile phone camera. In [9] a similar work was presented. Instead of using a mobile phone camera to acquire the fingerprint images, a digital camera Canon PowerShot Pro1, with 8 megapixels of effective resolution and a 7x optical zoom Canon "L" series lens was used. Although the proposal looked promising, no verification results using minutiae were provided. In [2] the use of mobile phone cameras was revisited. Using a Nokia N95 and an HTC Desire the authors achieved an EER of 4.5%. More recently, a webcam-based fingerprint system was proposed in [13]. Unfortunately, results were presented in a way which is very hard to validate. All of the above mentioned works focused only on fingerprints and not on palmprints.

In [14] the use of a digital camera for palmprint recognition was first introduced. Palm principal lines were used in conjunction with hand geometry features to match the palmprints. Inspired by this work, a custom palmprint scanner was presented in [21]. The custom scanner is a modified HP Scanjet 3500c document scanner. This work was revisited in [22] to investigate hand aging effects



(a) (b) (c) (d)

Fig. 1. Greenbit scanner MC517 (a, b) and a Document scanner HP Scanjet G4010 (c, d)

on palmprint matching. In both works, features regarding the palm shape and texture were used. Additionally, since the scanner was big enough to capture the whole botton side of the hand, minutiae were extracted from the fingertips. Results were highly encouraging, and the advantages of using similar scanners were nicely highlighted. However, no minutiae were extracted from palms, so in order to test the applicability of this type of technologies on palmprint-based forensics more studies are needed. These previous results motivate the present work.

2 Database description and acquisition

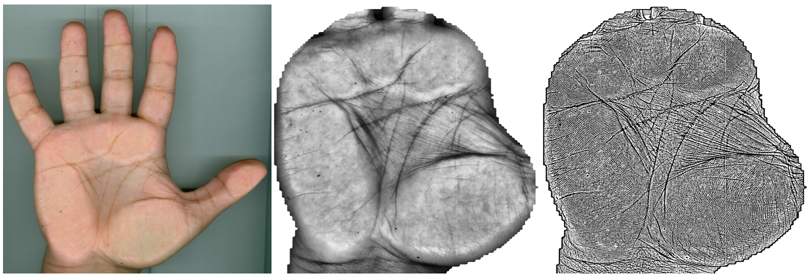
To test the feasibility of a document scanner for minutiae-based palmprint recognition and to compare its performance with an industry standard scanner, a database using both types of scanners was established. Scanners used in this study were a Green Bit MC517 palmprint scanner [7] (Figure 1a) and a HP Scanjet G4010 document scanner [10] (Figure 1c).

Sixty-four subjects were willing to participate in this study. Both hands from each subject were captured using both scanners. 5-6 imprints were captured from each hand for each scanner. Between each capture the surface of the scanner was cleaned. A total of 657 images were captured with the Greenbit MC517 scanner and 656 images were obtained with the HP Scanjet G4010 scanner. Figures 1b and 1d show examples of collected images.

Several problems arose during the acquisition process. While acquiring images with the Greenbit MC517 scanner users needed to apply a considerably high pressure on the surface of the scanner to be able to capture the whole palm. Sometimes the scan process had to be repeated and users needed to help themselves by putting one hand over the other to apply more pressure. Examples of images captured with too little pressure on the scanner device can be seen in Figures 2a and 2b. On the other hand, for the document scanner the pressure that has been applied to the palm was too high due to the weight of the lid that caused deformations of the palm imprints. This caused e.g. ridges

(a) (b) (c) (d)

Fig. 2. Missing information due to non-excessive pressure on the Greenbit scanner (a, b) and high deformations caused by excesive pressure on the HP Scanjet G4010 scanner (c, d)



(a) (b) (c)

Fig. 3. Pre-processing techniques: Original image (a), EQ1 (b), and EQ2 (c)

which were not clearly visible on the scanned images and high skin deformation in others (See Figures 2c and 2d). Leaving the lid open could cause too much over-illumination. All these problems, affect the recognition performance as it can be seen later in the experimental evaluation (section 3). Nevertheless, problems with the HP Scanjet G4010 scanner can be easily overcome by modifying the device as in [21].

2.1 Pre-processing of HP Scanjet G4010 scanned palms

Before extracting features from the palmprint images, the region of the palm has to be isolated to avoid extracting features from the fingertips. In order to do this a color segmentation algorithm similar to the one proposed in [9] was applied. After the color segmentation algorithm, a set of morphological operations is used to remove the fingers from the final mask.

Two pre-processing techniques were used for the segmented palms. First, a histogram equalization technique [20] was applied to compensate for the light entering the scanner due to the semi-closed lid. Second, a local contrast enhancement using a window size of 17 pixels and an enhancement factor of 0.005 is applied [3]. The idea is to morph the HP Scanjet G4010 scanned palms to become more similar images to the ones obtained with the Green Bit scanner. The impact of the pre-processing techniques is evaluated in the experimental section. Both pre-processing techniques are abbreviated as EQ1 and EQ2, respectively. Figures 3b and 3c show examples of the pre-processing techniques applied on the Figure 3a image.

3 Experiments

Verification experiments were carried out on each dataset to assess their discriminatory potential and the feasibility of each scanner for biometric recognition. Furthermore, cross-device matching experiments were conducted to evaluate a system where both scanners are employed. Since latent impressions resemble more the ones obtained with the GreenBit scanner, cross-device matching experiments assess the feasibility of using document scanners for forensic applications. Experiments were conducted following the FVC protocol [16].

Several systems were employed to conduct the experiments. Verifinger 4.2 [19] and VeriPalm [18] were used for feature extraction. Verifinger 4.2 (VF) and VeriPalm (VP) minutiae templates were matched using CPIM [8] and Minutiae Cylinder-Code (MCC) [1] algorithms. VeriPalm was used in conjunction with templates extracted by this matcher.

DET curves for each dataset are depicted in Figure 4 and Figure 5. For convenience, the GreenBit scanner dataset and the document scanner dataset had been named PalmA and PalmB datasets, respectively. The impact of the pre-processing techniques on the PalmB dataset can be seen in Figure 5. All systems performed better on the pre-processed sets achieving comparable results to the ones obtained in the PalmA dataset. In both datasets, as expected, VeriPalm minutiae templates are more discriminative than Verifinger 4.2 minutiae templates. None of the pre-processing techniques has been proven to be more effective than the other. The best results for Verifinger 4.2 minutiae templates were achieved with the EQ1 pre-processing but for VeriPalm templates the best results were achieved using the EQ2 technique. This, of course, is related to the intrinsic characteristics of both minutiae extractors.

Cross-device matching results are shown in Figure 6. These results were obtained by crossing the PalmA dataset with the pre-processed PalmB datasets. The results for the Verifinger 4.2 minutiae templates and in general for the CPIM algorithm were inferior compared to the single dataset results. Both MCC and the VeriPalm matcher performed well on the VeriPalm minutiae templates. Regarding the pre-processing techniques once more the results showed, that they are system dependent. MCC performed better on the EQ2 pre-processed images while the rest of the systems performed better with EQ1 technique. Further details and performance numbers are given in Table 1.

[3] http://homepages.inf.ed.ac.uk/rbf/HIPR2/adpthrsh.htm

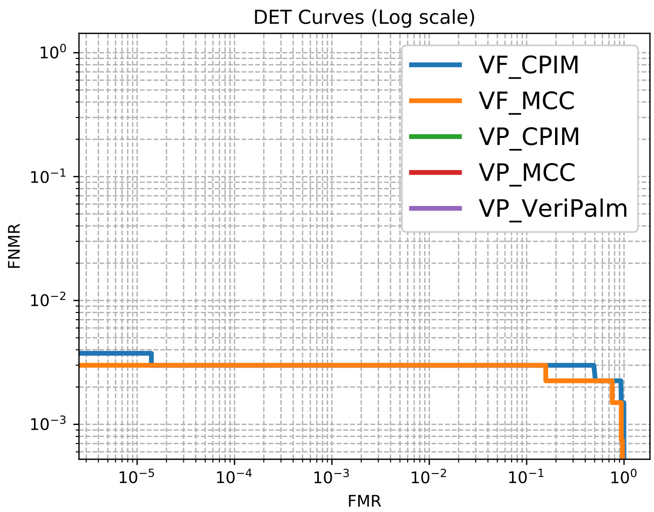


Fig. 4. DET curves on the PalmA dataset (curves for systems with an EER=0% are not visible).

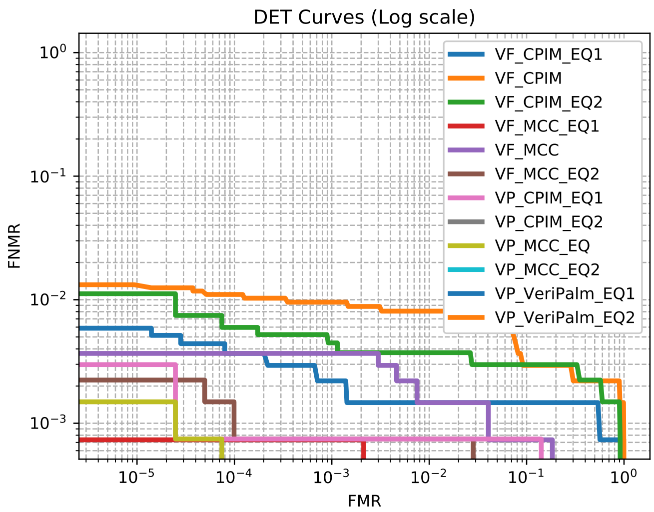


Fig. 5. DET curves on the PalmB dataset (curves for systems with an EER=0% are not visible).

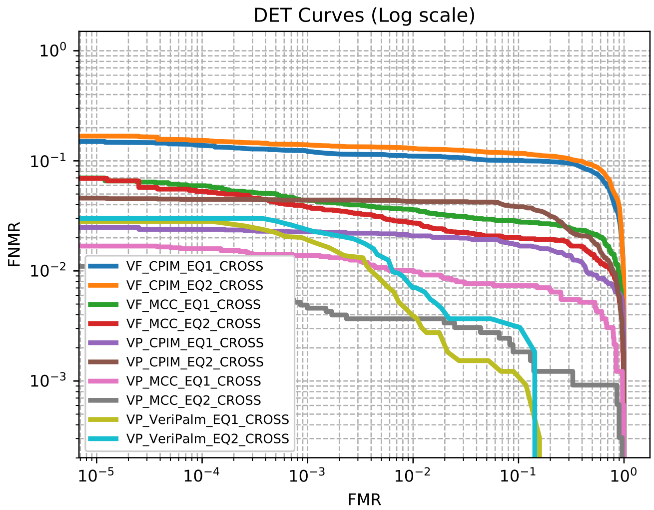


Fig. 6. DET curves for crossmatch.

3.1 Discussion

Experimental results show that the use of document scanners for minutiae-based palmprint recognition is feasible. Intra-datasets results are similar to each other and generally better in the case of the PalmB dataset. Considering the low cost of the HP Scanjet G4010 scanner compared to the Green Bit MC517, this is of great importance for law enforcement agencies and for the development of biometric palm recognition systems in general. However, there are some important issues that need to be taken into account before drawing any conclusions.

Acquiring palmprint images with the HP Scanjet G4010 scanner is considerably slower than with the Green Bit scanner. This can be a problem for civilian applications. Nevertheless, the final goal of this study is to apply this type of scanner in the context of forensic applications, and since palmprints are acquired offline, the acquisition speed is not a major issue. Additionally, the pre-processing stage in the PalmB dataset increases the total time for feature extraction. As mentioned before, the histogram equalization stage is needed to compensate for the over-illumination caused by semi-closed cover. This problem can be overcome by adapting the scanner as in [21].

Cross-device matching results, are applicable for real-world scenarios but worse compared to the intra-dataset results. This can be explained by the different origins of the images, but also by distortions introduced in the images in the acquisition process. As mentioned in section 2, to acquire the PalmA dataset users needed to put a strong pressure on the scanner surface which resulted in high non-linear distortion between minutiae. Additionally, for the

Table 1. Summarized results.

Dataset	Algorithm	AUC	EER	ZeroFMR	FMR1000
PalmA	VF_CPIM	0.9974	0.2971 %	0.3745 %	0.2996 %
	VF_MCC	0.9978	0.2952 %	0.2996 %	0.2996 %
	VP_CPIM	**1**	**0 %**	**0 %**	**0 %**
	VP_MCC	**1**	**0 %**	**0 %**	**0 %**
	VP_VeriPalm	**1**	**0 %**	**0 %**	**0 %**
PalmB	VF_CPIM_EQ1	0.9988	0.1449 %	0.5878 %	0.2204 %
	VF_CPIM	0.9973	0.7969 %	1.3226 %	0.9552 %
	VF_CPIM_EQ2	0.9979	0.3699 %	1.1186 %	0.4474 %
	VF_MCC_EQ1	0.9999	0.068 %	0.0735 %	0.0735 %
	VF_MCC	0.9998	0.2969 %	0.3674 %	0.3674 %
	VF_MCC_EQ2	0.9999	0.0745 %	0.2237 %	0.0746 %
	VP_CPIM_EQ1	0.9998	0.0732 %	0.2983 %	0.0746 %
	VP_CPIM_EQ2	**1**	**0 %**	**0 %**	**0 %**
	VP_MCC_EQ1	0.9999	0.0037 %	0.1491 %	0 %
	VP_MCC_EQ2	**1**	**0 %**	**0 %**	**0 %**
	VP_VeriPalm_EQ1	**1**	**0 %**	**0 %**	**0 %**
	VP_VeriPalm_EQ2	**1**	**0 %**	**0 %**	**0 %**
Crossmatch	VF_CPIM_EQ1	0.9279	9.8607 %	15.00 %	12.17 %
	VF_CPIM_EQ2	0.9167	11.5924 %	16.835 %	13.9884 %
	VF_MCC_EQ1	0.9798	3.136 %	6.996 %	4.403 %
	VF_MCC_EQ2	0.9861	2.2951 %	6.9177 %	3.7955 %
	VP_CPIM_EQ1	0.9890	2.001 %	2.4793 %	2.2651 %
	VP_CPIM_EQ2	0.9799	4.1566 %	4.5914 %	4.4077 %
	VP_MCC_EQ1	0.9954	0.9927 %	1.6835 %	1.3774 %
	VP_MCC_EQ2	0.9988	**0.367** %	**1.1019** %	**0.4591** %
	VP_VeriPalm_EQ1	**0.9997**	0.6463 %	3.0303 %	1.8365 %
	VP_VeriPalm_EQ2	0.9993	0.8414 %	3.3058 %	2.2957 %

PalmB dataset, the weight of the lid by closing over the palm increases the palm pressure over the scanner surface causing non-linear distortion between minutiae too. Furthermore, palm principal lines and creases are more notorious in the PalmB dataset. These features are known to cause problems in combination with minutiae extraction algorithms which are based on the gradient like the one used by Verifinger 4.2 [5]. Hence, the development of minutiae extraction algorithms which are more robust to creases as in [12] should improve the quality of the extracted features and therefore the cross-matching results. Table 2 summarizes the characteristics of the two capturing devices including the above mentioned issues.

Table 2. Characteristics of both scanners.

	GreenBit MC517	HP Scanjet G4010
Cost	Very expensive (3000-4000 USD)	Cheap (less than 500 USD)
Speed	Fast	Very slow
Pre-processing	No need for pre-processing; Algorithms can accurately extract minutiae from them	Segmentation and histogram equalization needed
Pressure	Users need to apply high pressure on the scanner	No need to apply pressure
Design	Specifically designed for palmprints	Designed for documents and images

4 Conclusions

The feasibility of using document scanners for minutiae-based palmprint recognition was explored. Document scanners are cheaper and more widely distributed compared to forensic palmprint scanners. The use of similar scanners has been evaluated but to the best of our knowledge this is the first time that minutiae are used for matching. Minutiae matching is mandatory for forensic applications. Results were encouraging and highlighted the issues that still need to be addressed for forensic applications. These issues are going to be the focus of our further work. Particularly, the performance in the case of cross-device matching needs to be studied in-depth. The last is crucial for the use of similar technologies in forensic applications. Moreover, in the context of this study, a new database was established, which will be made publicly available.

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