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Security of Hand Geometry

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Abstract

In this paper, the hand geometry biometrics and its advantages and disadvantages in terms of security will be described. How are disadvantages being addressed by current and future avenues of research and development will be explored. As of now, the existing systems utilizing hand biometrics are predominantly analyzing 2D representation of a hand, it's silhouette, which is acquired statically. As the static acquisition presents possible vector of attack on this system, the method of dynamic acquisition of hand geometry using a line scanner will be presented. The largest limiting factor preventing widespread of this technology however, is the relatively low entropy of hand silhouette, which in turn limits the size of the serviceable database and increases FAR and FRR and therefore its usage. This paper will therefore also explore how the 3D acquisition and following analysis of 3D model can lead to increased security and larger serviceable databases as well as how the line scan technology and 3D acquisition can be combined.

Keywords: Biometrics, 2D hand geometry, 3D hand geometry, structure light, 3D scanner, line scanner.

1 Introduction

How can we reliably identify a person or verify a person's identity and how secure this method is? The area of biometrics offers a solution to this issue by claiming, that in order to determine one's identity, we need only some of his/her physical traits. Many security systems of today identify people using various biometrics, most often fingerprint, facial markers or retina scan. These systems however, are not applicable in every situation either due to environmental, price or other reasons, and another method may be required. Hand geometry represents an alternative approach to human identification and verification, that avoids issues, that make more conventional approaches inconvenient, such as placement in areas where face needs to be covered or where fingerprints can become obscured (non-clean environment).

The fundamental idea of hand based geometry identification is built around the assumption, that each individual possesses a hand and its shape is unique. If we want to record a model of this hand, then, by comparing this hand against the model, we can identify a person, or verify the identity of this person. It was this assumption, that gave birth to first systems designed to do just so.

The first problem that needs to be solved, is to identify the characteristics, that can be both efficiently collected and without compromising the requirement for uniqueness. 2D hand geometry then represents a viable abstraction method where the parameters are such as silhouette or length, width and thickness of fingers, for example. [1]

In order to expand into a 3D system, a measurement of depth has to be introduced, this then in turn allows us to measure parameters such as curvatures of individual fingers and wrist as well as plastic deformations on the back or palm of the hand.

2 2D Hand Geometry Acquisition

To better understand the issues presented by hand biometrics, let us first take a brief look on principle of 2D acquisition.

The method itself is tantalizingly simple, since all we need is a silhouette of a hand. We may utilize for this task any CCD or CMOS camera with sufficient resolution. And whereas for fingerprint identification, we require a considerable resolution, e.g. 500 DPI, the hand geometry systems will operate with much lower resolutions, in commercial systems 100-200 DPI, but viable with even less then 100 DPI. [2]

During 2D acquisition we then usually capture a static image of a back of a hand followed by the extraction of required features. Depending on system, additional images may be acquired from different angles in order to gather additional features. This usually takes form of capturing the image from the top and side in order to gain all previously mentioned features [3]. As we can see on Figure 1 image from this direction allows us to efficiently gather the majority of required features.

Figure 1: Gathered image of a hand for 2D hand geometry extraction of features.

The system may be further modified, to improve the acquisition process and simplify the feature extraction stage, such as including reflective background to enhance edges or add cameras to have more sources of features, and pins which ensure that the hand is in a predictable position, the principle however remains the same. Figure 2 show possible set of features to be extracted.

3 Limitations of 2D Acquisition

The simplicity of acquisition and low demands on the resolution of the sensor, present us however, with several shortcomings, while some are still being addressed, other encounter the limitations of 2D acquisition.

Despite the improvement of existing commercial hand recognition tools such as HandKey II [4], due to the fact that only around 14-40 parameters are being extracted, which limits either the database size or compromises the success rate of identification, as proved by the continued research into uniqueness of one's hand and its measurements as viable identification parameter of large population [3]. The transition from 2D to 3D hand recognition, adds features and features vectors, thus increasing an entropy and offering a solution to the issue.

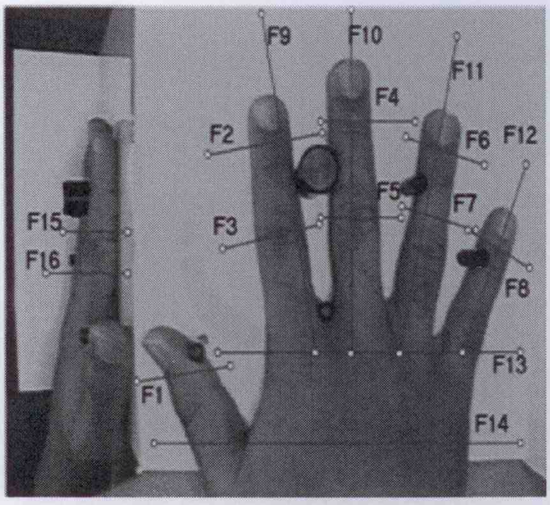


Figure 2: Viable hand features [1].

Spoofing presents another, challenge as was demonstrated in [5] where a simple paper silhouette was used as a spoof that could be used to introduce a successful impostor. The multi-dimensional approach can assist by increasing the complexity of an appropriate spoof. Necessary dimensions gathering from uncooperative target becomes a non-trivial task.

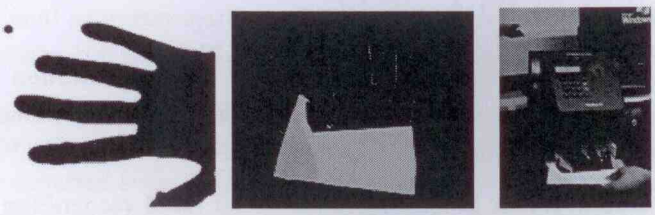


Figure 3: Paper silhouette spoof used to bypass commercial device [5].

The last limitation that we will mention here, is the difficulty in creating a pin-less and contactless solution. As far the authors are concerned, there are no existing pin-less and by extension contactless commercial devices available now. While the issue of pin-less hand recognition has been approached even in pure 2D hand recognition systems, it has been demonstrated that utilization of depth sensing devices is a viable method of approaching this problem [6] as well as the need for the physical contact with the sensing device.

4 3D Acquisition

The principle of 3D acquisition in biometrics has been successfully tested. The price and high computational demands limited these tests to academic research in the past. However, as the price of viable 3D acquisition devices keeps decreasing and the computational capabilities of even mobile hardware increasing, the 3D acquisition has become a viable alternative to 2D hand geometry systems.

On Figure 4 we can see a 3D image captured using low-cost Creative VF0800 camera [7]. On the image, we can see that, along with required 3D features, majority of 2D features can be inferred as well, which allows us to combine the 3D and 2D features with no additional hardware. The depth map also includes information that allow us to determine the absolute dimensions and thus create a basis for a contactless system.

Figure 4: 3D image of hand using low cost 3D camera.

While any 3D mapping method may be used, in the area of 3D hand geometry we can see that majority of works use a system based on principle of active triangulation. Be it the industrial 3D laser digitizers [8], or systems based on light pattern projection [9][10].

4.1 Using 3D Scanner

Utilization of professional laser scanner in biometrics can be seen in [8] – in this case a Minolta Vivid 910 has been used for creation of large database (3,540 items) of right hand scans. Where the device can work with accuracy in three axes up to X: 0.22 mm, Y: 0.16 mm and Z: 0.10 mm to the Z reference plane [11].

The method presented in [8] localizes the position of four fingers on intensity map, and based on this information extracts corresponding data from range map. The cross-sections of each finger are extracted at chosen distances along fingers length. This paper then proceeds to calculate features based on curvature and vector of normal of the finger segment. Figure 5 shows a depth data of cross section, calculated curvature and normal features.

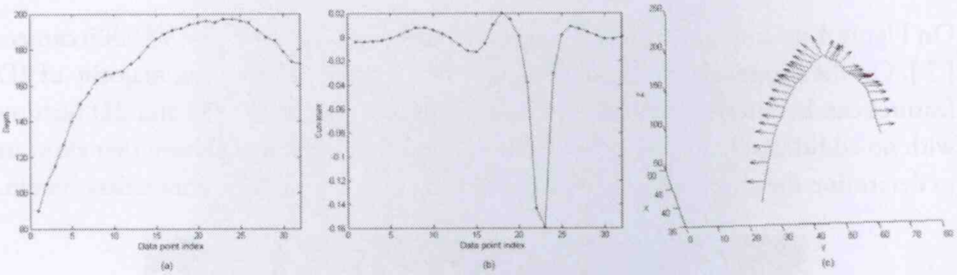


Figure 5: (a) Cross-sectional finger segment and (b) its computed curvature features; (c) Normal features computed for a finger segment [12].

In the paper, the 2D and 3D data is experimentally matched and EER (Equal Error Rate) and AUC (area under ROC curve) are calculated.

Matcher	EER [%]	AUC
3D Hand Geometry	3.5	0.9655
2D Hand Geometry	6.3	0.9722
(2D + 3D) Hand Geometry	2.3	0.9888

Table 1: EER and AUC of 2D, 3D and a combined matcher [12].

As expected, the combined 2D and 3D geometry data provides the best performance.

4.2 Using Structured Light

The use of structured light is based on the projection of visible, or infrared pattern of defined properties onto a surface of an object, in our case a human hand. On the surface of a plastic object the pattern appears deformed, by recording the direction and magnitude of this deformation, and comparing it to expected position, depth of the pixel in can be calculated. This approach has been used in several publications, where various sources of the pattern have been tested.

4.2.1 IR pattern projection

This approach became viable thanks to the spread of affordable 3D cameras such Intel RealSense or Microsoft Kinect. The cameras in this case provide both an RGB image as well as a depth map, with corresponding coordinates.

In [9] there was demonstrated that by using Intel RealSense camera, 2D and 3D features may be collected. After the preprocessing, during which markers such as fingertips, finger valleys and wrist lines are identified a vector including 41-dimensional vector of 2D features and 137-dimensional vector of 3D features can be extracted. Features are

- Finger length (2D)
- Finger valley distance (2D)
- Finger width (2D)
- Wrist to valley distance (2D)
- Finger axis surface distance (3D)
- Finger width (3D)

Figures 5 and 6 shows the respective features on the depth images and intensity images.

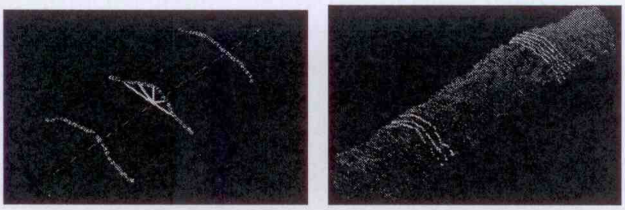


Figure 5: Extracted 3D features [9].

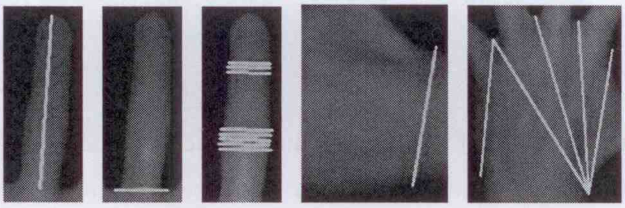


Figure 6: Extracted 2D features [9].

The feature vectors are in this case matched using the *Mahalanobis distance* [13], utilizing *large margin nearest neighbors* (LMNN) [14] the weights for individual features.

As the 2D and 3D feature vectors are calculated separately a comparison of individual vector performance as well as the performance of their combination can be examined.

		FRR [%]	
Features	**ERR [%]**	**@FAR = 0.5%**	**@FAR = 1%**
2D	2.76	6.50	1.63
3D	2.92	10.70	6.42
2D + 3D	1.61	4.81	2.23

Table 2: Overall performance of Bronstein and Drahansky system using LMNN metric learning approach [9].

From these data, we can infer that, while 3D features alone with low cost hardware, in combination with 2D features, the resultant method proves superior. The improvement is especially apparent in case of images where one of the source vector suffers high level of noise. Where second stream serves to improve to overall recognition rate, this method proved to be comparable even with the state of the art approaches.

Method	Features	Templates	Database	FAR [%]	FRR [%]	EER [%]
Jain and Duta	2D	1 – 14	53	2.00	3.50	N/A
Jain et al.	2D	1 (avg)	50	2.00	15.00	N/A
Woodard and Flynn	2D + 3D	1 (avg)	177	5.50	5.50	5.50
Malassiotis et al.	2D + 3D	4	73	3.60	3.60	3.60
Kumar et al.	2D + 3D	5	100	5.30	8.20	N/A
Kanhangad et al.	2D + 3D	5	177	2.60	2.60	2.60
Bronstein and Drahansky	2D + 3D	1 (avg)	88	1.61	1.61	1.61

Table 3: Qualitative comparison of hand biometrics based matchers [9].

4.2.2 Lasers and diffraction grating

A short coming of generic commercial light pattern based approach is its lack detail and operation on short range, and even though the results were still satisfactory, the system can be improved upon by designing the light projection for the application. Both the wavelength and the actual pattern can then be chosen, based on a priory information about the measured object.

In [10] the array of 532 nm lasers is being used with simple two MS Lifecam HD 3000 camcorders used for acquisition. Optics on laser turns the dot projection into line projection and diffraction grating then allows to turn the single line into an array of parallel lines. On Figure 7, we can see how the resultant line pattern appears on hand and how it can be separated from the background.

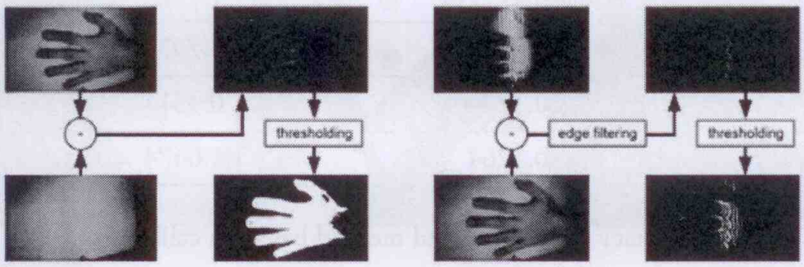


Figure 7: The process of extracting the deformation markers, created by diffracting line projection [10].

As we can see, the on Figure 8 the concept has been proven and the model of 3D hand may be reconstructed despite the low cost of entire setup.

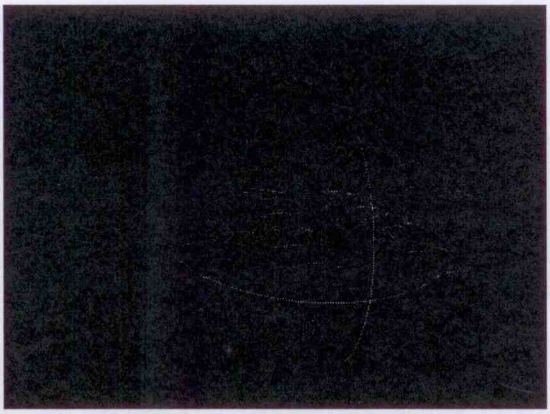


Figure 8: Resultant surface reconstruction from the lines projection [10].

So far, this method has only been presented as a viable scanning method and no database has been produced. As is, the method performs a pre-processing necessary for 2D hand geometry identification and thus can be seen, as a viable approach to increasing the entropy of the hand biometrics. The accuracy of method has been demonstrated by scanning an object of known dimensions.

The cube with side of length 25.5 mm has been scanned and the root mean squared and normalized root mean squared has been calculated.

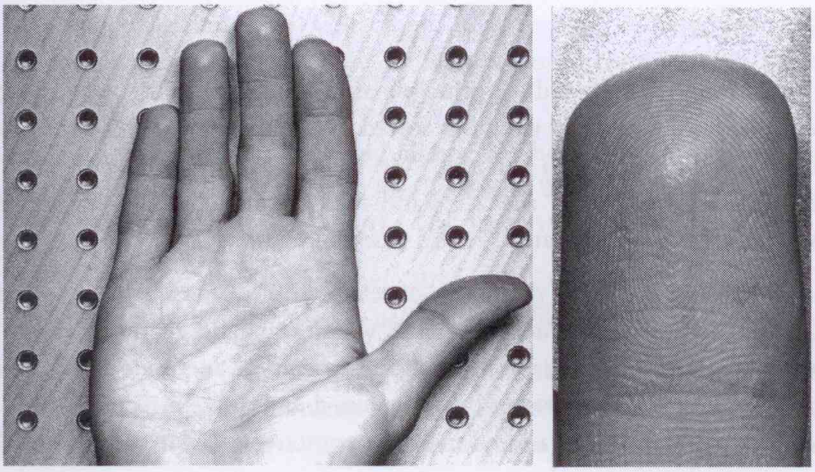
Model	NRMSE	RMSE
Laser 0	0.2190	1.4558
Laser 1	0.1993	0.7977
Laser 2	0.1764	0.4317
Merged	0.1764	1.0474

Table 4: Accuracy of the proposed method based on calibration [10].

5 Utilization of line scanners in biometric acquisition

Direction in image acquisition that is now being explored, is utilization of line scanners for 2D and 3D hand biometrics.

The advantages present themselves in the form of acquisition of a dynamic object (hand). This would lead to increasing a throughput at a gate utilizing this system, while maintaining image quality necessary for multimodal feature extraction, namely fingerprints and palmprints. On Figure 9 a) we can see an image acquired via line scanner fixed on a moving platform moving at a speed of 0.5 m/s. On Figure 8 b) we can see a detail of a little finger, demonstrating that output resolution is high enough for a fingerprint extraction and therefore high enough for 2D hand geometry extraction.



a) b)

Figure 9: a) Palmprint using line scanner mounted on moving platform;
b) detail of ring finger.

Reconstruction of hand model using a data from a non-calibrated movement is currently being explored. As we can see on Figure 10 the uneven movement speed and direction leads to deformations that make hand geometry extraction complicated, however, the overall details presented serve as proof of viability of this method for biometric feature extraction.

a) b) c)

Figure 10: a) Palmprint using a fixed line scanner scanning a moving hand;
b) detail of middle knuckle; c) detail of little finger.

6 Conclusion

In this paper, we have reviewed the principle of 2D hand geometry based recognition and identified limitations that would be solved by utilizing one of 3D hand geometry acquisition and identification method. We have explored approaches to the 3D acquisition and showed how the 2D hand recognition enhanced by 3D features improves the overall success rates of hand based biometrics.

We have identified two main directions of research in this area. One being research of methods of creating multimodal systems, which use hand geometry as one of the biometrics. Second one is research of new acquisition methods, using low cost hardware Usage of line scanner has been suggested and proven in concept as a viable method of extracting features related to hand geometry as well as texture details such as palm print and or fingerprint.

3D hand geometry biometrics builds upon the 2D hand geometry a good method for biometrics. 2D method has proven to be useful in applications where other methods of identification are inconvenient. It has been unable to become truly widespread, due to limited template size. With the advance of 3D approach this wish could become rectified and allow this technology to spread.

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