Increasing the Reliability of Biometric Verification by using 3D Face Information and Palm Vein Patterns

Olegs Nikisins, Modris Greitans, Rihards Fuksis, Mihails Pudzs, Zanda Serzane

Institute of Electronics and Computer Science
14 Dzerbenes Str., Riga, Latvia, LV-1006
olegs.nikisins@gmail.com
modris_greitans@edi.lv

Abstract: The improvement of the reliability for biometric image-based identification systems is discussed in this paper. Accuracy rising of the verification process is based on two main principles: implementation of multidimensionality and advanced image acquisition. The multidimensionality principle is based on two factors: the system structure (multimodality of biometric system) and the acquired biometric data (visual and spatial information about the object). The advanced image acquisition is based on multi-view principle and photography that is sensitive in infrared spectrum.

1 Introduction

Biometrical recognition process is mainly based on one parameter, such as face, fingerprint, hand, palm or iris, captured with single image sensor. However, mono-modal systems can be fooled by using fake parameters. Two methods of increasing the security level of the system are implementation of the multidimensionality and advanced acquisition of biometric data. Multidimensionality includes the combination of two or more biometric parameters in one system (multimodality) and diversity of single biometric parameter representation (intensity and shape descriptive arrays), but it is very important to choose the right parameters to achieve higher precision and easy enrolment. The advanced image acquisition makes unauthorized capturing of biometric data problematic and decreases identity stealing possibilities. The advanced imaging is based on two main approaches: multi-view photography and imaging in invisible light. In this paper we introduce the improvements of multimodal biometric system [BPM10] by implementing 3D facial information in addition with palm blood vessel pattern. This maintains previously described advantages and increases the security level of the system.

2. Basic idea of the proposed approach

The main idea of the proposed system focuses on reliability increasing of biometric verification process by introduction of multimodal approach and reliable biometric parameters. These parameters include 3D facial information over the eye-line and palm vein patterns. Proposed system consists of passive stereo camera module [BBK05] (multi-view imaging principle) for 3D face information extraction, palm vein image acquisition block (infrared imaging) and the PC for cameras output data storage and processing. This system configuration is suitable both for biometric parameters extraction and for the recognition tasks, however only the first stage is described in this paper. Passive stereo camera system consists of two calibrated cameras [SHB08]. We describe the methodology of face contour extraction over the line between eye pupil centres, what can be used to separate face photos from real faces. This approach allows the extraction of 3D face information without the usage of active light sources (projector), what is comfortable for the user. Palm vein image acquisition system consists of infrared camera with additional optical filter and an IR light source. The filter and the light source with the wavelength of 850nm are selected, because the visibility of palm veins in our system is the best at this wavelength, what is established empirically. An effective algorithm for palm vein detection is described in later sections.

3. Eye pupil detection based on modified Hough transform

Accurate eye detection is an important biometrical feature extraction task [PZV05]. This section of the paper proposes the method for eye pupil detection. Determined eye pupils location is used for 3D facial information extraction over the eye line, what is important for the increasing of biometrical system's fake resistance. Proposed eye pupil detection method is based on modified Hough transform [Ba81]. Eye pupil has circle shape and the concept of Hough transform for circle detection provides good eye pupils segmentation results. Algorithm for eye pupil detection consists of following stages: captured image Gaussian low-pass filtering; edge detection with Sobel operator; Hough transform of the image for circle detection; resulting (transformed) pattern Gaussian low-pass filtering; detection of two maximums (coordinates of eye pupils) in the pattern. The central idea of Hough transform for circle detection is to determine all potential circle points (image edges) and to transform them into parametric space. The parametric space is three-dimensional *(a,b,r)*, where coordinates *(a, b)* defines the centre of the circle and *r* is radius.

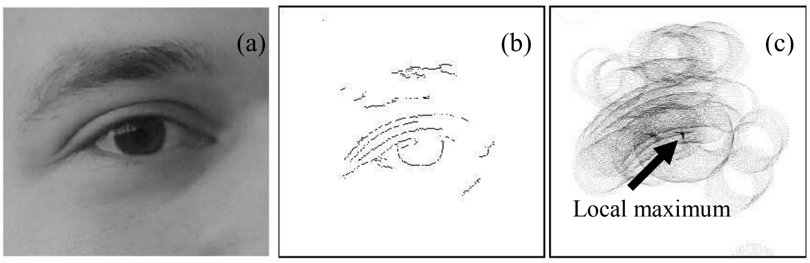

Figure.1: Hough transform for eye pupil detection. (a) Original image. (b) Edges detected with Sobel operator after low-pass filtering (c) Parametric space.

The main idea of our modified Hough transform is to exclude accumulator and to process parameter space (Figure.1 (c)) directly. This processing is performed with low-pass filtering of the parametric space pattern, what results in space blurriness. The operation of local maximums detection is performed next to the blurred parametric space, what is the resulting stage of eye pupil detection.

4. 3D information extraction over corresponding line segments

One of the methods to increase reliability of face recognition system is to implement the use of 3D face information. However the main problem is to create precise and task - appropriate 3D image acquisition system. Offered solution is based on the “passive” stereo system [BBK05]. The operation of passive stereo imaging system is the most comfortable for the user, but this approach commonly requires complicated algorithms to resolve the *correspondence problem*, so we propose to use well – observable facial features for the calculation of 3D information. In details, points of face contour along the eye-line are selected as a parameter for 3D face information evaluation, what will let to segregate real faces from spoof objects (face photos).

Once eye pupil detection task is performed an equation of the line between eye pupil centres can be found. This allows to find brightness values along the eye-line (Figure.1).

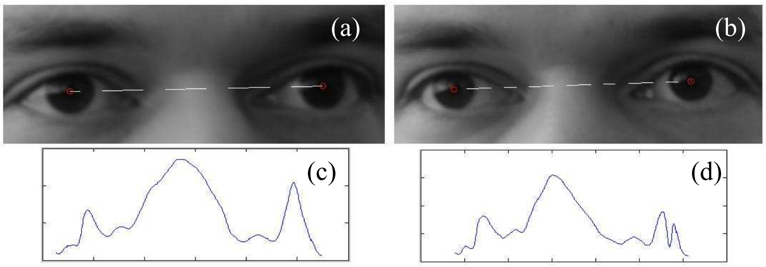

Figure.2: images form stereo system. (a) Image from left camera with detected eye-pupils and corresponding eye-line. (b) Image from right camera with detected eye-pupils and corresponding eye-line. (c), (d) Intensity along the eye-line for left and right camera images

Intensity signals are used to resolve a correspondence problem. Algorithm for corresponding point detection consists of following stages: Gaussian low-pass filtering of the signal (Figure.2, (c) and (d) signals); signal rationing to same maximum and minimum values; extremum calculation for both signals; locating corresponding extremums in both signals. Once corresponding image points are located we can compute the scene points using the **triangulation** method [SHB08]. The solution of the triangulation task for corresponding points gives their 3D coordinates, however only 2 coordinates (Figure.3) are used in our approach: horizontal position of the point (location along x axis) and the distance from points to the stereo system (location along y axis). Information about locations of the eye - line points (Figure.3) is next used for object shape estimation. We use distance **d** from point to line between eye centres, as an estimation parameter. Obviously, that distances **d** are small, if face photo is placed in front of biometric recognition system, so the implementation of this parameter into recognition process will increase fake resistance of the system.

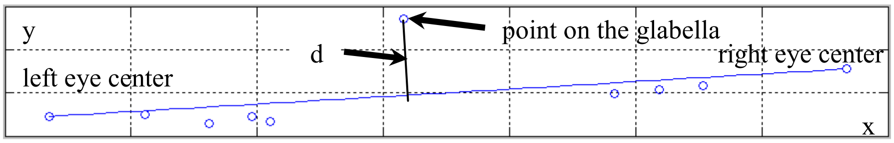

Figure.3: location of points detected along the eye-line in x, y coordinates

5. Palm vein image acquisition in infrared light

The idea of palm vein imaging is based on absorption of infrared (IR) light [LL06]. Haemoglobins in blood have different absorption properties. Absorption maximum within the near-infrared (NIR) area for deoxygenated haemoglobin is 760 nm, but for oxygenated is 850nm. Thus, palm veins appear darker than the surrounding tissue when captured in IR light.

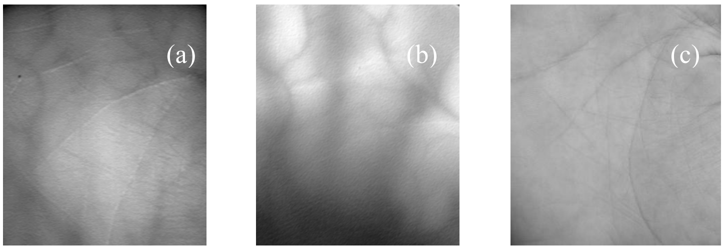

Figure.4: Infrared palm images captured with reflection (a) and transmission (b) methods. Palm image in visible light (c).

Infrared palm images can be obtained by two approaches – reflection and transmission method [FGNP10]. Based on previous experiments [FGNP10] it is effectively to choose reflection method, because it requires less power for the light source and reduces system dimensions in comparison with transmission setup. Blood vessel images captured with described methods are displayed in Figure.4. In the image captured with reflection method palm vein layout is visible and could be considered as an additional biometric parameter for person recognition; in image acquired with transmission approach two parameters are visible: bone structure and palm veins. Both parameters detected with transmission method are useful for reliability increasing, because vein layout is excellent uniqueness identifier, but bone structure could be used for aliveness detection. An infrared light source and IR filter with central wavelength of 850 nm has been selected for our system.

6. Image pre-processing. Complex matched filtering

To perform palm blood vessel extraction task complex matched filtering (CMF) approach was developed. Method is based on two-dimensional matched filtering (MF) [CSKNG89]. CMF was introduced in [GPF09] for feature detection in images with structured objects. This method improves computational efficiency and provides additional information about the object, such as vessel orientation. CMF filters an image with one complex mask, which incorporates all necessary angles and scales, what is an advantage in comparison to MF approach. The kernel of complex matched filter is defined by following equation:

$$CMF(x,y) = \sum_{m=1}^{M} \sum_{l=0}^{L-1} \exp(j2\varphi_n) G(x,y,\varphi_l,c_m),$$

where c_m is scaling factor, M – total number of used scales, L – total number of used angles, $\varphi_l = l\pi / L$ and $G(x,y,\varphi_l,c_m)$ - Gaussian mask for matched filtering.

CMF output is a matrix of vectors. Vector magnitudes illustrate matching intensity, while angles characterize the orientation of blood vessel. These vectors might be used for person identification and is a good biometrical parameter for highly reliable biometric system design, due their advanced acquisition.

7. Experimental results

We use an average distance from points to line between eye centres (Figure.3), as an estimation parameter. Usage of 7M pixel digital cameras for stereo system setup provides following experimental results: average distance is less than 1 (mm) for face photo images, and more than 2.5 (mm) for real faces (notes: distance from stereo system to the object is less than 70 cm; distance between optical centres of two cameras is 15 cm). Difference in limits of average distances is not significant, what could be explained with “relatively flat” face contour over the eye-line.

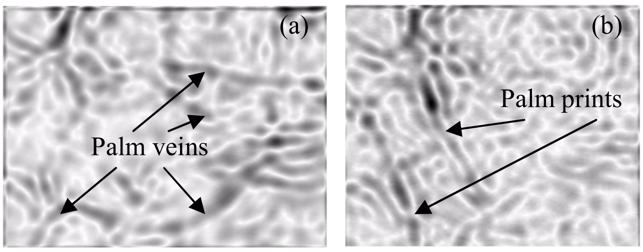

Figure.5: Palm vein image complex matched filtering. (a) Image is acquired in infrared light. (b) Image is acquired in visible light

Infrared palm vein imaging system with CMF algorithm has been tested on a database of 400 images from 50 persons (8 from each person). Figure 5 shows typical complex matched filtering result of palm images acquired in infrared and visible light for the same person. The segmentation of biometric features will obviously provide different results for visible light image (Figure.5, a) and IR image (Figure.5, b), what is excellent parameter for aliveness detection. When real hand is replaced with palm photo, the result of complex matched filtering for images acquired in visible and infrared light will be the same. This fact is useful for the purpose of fake object rejection. The combination of visible and infrared palm imaging techniques is a powerful tool for aliveness detection and reliability increasing.

8. Conclusions

The implementation of advanced imaging and multidimensionality factors into biometric recognition system benefits in increased reliability of the result. Information about the face shape and palm vein layout adds to the system such decidable factors as fake resistivity and ability of aliveness detection. Proposed methodology for 3D data extraction could be extended for the reconstruction of the whole face, by simple line transfer along the face in parallel to the eye-line, what is an effective solution of "correspondence problem". The complex matched filtering of the palm vein image decreases computation complexity and provides extra information for the recognition stage. Our future research will be focused on the explication of 3D face reconstruction idea, its combination with IR palm imaging and the development of robust recognition algorithms in order to develop reliable multimodal biometric authentication system.

9. Acknowledgments

This research is supported by the Latvian State research program in innovative materials and technologies and ESF project Nr. 1DP/1.1.1.2.0/09/APIA/VIAA/020.

Bibliography

[Ba81] Ballard, D.H.: Generalizing the Hough Transform to Detect Arbitrary Shapes. Pattern Recognition, Vol.13, No.2, 1981; pp. 111-122

[BBK05] Bronstein, A.; Bronstein, M.; Kimmel, R.: Three-Dimensional Face Recognition. International Journal of Computer Vision 64(1), 2005; pp. 5-30

[BPM10] Boulgouris, N.; Plataniotis, K.; Micheli-Tzanakou, E.: Biometrics, theory, methods and applications. Wiley, USA, 2010

[CSKNG89] Chaudhuri, S.; Shatterjee, S.; Katz, N.; Neleson, M.; Goldbaum, M.: Detection of Blood Vessels in Retinal Images Using Two-Dimensional Matched Filters. IEEE Transactions on medical imaging. Vol. 8, No. 3, 1989; pp. 263-269

[FGNP10] Fuksis, R.; Greitans, M.; Nikisins, O.; Pudzs. M.: Infrared imaging system for analysis of blood vessel structure. Electronics and Electrical Engineering, 1(97), 2010; pp. 45-48

[GPF09] Greitans, M.; Pudzs, M.; Fuksis, R.: Object Analysis in Images using Complex 2D Matched Filters. Proceedings of the IEEE Region 8 Conference EUROCON 2009; pp. 1392-1397

[L96] Lutkepohl, h.: Handbook of Matrices. John Wiley & Sons, Chichester, England, 1996

[LL06] Lingyu, W.; Leedham, G.: Near- and Far- Infrared Imaging for Vein Pattern Biometrics. Proceedings of the IEEE international Conference on Video and Signal Based Surveillance (AVSS'06), 2006

[PZV05] Park, K.; Zhang, H.; Veznevets, V.: Image-Based 3D Face Modelling System. EURASIP Journal of Applied Signal Processing, 13, 2005; pp. 2072-2090

[Ro06] Roberts, C.: Biometric Technologies – Palm and Hand. Link: http://www.ccip.govt.nz/newsroom/information-notes/2006/biometrics-technologies-palmhand.pdf, 2006

[SHB08] Sonka, M.; Hlavac, V.; Boyle, R.: Image Processing Analysis, and Machine Vision. Cengage Learning, USA, 2008