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, LV-1006, Latvia

Introduction

In our research we present the idea of reliable multimodal biometric system that combines the analysis of 3D facial information and palm blood vessel pattern. The increasing verification of result reliability is based on *multidimensionality* and *advanced acquisition* of the 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). The advanced imaging is based on two main approaches: multi-view photography and imaging in invisible light.

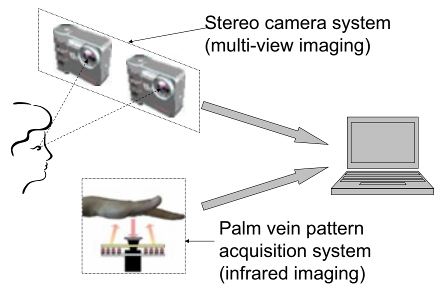

Figure.1: Schematic representation of the proposed system

Eye pupil detection based on modified Hough transform

In our work determined eye pupils locations are used for 3D facial information extraction over the eye line, what is one of parameters we use to increase the fake resistance of the biometric system. 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:

1. Gaussian low-pass filtering of captured image;
2. edge detection with Sobel operator;
3. Hough transform of the image for circle detection;
4. Gaussian low-pass filtering of transformed pattern;
5. detection of two maximums (eye pupils) in the pattern.

The main idea of our modified Hough transform is to exclude accumulator and to process parameter space (Figure.2) directly.

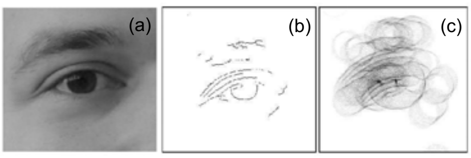

Figure.2: Hough transform for eye pupil detection. (a) Original image. (b) Edges detected with Sobel operator after low-pass filtering (c) Parametric space.

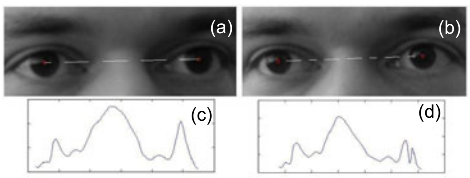

Figure.3: images form stereo system. (a) Image from left camera with detected eye-pupils and corresponding eye-line. (b) Image from right camera with detected eye-pupils and corresponding eye-line. (c), (d) Intensity along the eye-line for left and right camera images

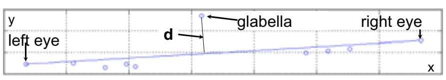

Figure.4: location of points detected along the eye-line in x, y coordinates

3D information extraction over corresponding line segments

3D image acquisition system is based on the "passive" stereo camera setup [BBK05] (Figure.1). 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 the 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).

Intensity signals over the eye-line are used to resolve a *correspondence problem*. Algorithm for corresponding point detection consists of following stages:

1. Gaussian low-pass filtering of the signal (Figure.3, (c) and (d) signals);
2. signal rationing to same maximum and minimum values;
3. extremum calculation for both signals;
4. locating corresponding extremums in both signals.

Once the corresponding image points are located we can compute the scene points using the **triangulation** method [SHB08].

Depth mask (distances **d,** Figure.4) over the eye-line is used next for object shape estimation. 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.

Palm vein image acquisition in infrared light

The idea of palm vein imaging is based on absorption of infrared (IR) light in the blood [LL06]. It is effective to choose the reflection method (Figure.5) to capture the palm vein image [FGNP10] . Blood vessel images captured with described methods are displayed in Figure.6. In the image captured with reflection method palm vein layout is visible and could be considered as an additional biometric parameter for person recognition. An infrared light source and IR filter with central wavelength of 850 nm has been selected for our system.

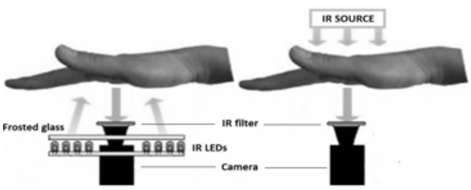

Figure.5: Image acquisition setup for reflection approach (left) and transmission approach (right).

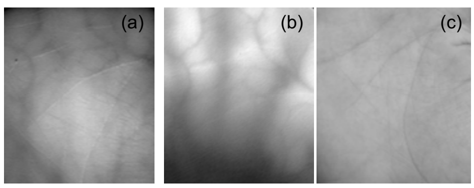

Figure.6: Infrared palm images captured with reflection (a) and transmission (b) methods. Palm image in visible light (c).

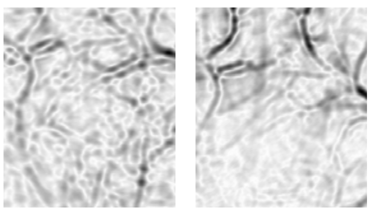

Figure.7: CMF filtering results: for reflection method image (left) and transmission method image (right)

Experimental results

1) Face contour depth map over the eye-line

We use the following estimation parameter: an average distance from points to line between eye centers (Figure.8):

$$\bar{\mathbf{d}} = \frac{\left(\sum_{i=1}^{N} \mathbf{d}_i\right)}{N}$$

Stereo system setup with 7M pixel digital cameras provides following experimental results:

average distance for face photo images is
•less than 1 (mm)
• 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 centers 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.

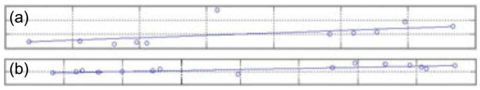

Figure.8: typical location of points detected along the eye-line. (a) Real face. (b) Photo of the face

2) Infrared palm vein imaging

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.9 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.9, a) and IR image (Figure.9, b), which is an 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.

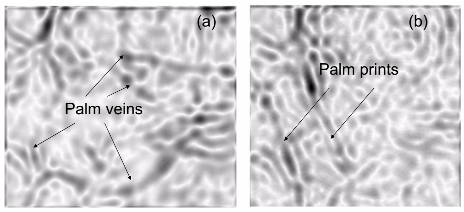

Figure.9: Palm vein image complex matched filtering. (a) Image is acquired in infrared light. (b) Image is acquired in visible light

Conclusions

The implementation of advanced imaging and multidimensionality factors into biometric recognition system benefits in increased reliability of the result. The effectiveness of described approach is based on a few aspects. 3D face and palm vein infrared imaging system could be developed with only two photo capturing devices, which provides an ability to design a low-cost and at the same time a reliable system. Information about the face shape and palm vein layout improves fake resistivity and ability of liveness detection. Proposed methodology for 3D data extraction could be extended for the reconstruction of the whole face by moving line 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.

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For further information:

Olegs Nikisins olegs.nikisins@edi.lv
Modris Greitans modris_greitans@edi.lv

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