16th IMEKO TC4 Symposium
Exploring New Frontiers of Instrumentation and Methods for Electrical and Electronic Measurements
Sept. 22-24, 2008, Florence, Italy

A hand vein structure simulation platform for algorithm testing and biometric identification

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Abstract - Scanning the veins in human hands for biometric purposes has become more and more appealing due to inexpensive hardware requirements and rather simple software processing algorithms. However, there are few studies regarding the repeatability or uniqueness of the actual vein pattern. Furthermore, algorithm testing is usually carried out on a limited number of sample images acquired under different hardware setups. This is mainly due because of the lack of a vein pattern image database aimed to provide researchers with sufficient data to test recognition algorithms. Creating a large database of real hand vein patterns is a difficult task in terms of time and money. Other biometric domains, such as fingerprint recognition, benefit from synthetic generated images that greatly aid the accuracy of a given processing technique. This paper will offer a novel implementation of a platform for synthetic vein pattern images of the back of the hand. While the reasons behind pattern forming of veins are not completely known, there is sufficient data to create realistic images of vein patterns based on model reconstruction from crossing points, terminations and general anatomy of the hand.

I. Introduction

Vein patterns as a biometric feature comply with the definition of a biometric system - a pattern recognition system that recognizes a person based on a feature vector derived from specific physiological or behavioral characteristic that the person possesses [1] – and it provides many important biometric features, such as permanence of the pattern, intricate model, non-contact detection procedure [2][3].

While there are many areas preferred for vein scanning, three locations have been used recently in various scientific papers:

- Finger veins
- Palm veins
- Veins in the back of the hand

As a main topic of interest, biometric identification of hand vein patterns has been actively researched by the authors [4][5][6]. After implementing several systems for scanning the veins in the back of the hand, thousands of vein pattern images for this area have been acquired. Some of the developed scanning algorithms can be efficiently reversed to create realistic images of the vein pattern. Using key points of a vein structure: crossing points, terminations, general direction of the model, relative angles etc, the model can be recreated. When combining this information with the local anatomy of the hand, the position of bones and tendons, images of a simulated vein pattern can be constructed.

This paper introduces VEINSIM (VEIN SIMulator), a novel platform for creating large databases of accurate synthetic images of the back of the hand containing vein patterns, to be used for algorithm testing and biometric identification. This is meant as a response to SFINGE, the simulation platform used for creating fingerprint images. There is no simulation package designed for vein patterns and this implementation will try to address the needs of researchers working in the field of vein pattern recognition.

II. Methodology and simulation

As mentioned in the introduction, there is no specific platform for creating simulated images of hand vein patterns, as it is the case with other biometric technologies. However, in the case of fingerprints, the actual simulation is simpler, since there are clearly defined classes for fingerprints and the ridges and valleys are easily reconstructed from a few key points.

Vein patterns have fewer intersections then fingerprints, but an increased length of the structures with many unpredictable angles and trajectories compensates what they lack in complexity. Since veins are a hidden feature of an individual, there are difficulties in reproducing a vein pattern. Veins anastomose frequently and their depth under the skin varies greatly even for the same hand. Using the scanning techniques described in [4][7][8], the penetration of near infrared radiation in human tissue is small due to scattering and absorption phenomena. Only some of the veins from the back of the hand will be fully visible under infrared radiation while others are impossible to detect. Since a vein biometric system can only detect superficial veins, the simulated images will have to possess the same characteristics.

While local anatomy and hemodynamic needs, together with several signaling molecules dictate the overall shape of the pattern, it is impossible to predict the exact structure of the model. This being the case, the simulation tries to generate probable vein patterns based on experimental results from thousands of previously scanned images. Several factors are taken into account, including the preservation of connectivity and the statistical spread of blood vessels in the hand in order to irrigate the whole area of interest.

Images are first created as perfect models with no noise or interferences from visible factors such as hair or pigmentation of the skin. Since the whole method of biometric scanning is based on the flow of deoxidized hemoglobin in veins, the inner diameter of the vein and blood flow speed dictate the degree of visibility of the pattern. In order to simulate this aspect, the first step of the image processing will create the largest veins that should supply blood to the extremities of the hand.

The quality of images in a hardware recognition system varies greatly due to the illumination and acquisition methods used in the process as depicted in figure 1.

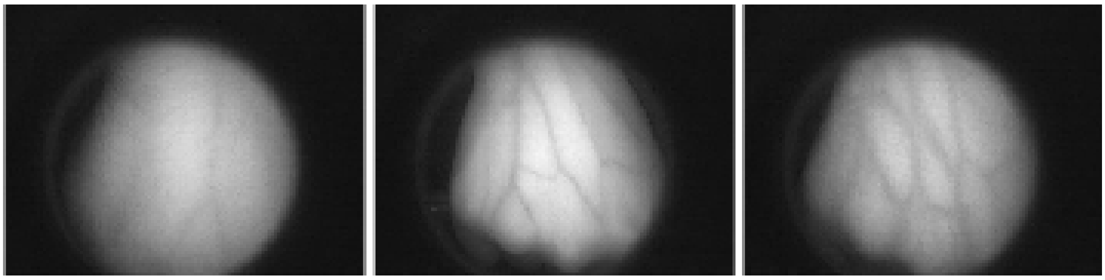

Figure 1. Different images of real vein patterns depending on hardware and illumination setup

There are a lot of error-generating situations:

- camera noise
- hot-spots from the lighting system
- position of the hand under the scanner
- environment noise
- hair on the back of the hand
- depth of veins under the skin
- thickness of veins

These parameters can be reproduced in the creation of simulated vein patterns in order to offer a more realistic scenario and to challenge even the smartest detection algorithms. The resulting images look similar to those acquired under near infrared illumination but the system can be easily configured to create images resembling those scanned with far infrared radiation.

III. Reconstruction of hand vein patterns

The procedure used to extract features from real vein images is based on the algorithm created by the authors in [5]. After binarizing the image using the local adaptive thresholding method a thinning operation is applied. Several key points can then be extracted from the resulting thinned model of the vein structure.

Assuming no connectivity is lost due to poor imaging, the border points of the visible vein pattern usually belong to the biggest veins.

Using a modified version of the crossing number [9], each point of a thinned model of the pattern can be classified as a termination, a node, or a point belonging to a segment (figure 2).

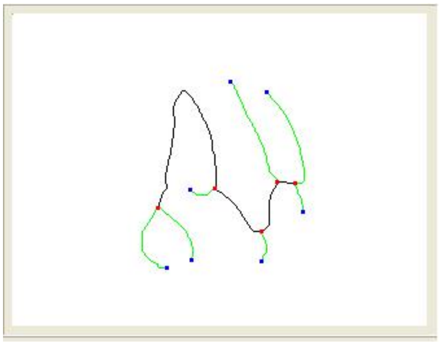

Figure 2. Key points in the vein pattern extracted using the crossing number method

In order to create a synthetic image of the vein pattern of a given human hand, the software application works in reverse. The reconstruction algorithm can either be supplied with the desired position of key points or it can create random yet realistic locations of nodes and terminations in order to create the basis of the vein structure.

When given these key points and the number of neighbors, for each node the software will extrapolate the pattern in between, while obeying the general direction of the model. Various constraints are applied:

- no vein segment can reconnect to itself
- all lower veins should converge to three points, each point connecting two fingers [10]
- the algorithm will try to connect the closest points first (efficiency of the vessel model)
- shorter veins will have precedence over longer ones
- the complete structure will have to overlap the entire region of interest in the hand
- the vein model can not exceed the dimensions of the assigned shape of the hand

After calculating the segments, a dilation algorithm is used to recreate the veins. The maximum width of a vein is either calculated based on the overall dimensions of the simulated hand or introduced as a constant. The process is shown in figure 3.

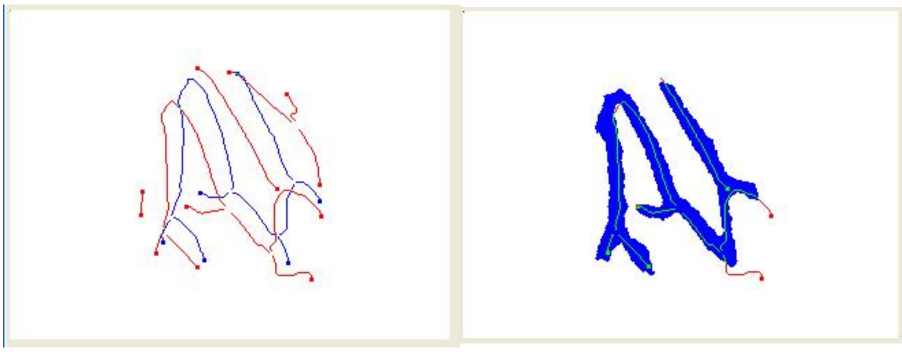

Figure 3. Reconstruction of the vein pattern at full width

The vein pattern is placed inside the simulated hand and a texture is applied to give the hand a more realistic aspect. The texture parameters are calculated using a contrast variation coefficient C_v based on the following formula:

$$C_v = \frac{\sum_{y=1}^{m}\sum_{x=1}^{n}(P_{x,y} - P_{x+1,y})}{xy} + [\max(P_{x,y} - P_{x+1,y}) - \min(P_{x,y} - P_{x+1,y})]/10 \qquad (1)$$

where:

$P_{x,y}$ represents the intensity value of a pixel at coordinates x,y in the image

$P_{x+1,y}$ represents the intensity value of a pixel at coordinates x+1,y in the image

m,n are the width and the height of the area of interest in pixels

max,min are the maximum and minimum values of the differences between adjacent pixels

Camera noise or illumination hotspots can be applied using salt and pepper noise and by modifying the contrast variation coefficient on different parts of the image using adaptive kernel sizes. This technique is also used to provide a virtual polarization in the simulated hardware setup. The visibility of the veins can be altered by increasing the intensity of the pixels for the pattern to closely match the simulated skin. The same method is used to show the effects of increased physical activity or blood loss.

Virtual hair can be applied by creating curved segments of similar length with slightly lower intensity values then the skin. The position of the hair root starts as fixed on a grid and it is randomly rearranged in the proximity of the grid point to create a more natural appearance.

A simulated image can be observed in figure 4

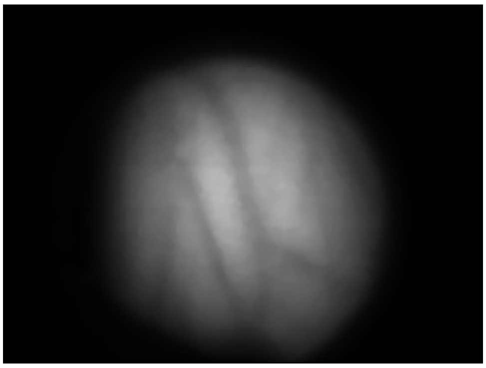

Figure 4 Simulated image of a vein pattern in the back of the hand

The final image can be rotated or scaled and then saved as an entry in the database. A compression and storage model for vein structure information has been developed in [19] and it has been equally useful in recording simulated vein patterns.

IV. Conclusion

Our research has focused on developing a simulation platform for hand vein biometrics, more precisely the vein pattern in the back of the hand. Using previous knowledge from implemented biometric systems, combined with image analysis and processing techniques, realistic vein models have been created and included into a package called VEINSIM. In order to provide a scalable database of generated vein structures for biometric testing, the vein pattern has been visually inserted into a simulated image of a hand with various customizable parameters such as shape, depth of the veins, noises from different sources, variable complexity of the vein model etc. The resulting images are in grayscale with a bit depth of 8 and can be recreated using the same key points and features described in this paper.

While the images were simulated for near infrared illumination, representations of hands acquired passively with far infrared radiation emitted from the body can be created, although there is the need for more in-depth analysis of images from real hands.

The experiments have shown that the generated images are consistent with scanned images of real hands and several algorithms have been tested on the simulated results. Using the algorithm described in [5], the results for 1000 generated images have been similar to what has been obtained from the same number of real hand images.

Future work will focus on a vein pattern simulation platform for finger veins and for veins in the palm.

References

[1] S. Prabhakar, S. Pankanti, A. K. Jain, *“Biometric Recognition : Security and Privacy Concerns”*, IEEE Security & Privacy, March/April 2003 pp 33-42

[2] J. L. Wayman, "*Technical Testing and Evaluation of Biometric Identification Devices*", în Biometrics: Personal Identification în Networked Society. Kluwer Academic, December 1998

[3] *** Vein pattern recognition www.fujitsu.com

[4] Septimiu Crisan, I.G. Târnovan, T.E.Crisan. "*A low cost vein detection device using near infrared radiation",* Proceedings of the IEEE Sensors Applications Symposium, San Diego, 2007.

[5] Septimiu Crisan, I.G. Târnovan, T.E.Crisan, *„Vein pattern recognition. Image enhancement and feature extraction algorithms",* 15th IMEKO TC4 Symposium, Iaşi, Romania, 2007, ISBN 978-973-667-260-6

[6] Septimiu Crişan, T. E. Crisan, C. Curta, „ *Near infrared vein pattern recognition for medical applications. Qualitative aspects and implementations*", Advancements of Medicine and Health Care through Technology, Meditech, Cluj-Napoca, România 2007

[7] Badawi, A. M. "*Hand Vein Biometric Verification Prototype: A Testing Performance and Patterns Similarity".* Proceedings of the 2006 International Conference on Image Processing, Computer Vision, and Pattern Recognition, Las Vegas USA

[8] Nadort, Annemarie, "*The hand vein pattern used as a biometric feature*", Nederlands Forensisch Instituut, May 2007

[9] Diefenderfer, C. T. *"Fingerprint Recognition"* Naval Postgraduate School, Monterey, California, SUA, 2006

[10] Gray, Henry. *Anatomy of the Human Body.* Philadelphia: Lea & Febiger, 1918; Online edition Bartleby.com, May 2000, fig 574 [11] Mansfield A.J., Kelly G., Chandler D. & Kane J. (2001) "*Biometric Product Testing"* Final Report, Issue 1.0, March 2001

[11] Thalheim L., Krissler J. & Ziegler P.-M. (2002) 'Body Check: Biometrics Defeated' c't Magazine, June 3, 2002

[12] *** Finger vein scan technology, www.hitachi.com

[13] Dragomir, N.D., et. al.. - *Măsurarea electrică a mărimilor neelectrice*, Vol 2, Ed.Mediamira Cluj-Napoca, 1998

[14] Farina et al, *Physics in Medicine and Biology*, Vol 44, Jan 1999, pp1 –11

[15] S. Erturk, "*Digital image processing*", University of Kocaeli, 2003

[16] *** The Biometric Consortium "*Introduction to Biometrics", 2002*

[17] Jain A.K., Bolle R. & Pankanti S. "*Biometrics: Personal Identification in Networked Society"* Kluwer Academic Publishers, 1999

[18] A. D. Kim, *"Transport theory for light propagation in biological tissue,"* Optical Society of America Journal A 21, pp. 820–827, May 2004.

[19] Septimiu Crişan *„Researches concerning the development of infrared biometric measurements"* PhD Thesis, Technical University of Cluj-Napoca, Romania, 2008