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SECURED ACCESS SYSTEM BASED ON THE RECOGNITION OF ECG CHARACTERISTICS

BY

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Abstract. The paper presents two approaches for the same idea, a system for personal recognition based on two joint characteristics of the biometric signal: heart rate and growth rate of the slope QR, segment by the electrocardiography (ECG) biosignals. The main difference is about the acquisition method: photoplethysmography (simpler, but allowing some errors) or classic, with electrodes (proven to be more accurate). The software developed in LabVIEW filters, processes and finally applies the wavelet transform on whose basis the authors propose a software algorithm for a simple, fast and accurate method for measuring the heart rate, followed by the determination of the growth rate of the slope QR. We aimed to obtain a reliable balance between accuracy and response time of the system. By correlating these two parameters, we obtained a pattern that has been stored in a database. For a right decision on the person recognition, the system has to compare the acquired pattern with that stored in the data base. The first system was tested on fifteen people and we obtained a 84% success rate. The second system was tested on twenty-one persons, including all the members of the previous volunteer group. The success rate of the second system relative to twenty-one persons was 96.19%, but reported to the fifteen common people, was 97.33%.

Key words: biometric signal; ECG signal; identification system.

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1. Introduction

Automatic and undoubted authentication of a person could be critical in some special frameworks, like financial transactions or highly-secured locations. The concept of identification based on ECG signal is relatively recent. Despite its novelty, this idea is gaining more and more adepts, mainly due to the high level of safety provided. In 2001 (Biel *et al.*, 2001), it was published for the first time an approach on the possibility of using the ECG specificity as biometric signal. Aiming to automatic identity verification and validation, the biometric signal should be unique, measurable and specific (Riera, 2009). ECG signal could be considered as uniquely associated to a person due to the differences in the heart dimensions, shape or position in chest cavity, sex, age (Hoekema *et al.*, 2001). Most of the ECG-based biometric systems are implemented using the paradigm of the signal collection by adequate sensors, while the signal processing and recognition algorithm are performed by a computer (Silva *et al.*, 2012). Many methods have been used for the recognition of a person. An interesting method is the extraction of different temporal characteristics, to be compared with a stored pattern by means of a neural network (Shen *et al.*, 2002). Using the Wavelet Transform, different ECG characteristics were extracted, and used later for the identification of the person (Chan *et al.*, 2008). In another study is presented an application of the discrete wavelet transform that allowed a 100% success rate for person identification (Chiu *et al.*, 2009). Other complementary approaches for person identification were developed by considering the heart rate variability (Irvine *et al.*, 2001). Another proposal considers the segments morphology of the ECG heartbeat (Islam *et al.*, 2012). Wavelet transform was also used to calculate the heart rate in photoplethysmogram (PPG) systems, by using the peak value *R* (Păuleț *et al.*, 2014)

2. Material and Methods

2.1. Person Recognition System Based on Photoplethysmography

Photoplethysmography (PPG) systems allow non-invasive study of important physiological parameters. The method involves the measurement of the organ volume. In other terms, while applying a light on the skin, it is possible to measure the change of light absorption in the blood under the skin. PPG highlights changes in the volume of the finger blood, so acquiring information about the vascular system and any related changes caused by age or disease. These signals can be easily obtained from highly vascularized extremities, such as earlobes, fingers or toes (Jago *et al.*, 1988). The electric diagram of the analog module for signal acquisition by the PPG system is presented in Fig. 1.

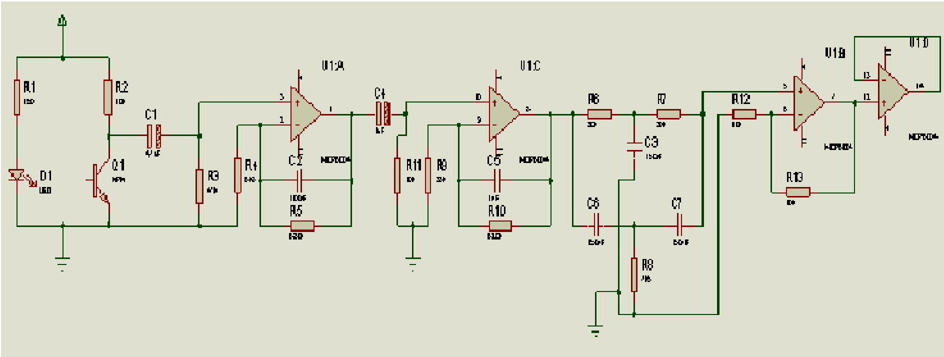

Fig. 1 – The electric diagram of the analogue module.

a) *The filtering hardware*

The signal acquired from each sensor has two voltage components: direct current (DC) voltage and an alternating voltage (AC). The AC component of the signal containing the useful information about the heart rate occurs due to the variation of the blood volume. The variation of the arterial blood volume is proportional to the heartbeat. This AC component of the acquired signal is superimposed to a large DC component which refers to tissues and average of the blood volume. The DC component of the signal must be removed in order to measure the AC waveform with a high noise rejection. Because the AC signal containing information has small amplitude, a high gain is required in order to obtain a signal that could be further processed. The signal acquired from the TCRT1000 sensor is passed through a RC high pass filter, in order to remove the DC component of signal. For the high pass passive filter, the cutoff frequency is set at 0.8 Hz. The signal is then passed through a low pass filter having the cutoff frequency set at 2.5 Hz. In order to reduce the noise captured or produced by the power source connection, we used a quad structure of operational amplifiers on the same chip. This signal is acquired using an NI USB type 6009 acquisition board through an analogue input and data are sent to a computer using the USB port., The ECG signal is acquired and processed using „LabVIEW” and „Biomedical Startup Kit” software.

b) *Filtering and processing software*

The signal will be analyzed using the wavelet transform. Wavelet mother is scaled by a factor "a" and translated/moved by a factor "b", in accordance with eq.

$$\Psi_{a,b}(t) = \sqrt{a} \cdot \Psi\left[\frac{(t-b)}{a}\right]. \qquad (1)$$

Wavelet Transform provides a multi-resolution analysis of a signal. It splits the signal into small windows; every such partition can be studied with a good enough resolution. Most noise is to be found in the signal contained in the windows that analyze high frequency signals. Useful information could be reflected in windows that analyze low frequency signal.

One advantage of using decomposition windows is to minimize the noise generated by artifacts due to the motion. In the wavelet transform, in order to detect the peak value, it is necessary to establish a threshold.

Our option was to use the wavelet transform because it can more easily represent functions that have discontinuities, peaks for signal decomposition and reconstruction of finite, non-periodic and/or non-stationary signals. Wavelet transform is generated by dilating and translating a single basic prototype.

In our study, the wavelet transform was used to detect the R-wave peak and to eliminate noise from the signal taken from PPG system. The authors propose a new method of identifying a person. By using wavelet transform, the peak value of the *R* signal is detected and consequently, are determined the corresponding values for 10% and 90% of the *R* peak value. The segment growth rate will be calculated, between 10% and 90%. Complementary, having detected the peak value *R*, it is calculated the heart rate as the time between two consecutive appearances of peak *R*. The characteristics of the determined two biometric signals are compared with a pattern from the database.

The measurement process lasts for 25 s; during the first five seconds the system performs a comparison between the signals acquired in the first five seconds to see if they have the same value. It is accepted by the software, a 5% difference between these signals. If measured values are quasi-similar (with 5% difference accepted), we proceed to the next step: measurement of the biometrical signal, lasting for 20 s.

The obtained values are averaged and the result is compared with the values in the database. At the same time it is compared the stored peak value of the R-wave to the value measured in the identification process. If this two values of the characteristics of the biometrical signal overlap, the system will identify the person as being in the database.

It is accepted by the software, a 5% difference between the measured value and the one stored in the database.

The recognition algorithm implemented in LabVIEW is presented in Fig. 2.

Fig. 3 graphically presents the statistics of the number of correct identifications and the number of misidentification. It wasn't possible to establish a link between identification errors appeared with age or sex of the identified subject.

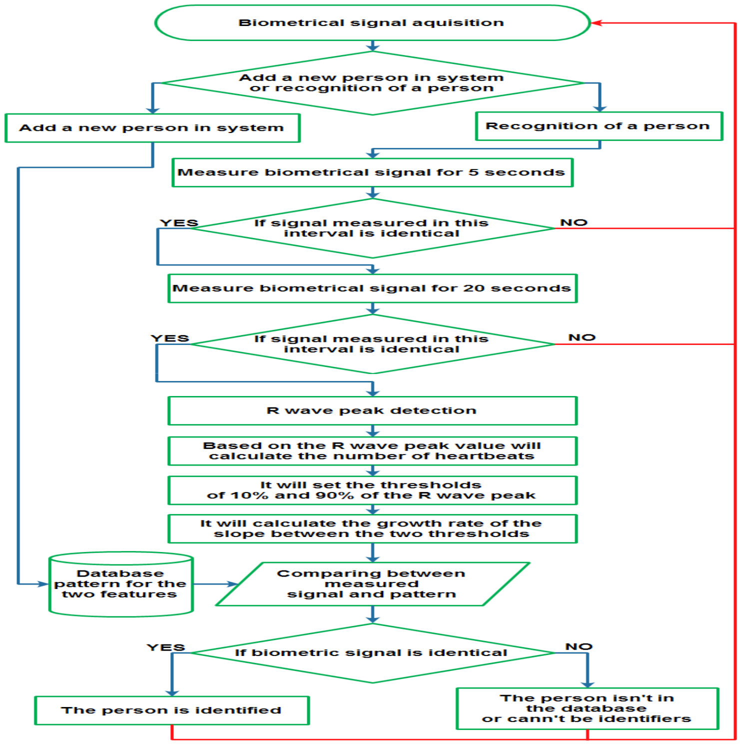

Fig. 2 – Recognition algorithm implemented in LabVIEW.

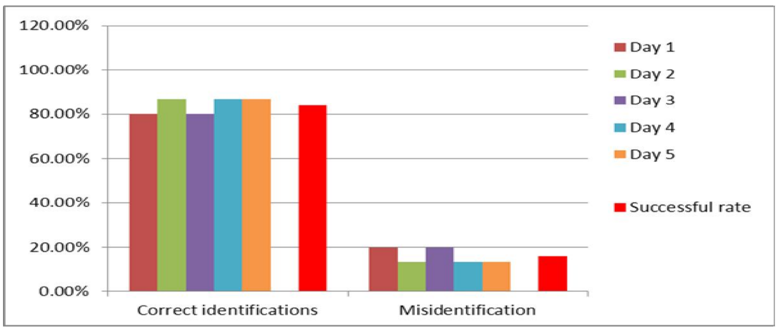

Fig. 3 – Statistics of performed identifications and success rate (Photoplethysmography).

2.2. The Recognition System of a Person using Electrodes

Because the system based on PPG does not accurately track the ECG waveform, it was developed a signal acquisition system based on electrodes and gel (BIOPAC - EL500 SERIES - DISPOSABLE ELECTRODES - Ag/AgCl).

After acquisition, the ECG signal is software processed. The wavelet transform is a mathematical tool for decomposing a signal into a set of orthogonal waveforms localized both in time and frequency domains.

The wavelet transform is suited for following ECG analyses: feature extraction, feature detection, noise reduction and data compression. The practically applied wavelet transform belongs to Daubechies family. This wavelet family shows similarity with QRS complexes and energy spectrum, being concentrated around low frequencies. The ECG feature extractor firstly detects all the beats (*R* waves) of the signal. The pre-processed ECG signal is used to detect the position of *R* waves. After testing, there were chosen Orthogonal Daubechies coefficients (DB6 and level 7) by discrete wavelet transform. After having detected *R* waves, it is possible to calculate the heart rate, as the time between two consecutive appearances of *R* waves. After successfully detecting the *R* peaks, we can determine the value of the point Q (minimum point) and then the peak value of the signal (wave *R*), followed by setting the OX axis, the reference. We calculate the thresholds of 10% and 90% from the waveform amplitude, allowing us the determination of the growth rate signal. In other words, we measure the time elapsed between the occurrence of 10% and 90% values and calculate the growth rate. With these two signal characteristics, we can apply the algorithm described in Fig. 2.

Fig. 4 graphically presents the statistics of the number of correct identifications and the number of misidentification. As we can see, the achieved success rate by the system with electrodes is higher than that obtained with the PPG system.

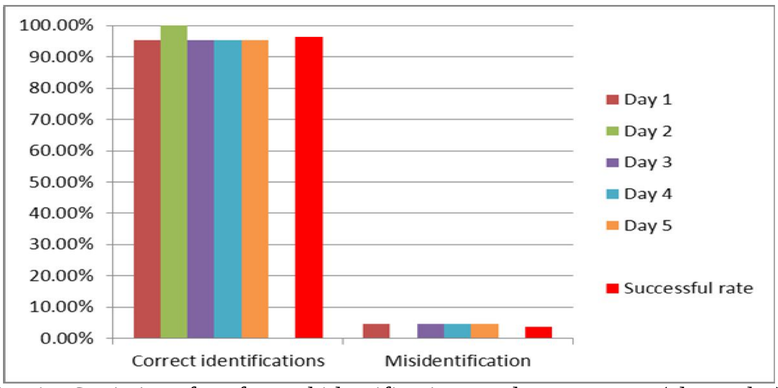

Fig. 4 – Statistics of performed identifications and success rate (electrodes).

3. Results and Discussion

Measurements with both systems were made in the same conditions, close to the real ones.

The system with PPG was tested on fifteen people with ages between 25 and 54 years. The success rate was only 84%. Problems with correct signal acquisition occur when dealing with people having thick skin (jobs requiring manual work). Anyway, after testing we have found that if the signal acquisition time increases to minimum 30 s, the success rate is better.

The recognition system of a person having signal acquisition via electrodes was tested on 21 people, aged between 19 and 56. The success rate was 96.19%. The error occurred in 3.81% of the identifications for persons having more than 54 years (they were disturbed by the high environmental temperature). By increasing the signal acquisition time up to 30 s and the value of the wavelet transform to 8, we obtained a better success rate (+0.15%), paying the price of a longer process.

Comparing the identification results delivered by the two systems (obtained while testing the same group of fifteen persons), we can conclude that the success rate obtained with the electrode-based system, (97.33%) is significantly better than the one obtained with the PPG system.

4. Conclusions

We have developed a software algorithm for person recognition based on biometric signals. It was implemented and verified on two different systems: a system based on the PPG signal and the other using electrodes for acquiring the ECG signal.

Two types of wavelet transform were used. Person recognition is performed by considering two distinguished characteristics of the biometric signal: heart rate and growth rate of the slope (between 10% and 90% of *R* wave).

The usage of QR growth rate of the slope in person identification offers the advantage of high stability, unlike the *R*-wave amplitude which may change, (due to a heart attack, for instance). Anyway, depending on the location where the system is effectively used (at ground floor or at upper floors, involving stairs to be climbed), the stored pattern should be acquired after similar efforts performed in the check-in procedure.

During the performed operations we could observe that the wave amplitude does not appreciably change with ageing, an argument for being used in biometric recognition.

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REFERENCES

Biel L., Pettersson O., Philipson L., Wide P., *ECG Analysis: a New Approach in Human Identification*. Instrumentation and Measurement, IEEE Trans., **50**, 808-812 (2001).

Chan D.C.A., Hamdy M.M., Badre A., Badee V., *Wavelet Distance Measure for Person Identification Using Electrocardiograms*. IEEE Trans. on Instrumentation and Measurement, **57**, 2, (2008).

Chiu C.-C., Chuang C.-M., Hsu C.-y., *Discrete Wavelet Transform Applied on Personal Identity Verification with ECG Signal*. Internat. J. of Wavelets, Multiresolution and Information Proc., **7**, *3*, 341-355 (2009).

Hoekema R., Uijen G.J.H., vanOosterom A., *Geometrical Aspects of the Inter Individual Variability of Multi-Lead ECG Recordings*. IEEE Trans. on Biomedical Engng., **48**, *5*, 551-559 (2001).

Irvine J.M., Wiederhold B.K., Gavshon L.W., Israel S., McGehee S.B., Meyer R., Wiederhold M.D., *Heart Rate Variability: A New Biometric for Human Identification*. Proc. Int. Conf. Artif. Intell., 1106-1111 (2001).

Islam M.S., Alajlan N., Bazi Y., Hichri S.H., *HBS: A Novel Biometric Feature Based on Heartbeat Morphology*. IEEE Trans. on Information Technol. in Biomedicine, **16**, *3*, 445-453 (2012).

Jago J.R., Murray A., *Repeatability of Peripheral Pulse Measurements on Ears, Fingers and Toes Using Photoelectric Plethysmography*. Clin. Phys. Physiol. Meas., *9* (1988).

Păuleț M.V., Neacşu O. M., Sălceanu A., *Wireless Monitoring System of the Heart Rate*. Internat. Conf. on Electrical a. Power Engng., 581-584, 2014, available: DOI: 10.1109/ICEPE.2014.6969976

Riera A., Soria-Frisch A., Caparrini M., Cester I., Ruffini G., *Multimodal Physiological Biometrics Authentication.* In Biometrics: Theory, Methods, and Applications, Starlab Barcelona S.L., Barcelona, Universitat Pompeu Fabra, Barcelona, 2009.

Shen T.W., Tompkins W.J., Hu Y.H., *One-Lead ECG for Identity Verification.* 2nd Joint Conf. of the IEEE Engng. in Medicine and Biology Soc. a. Biomed. Engng. Soc., Houston, USA, 23-26, 2002.

Silva A. L., Fred A., *ECG-Based Biometrics: A Real Time Classification Approach.* In Proc. of the 22nd IEEE Internat. Workshop on Machine Learning for Signal Processing, 2012.

SISTEM DE ACCES SECURIZAT BAZAT PE RECUNOAŞTEREA CARACTERISTICILOR SEMNALULUI ECG

(Rezumat)

Sunt prezentate două sisteme de recunoaştere a unei persoane pe baza semnalului biometric ECG, pentru garantarea unui acces securizat. Din caracteristicile semnalului ECG s-au analizat: ritmul cardiac şi viteza de creştere a pantei QR a semnalului ECG. Articolul prezintă două sisteme de recunoaştere a unei persoane pe baza semnalului biometric ECG. Dintre caracteristicile semnalului ECG, autorii au analizat ritmul cardiac şi viteza de creştere a pantei QR semnalului. Principala diferenţă dintre cele două sisteme este metoda de achiziţie a semnalului: fotopletismografie (simplu, dar cu unele erori) sau clasic, cu electrozi (care s-a dovedit a fi mai precis).