THE IDENTIFICATION OF ARTIFACTS IN ECG SIGNAL ACQUISITION PROCESS

Ana-Maria Paraschiv
SC Wing. Computer SRL, Bucharest
E-mail: ana.paraschiv@wing.ro

Sabina Potlog
University POLITEHNICA of Bucharest
E-mail: sabina_potlog@yahoo.com

Costin Cepişcă
University POLITEHNICA of Bucharest
E-mail: costin.cepisca@upb.ro

Abstract. ***The present work reports on remote acquisition system measurements of ECG bio-signals. The aim is to define the artifact types appearing in data acquisition process, to classify them and to find rejection methods. The measurements were carried out on various patients, in different situations, for each case the conclusions of data analysis being presented.***

Keywords: ECG, artifact, remote monitoring, wavelet

1. INTRODUCTION (TIMES NEW ROMAN BOLD 10 ALL CAPS)

The European Commission has designated 2012 as the European Year for Active Ageing and Solidarity between Generations (EY 2012). One of the aims for EY 2012 is "the independent living", which promotes any activities or device development leading to a longer independent life [1]. In these circumstances, it has to be acknowledged that the health systems need to be addressed to older peoples and to be adequate to their necessities.

Adopting the IT&C solutions in the medical field yields benefits like electronic information storage, while improving the treatment and reducing the medical errors is a priority of using technology in this field. Statistics shows that, in Romania, the incidence of cardiovascular diseases is high; the prevention system is at reduced development and the hospitalization time is continuously raising leading to the hospital supervising necessity of cardiovascular risk patients. [2], [3].

The applications for the medical field utilize the possibilities of communication technology. Fiber optics usage and integrated mobile transmission technology, including 3G and 4G, offer the possibility for on-line transmission of a high quantity of acquired data.

Monitoring the vital parameters by means of information technology became an influential factor in disease prevention and population heath care. With new remote measuring systems, an increasing number of vital parameters became available for population not only in hospitals or other exclusivist facilities.

Telemedicine refers to the remote acquisition of various medical data throughout information and communication technology (IT&C) means. There are various ways for data and medical information transmission: images, sound, text and data packs.

Remote vital parameters monitoring reduce the time to access the patient data file for rapid evaluation of his affections. Lately, the remote monitoring is itself more efficient in medical affections or accident prevention.

Presently, wearable systems for remote monitoring of cardiovascular risk patients are a central subject. The emphasis is on new equipment, sensors, various measuring systems or using new types of materials [4] - [9].

Since 1997 have started major research on remote monitoring systems design. Such devices, unlike usual data acquisition systems, give a real time feedback to the subject as an imminent medical emergency warning or exercise monitoring help.

An example of transmission system is the one developed by Vitaphone GmbH from Germany. Their product, Tele-ECG-Loop-Recorder, have a three channel ECG signal recording. The software automatically detects pathological anomalies (supra-ventricular and ventricular tachycardia, bradycardia, atria fibrillation) and transmits via Bluetooth a message to a mobile phone.

In 2010, at Chiao-Tung National University, Brain research department, a similar device is presented to measure ECG signals, transmit them via Bluetooth to a mobile terminal and then process them using an expert system.

This paper presents a new monitoring system developed for ECG signal acquisition and processing signal methods for defining the artifact types appearing during data acquisition process categorize the artifacts and establish methods for selection.

2. REMOTE MONITORING SYSTEM E-RISC FOR ECG SIGNALS

Figure 1 is a block diagram of remote ECG monitoring system E-RISC, designed, built and tested by the authors.

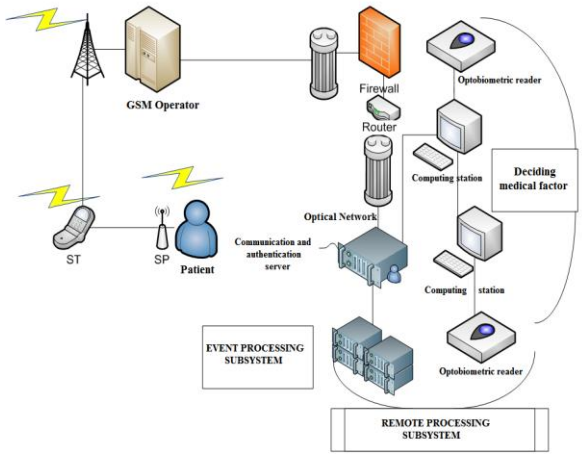

Figure 1. System E-RISC block diagram

This block diagram includes:

a) Wearable subsystem (SP) – part the subject wears, composed of all the modules on the elastic belt;

b) Communication subsystem (ST) – the relay which transfer information from SP to the public network of hospital;

c) Remote analysis subsystem (SPD) – summarizes all the components for remote analysis of acquired and transmitted signal using their management software.

The sensor's system for ECG signal acquisition based on Zephyr BioHarness belt –figure 2 – is the wearable part of the proposed system. Using an elastic belt will significantly reduce the signal noise produced by the body movement.

Figure 2. Zephyr monitoring belt

The technical characteristics of the belt:

- Bluetooth information transmission;
- Cardiac rhythm measurement: 0-240 BPM (beats per minute);
- Respiratory rhythm measurement: 0-120RPM (respirations per minute);
- Position sensor: ±180° (vertical or horizontal position);
- Activity: repose, walking, running;
- 3 axes accelerometer (16g);
- Status indicator: red/orange/green;
- ECG transmission and recording 250Hz;
- USB connectivity for data download and recharging;
- Up to 500 hours of various recording;
- Internal algorithms: estimated temperature, jumping test, slide detection, cardiac rhythm fluctuation, etc.

The conductive sponge substrate between the support band and the e-textile layer reduce the artifacts, due to better electrical contact, independent of the dynamic skin deformation.

Figure 3 shows an example of data transmitted to a mobile phone. The application than runs on a mobile phone shows the RR series, ECG signal, breathing rate, heart rate and attitude (position of the subject).

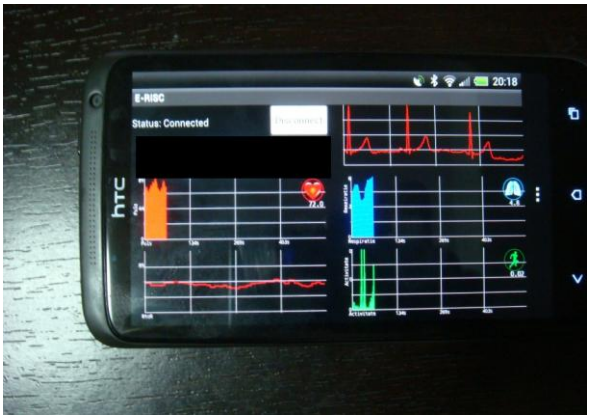

Figure 3. ECG recording and transmission system

3. THE ARTIFACTS AND THE DATA ACQUISITION AND PROCESSING OF ECG SIGNALS

Similar to any other measurement system, the system proposed here for bio-signal acquisition is affected by various permanent factors. These factors can be described as follows:

a) Stimuli artifacts. Are generated by electrical, mechanical or chemical stimuli interfering with the useful signal;

b) Biological artifacts. Are generated by the coexistence of various biological activities with the useful signal;

c) Electrical perturbation. An electromagnetic field with around 50 Hz is generated in any room with an electrical device and additionally acoustic or radiofrequency fields could be generated by command and automation devices.

The device chosen for data acquisition from a subject has auxiliary components for automate rejection of some artefact types such as those caused by electrical perturbations. Presently, surrounding electric and magnetic fields have intensified due to the abundance of electronic devices in any home and as consequence electromagnetic compatibility standards were adopted. The belt of Zephyr BioHarness, used in these experiments guarantee the automated rejection of electrical perturbations artifacts.

Although, the data acquisition belt has a strong fastening system sometimes due to sudden movement of the subject the contact become imperfect for short periods of time leading to artifacts.

The complex data acquisition device can correlate the ECG data with respiration and movement data. This particularity is due to its sensors for thoracic deformation (during respiration) and movement measurement.

The selection of artifacts and the way that they are produced differ for each type described earlier.
The artifacts resulted from an imperfect contact between the belt and skin can be also caused by an extensive respiration which may lead to a gap between the belt and the body or other body movements which may change the position of the equipment from the correct one.
The mechanical artifacts can be categorized function of the type of motion as follows:

- Sudden movement artifacts leading to a change of the belt position;
- Slow movement artifacts (characteristic to old people) leading to imperfect contact.

In the first case, the artifacts can be avoided applying filters to the belt signal and utilize algorithms that correlate the data from the 3 axes accelerometers with the ECG signal.
The second artifact type, caused by slow movements and characteristic to old people, cannot be eliminated from the useful signal by a simple correlation between accelerometer signal and ECG signal, RR series respectively. Thought very sensitive, accelerometers cannot correctly record the slow movements because of their low characteristic values hardly distinguishable from the noise signal. Changes can be distinguished, associated to a sigh or to an accentuated respiration which leads to a higher thoracic deformation.
Visualizing the artifacts caused by the imperfect contact resulted from daily activities, characteristic to a normal activity, can be made easily following a Wavelet type transformation – time-frequency.
The first step for obtaining the Wavelet transformation is the RR series extraction from ECG signal [10]. The RR series is obtained by classical methods measuring the distance between two R peaks or using the belt specific software. In this work, the study used the RR data acquisition method directly analyzed by the belt.
An overview of the causes for band frequency formation leads to the following observations:

a) A low frequency component (LF), generally around 0.1 Hz (0.4 – 0.15 Hz), which power variations were associated to the sympathetic activity as a result of clinical and pharmaceutical investigations;
b) A high frequency component (HF) synchronized to the respiratory rhythm (ranging between 0.15 and 0.4Hz) considered as an expression of the respiratory noise mediated by the vagal activity;
c) The relevant section of the power spectra is concentrated in a very low frequency band (VLF), down to 0.04 Hz, which function is to slow the adjustment mechanisms such as humoral and thermo- regulatory factors. For a correct evaluation of these rhythms, the analysis should be made on longer periods (at least for several hours) [11], [12].

The following chart shows a Wavelet analysis of measurement in the case of a subject with normal respiration without sudden moves that might displace the sensors.

Figure 4 shows the correct respiration Wavelet result, with a clear difference between the three bands, LF, HF and VHF.
In the case of slowly moving subject, the measurements show that low to high frequency band magnitude ratio is decreasing.

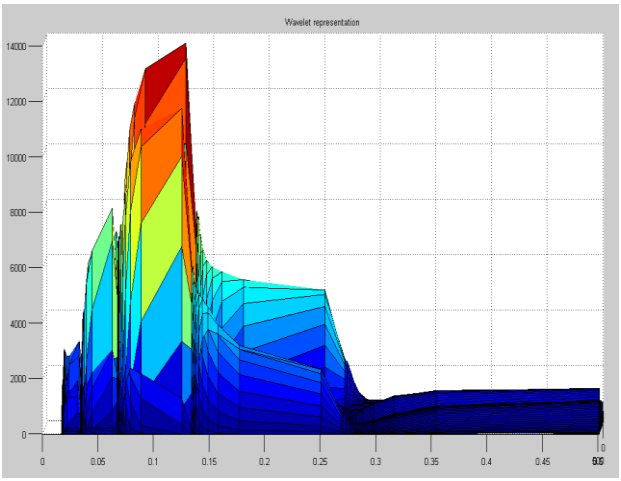

Figure 4. Correct respiration Wavelet (with a clear difference between the 3 bands)

Figure 5 shows the result of Wavelet processing when the patient has an abnormal breathing due to irregular movements.

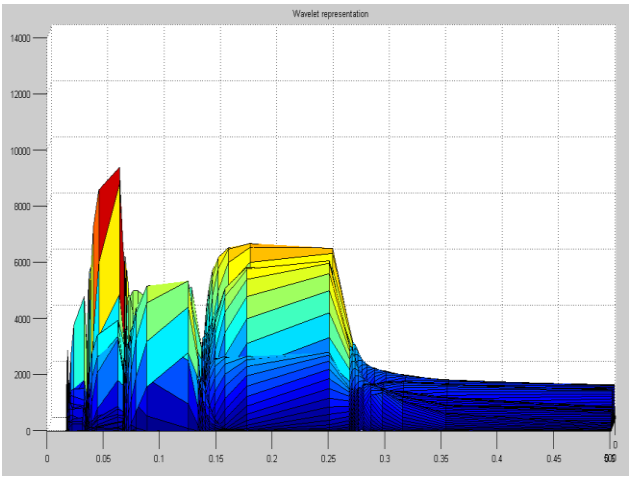

Figure 5. Incorrect respiration Wavelet

The artifacts can be identified at subjects with sudden movements. Applying the Wavelet transformation, the artifacts can be emphasized in the form of pulses of extremely high magnitude in the extremely low frequency band. This band is characteristic to the thermo- regulatory processes were this artifact should not be present.
Figure 6 shows the results of Wavelet processing for artifacts from sudden movement of the subject.

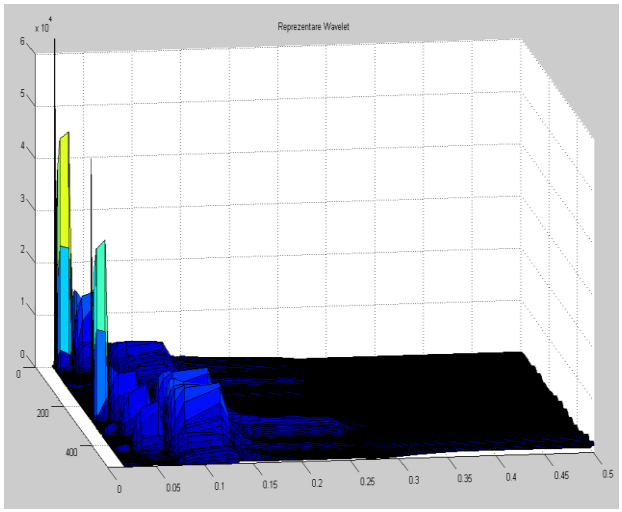

Figure 6. Wavelet with artifacts resulted from sudden movement

In figure 7 are reveled the artifacts from slow movement, within Wavelet.

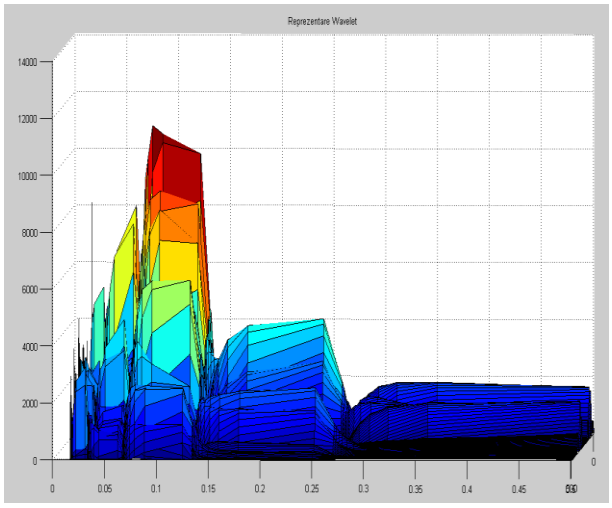

Fig. 7. Slow movement artifacts

From the above charts can be observed that the artifacts from the sudden movement are of much higher magnitude compared to those generated by the slow movement.

4. CONCLUSIONS

Measurements carried out with a Zephyr BioHarness belt and analyzed using a Wavelet transform revealed the types of artifacts appearing in the ECG bio-signal acquisition process.
Removing artifacts, such as a sudden movement of the patient, sensor displacement, electromagnetic interference, represents a critical point in ECG signal measurement and analysis.

The artifacts resulting from sudden movements can be eliminated applying filters that consider the three-dimensional movement of the accelerometer.

The artifact originating in a slow movement cannot be eliminated using numerical methods because the low accelerometer signal amplitude cannot be distinguished from the background noise.
The correct identification and selection of artifacts in these measurements could diminish the number of false alarms registered in emergency medicine, false alarms that are encountered all along the monitoring period of the patient.

5. ACKNOWLEDGEMENTS

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/134398 and by Grant no.30_PCCA_2012 of the Romanian National Authority for Scientific Research CNDI– UEFISCDI.

6. REFERENCES

[1] Raport. Anul European al îmbătrânirii active și al solidarității între generații 2012. www.europa.eu
[2] Negoescu R, Instrumentația electronică biomedicală, Editura Tehnica, București, 1985
[3] Nagy I., Curs de electronică medicală, Editura Eurobit, Timișoara, 1999
[4] Scheffler, M, E. Hirt (2005), Wearable devices for telemedicine applications, J. Telemed Telecare11 Suppl 1: 11-14
[5] Thulasi Bai, V., S. K. Srivatsa (2007). Design of wearable cardiac telemedicine system, Int. J.Electron Healthc 3(3): 303-316.
[6] Yazicioglu, R. F., T. Torfs, et al. (2009). Ultra-low-power wearable biopotential sensor nodes, Conf Proc IEEE Eng Med Biol Soc.
[7] Leif Sornmo, Pablo Laguna, Electrocardiogram (ECG) Signal Processing. Wiley Encyclopedia of Biomedical Engineering,2006 John Wiley & Sons
[8] Rincón F., Recas J., Khaled N., Atienza D., Development and Evaluation of Multilead Wavelet-Based ECG Delineation Algorithms for Embedded Wireless Sensor Nodes, IEEE Trans.Technol Biomed. 2011 Nov.
[9] Augustyniak P., Wearable wireless heart rate monitor for continuous long-term variability studies, Electrocardiol 2011 Mar-Apr;44(2):195-200
[10] Banica, C., Biosemnale – prelucrari numerice, Editura Electra, Bucuresti, 2007
[11] Deepak Vala, T. Pawar, "A Survey on Ambulatory ECG and Identification of Motion Artifact" International Journal of Engineering Research and Development, Volume 1,Issue 7 ,(June 2012)
[12] Geeta Kaushik, H.P.Sinha "Biorthogonal wavelet transforms for ECG parameters estimation", International Journal of Advanced Research in Computer Science and Software Engineering, Volume 2, Issue 9, September 2012