Mobile Platform Electrocardiogram Wavelet Analysis with Sailfish OS Operating System

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***Abstract*—The article describes the results obtained in the development of ECG wavelet analysis system on a mobile platform with Sailfish OS operating system. The application designed for the platform enables a continuous ECG wavelet transform and displays graphs of the original signal and the wavelet-spectrogram. Further development of the project involves increasing the resolution of the wavelet-spectrograms which should ensure greater accuracy of the analysis and the possibility of automation.**

I. INTRODUCTION

Mobile human health monitoring systems are becoming more popular around the world. Electrocardiogram (ECG), as a signal that monitors the human heart function, may be regarded as the most interesting one for the analysis of such systems. Of particular interest is the implementation of the mobile electrocardiographs on the basis of smartphone or tablet. The information from the sensors may be transmitted to the mobile device, where the processing of the electrocardiogram (ECG) is performed to detect information features in the signal, set clinical conclusion and display ECG. If necessary, the signal can be transmitted to a remote monitoring center, where a more accurate analysis can be performed by a doctor. ECG processing on the mobile device requires addressing a number of challenges, but if they are solved, it can significantly extend the functionality and increase the attractiveness of the application. In this case, the mobile electrocardiograph is able to perform continuous monitoring of the state of the cardiovascular system and in case of danger issue an alarm. This signal can be reproduced as an audio signal, backlight, or message transmitted in the control center indicating the positional data.

Sailfish OS operating system is one of the well-known operating systems. Comparing it with other operating systems such as Android and iOS, one can highlight a number of its main advantages:

- Sailfish OS is an open mobile system, which means that any developer not only can create applications, but also change the system itself. Android follows the same ideology, but does not provide such wide opportunities. iOS is a closed system, in which each application is separately moderated, changes to the system are prohibited.
- SailfishSDK, based on Qt makes it possible to develop programming languages such as C ++ and Python. Compared with the development on Android, where Java is more commonly used, it has minor differences. While iOS requires knowledge of Objective-C and Swift.
- Original simple interface is designed to manage "swipe" (swipe), which makes the interaction with applications user-friendly and understandable.
- Smartphone operation emulation during the development process. It allows you to create applications and test them without the use of a real smartphone or tablet. Android also supports emulation through a virtual machine.

All these advantages have influenced the choice of the operating system as the basis for the implementation of the project described in the paper.

This paper describes the initial stages of this project. It deals only with the mathematical apparatus which can be used, the simulation results are in MATLAB and test implementation is performed on the Sailfish OS emulator.

II. ELECTROCARDIOGRAM

Electrocardiogram (ECG) is a signal that can be registered from the body surface and represents an electrical potential accompanying contraction of the heart. Electrocardiography is the main method for diagnosing heart problems associated with the violation of its rhythm [1].

For ECG analysis, it is required to take into account the time distance between their individual components. The basic form of a normal electrocardiogram includes five deflections: P, Q, R, S, T.

Automation of ECG analysis process requires a precise mathematical apparatus.

III. THE MATHEMATICAL APPARATUS

In the paper, wavelet mathematical apparatus was selected to automate the process of ECG analysis. Wavelets are a generic name for special functions with zero integral value, localized along the time axis, able to shift on it and scale [2], [3], [4].

Continuous wavelet transform (CWT) is widespread when analyzing signals. Its formula is as follows [5], [6]:

$$W(a,b) = \frac{1}{|a|^{1/2}} \int_{-\infty}^{\infty} f(t)\psi\left(\frac{t-b}{a}\right)dt, \tag{1}$$

where $\psi(t)$ – wavelet, a – scale value, b – time shift.

In case of the discrete signals analysis, the integral is replaced by summation sign in the formula of continuous wavelet transform. The formula takes the following form:

$$W(a,b) = \frac{1}{n(a,b)} \sum_{k=0}^{N-1} f(t_k)\psi\left(\frac{t_k-b}{a}\right), t_k = k\Delta t. \tag{2}$$

When performing a continuous wavelet transform, a variety of wavelets can be used.

When choosing a wavelet for the continuous wavelet transform, one should be guided by the following principles:

1) A wavelet must be suitable for analysis of the signal type. For example, for smooth signals the Haar wavelet is not advisable to choose, as it has the shape of a step function.
2) In some cases, it is important to choose a wavelet having a formalized representation.
3) Depending on the desired accuracy of the results, in addition to traditional wavelet families, synthesized wavelets can be used.

In this paper, wavelet Mexican hat (Fig. 1) was selected for the ECG analysis.

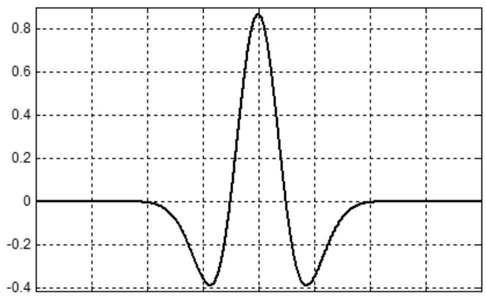

Fig. 1. Mexican Hat Wavelet

Studies have shown that this wavelet is well suited for the analysis of similar types of signals [7]. It has formalized representation which is a rare thing for traditional wavelet families. Since the study is at an early stage, a wavelet having a low complexity compared with synthesized wavelets was chosen. It is assumed that this may have a negative effect on the accuracy of the analysis of individual ECG fragments. But the choice of this wavelet at this stage is determined by the need to evaluate of the possibility of the implementation of such algorithms on a given operating system. Further studies suggest the transition to synthesized wavelets [8], [9].

The result of the continuous wavelet transform is a wavelet-spectrogram. It allows displaying the slightest changes in the signal.

Fig. 2 shows an example of the ECG analysis using Mexican hat wavelet. The signal fragment was uploaded from the biomedical signals database. Its sampling rate is 720 Hz. In constructing graphs MATLAB package was used.

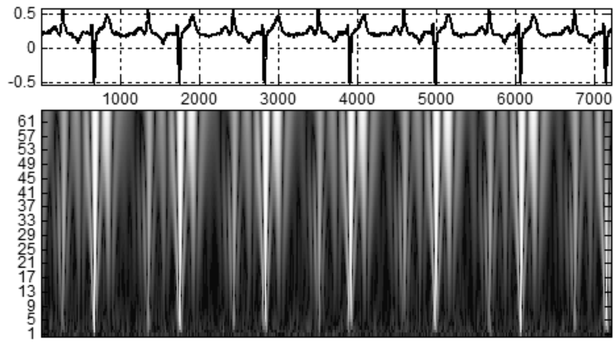

Fig. 2. Part of an electrocardiogram and wavelet spectrogram obtained using wavelet Mexican hat

IV. Wavelet analysis implementation

To implement mobile electrocardiograph, it is necessary to make an ECG recording from electrodes installed on a person's body. The mechanism of electrodes, the principle of their connection to the phone or tablet is not considered in this paper. Further, the ECG analysis is performed on a mobile device or it is transferred to a remote control center (if necessary). ECG analysis on a mobile device can be made according to the following algorithm:

1) *First step:* Receiving signal samples on a mobile device input.
2) *Second step:* Selecting fragments for analysis.
3) *Third step:* The continuous wavelet transform of each fragment.
4) *Fourth step:* Analysis of factors in order to identify the information signs.

The second and third phases have been implemented at this stage of project development. We used the ECG fragments uploaded from the biomedical signals bank. ECG registration from the sensors has not been performed.

At this stage of project development, the second and third stages were implemented.

The following software was used to create the application:

- IDE SailfishSDK, based on the Qt Creator.
- VirtualBox virtual machine to emulate the Sailfish OS.

We used programming languages:

- QML (Qt Meta-Object Language) to create the application interface.
- Python 3.5.2 for the implementation of continuous wavelet transform and basic computing. Third-party

NumPy library (for database arrays), SciPy (NVP), Matplotlib (the output data in the graphs).

The original signal and the obtained wavelet spectrogram are displayed as an image on the screen. This is done by pressing «Show / Hide image» button. Fig. 3 shows a view of the application window in the emulator.

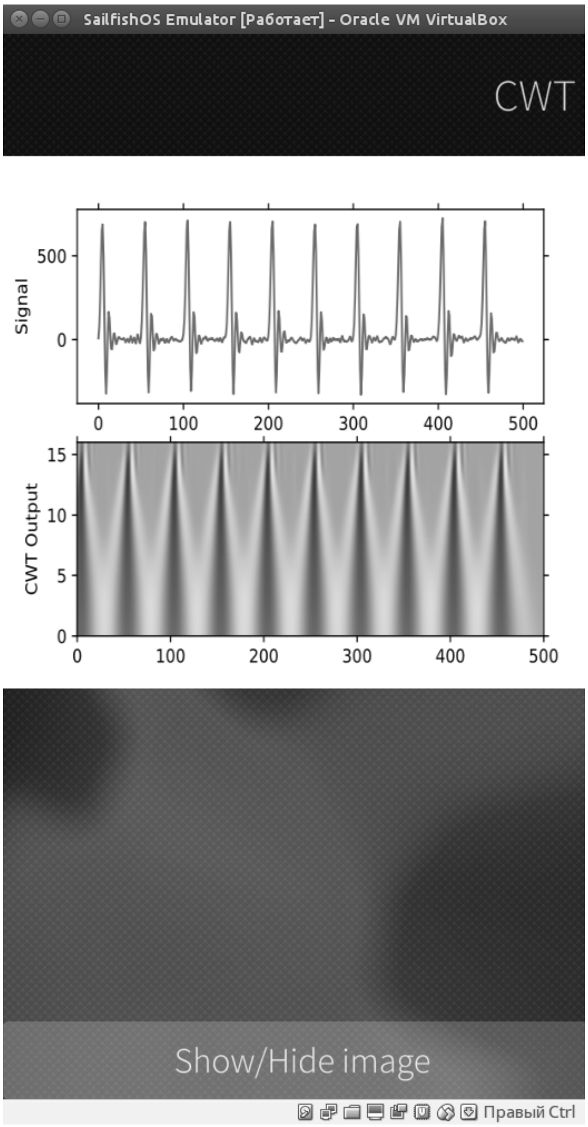

Fig. 3. Display of application window in the emulator

Analyzing this figure, we can make a conclusion about the poor resolution of the wavelet-spectrograms, and the presence of the wavelet spectrogram offset in relation to the signal graph.

The second problem can be solved by shifting and scaling wavelet-spectrogram. However, at this stage, the problem of poor resolution wavelet-spectrogram remains unresolved.

V. Conclusion

At this stage of the project implementation the following results have been received. An application allowing you to download and execute a continuous wavelet transform of ECG has been developed. The app allows you to make all the necessary calculations and construct a graph of the analyzed signal and wavelet-spectrograms.

At this stage, the question of obtaining the necessary resolution of wavelet-spectrograms, which would allow automating the process of ECG analysis, remains unresolved. The resulting accuracy only allows us to detect the presence of the QRS complex and calculate the number of heart beats per minute. The problem of poor resolution can be solved by reducing the scale and shift.

Acknowledgement

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