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Digital Signal Analysis for Abnormal Electrocardiogram (ECG) Signal Research and Development of Open Source Abnormal ECG Signal Generator

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Summary
Digital signal processing for ECG is needed for the development of ECG signal generators, mobile diagnostic devices and diagnostics of heart diseases in general. Most of regular signal processing methods have to be adjusted to fit ECG signal processing especially when the ECG signal is abnormal. During this research, filtering methods were applied to raw digital ECG data, new normalization method was developed and signal decomposition methods (Fourier transforms, empirical mode decomposition and wavelet transforms) were applied to samples of arrythmic ECG signals and decomposition results for arrhythmic and non-arrhythmic ECG signals of arrythmia patients were compared.

Introduction
For digital signal research it is important to choose suitable signal processing methods, for example, filtering and normalization, which help to select relevant signal details from the unneeded noise. Signal processing methods and signal generators can be used in the development of mobile diagnostic devices, which may gain popularity in this smart-phone era. This in turn will bring more awareness to heart diseases [1] and health of human population.

Methods
Raw ECG signals were acquired using BioRadio wireless data acquisition system by Cleveland Medical Devices Inc. Samples of digital arrhythmia ECG signals were selected from the online physiological signal database PhysioNet.org and exported using PhysioBank ATM. [2] The signals were further processed in MatLAB program using Filter and Wavelet toolboxes, built in functions, functions available online [3] and ones developed by the author.

Results
In Fig. 1, the results of the application of the series of filters are shown, used to decrease unwanted high frequency and 50 Hz noise. The processed signal is smooth; however, its profile is distorted due to the application of wavelet filter. In Fig. 2, the comparison of patients signal from the database and signal produced by the generator is performed, showing high

resemblance. However unlike the original, the generated signal has less variability in the amplitude or base wander and has no random noise.

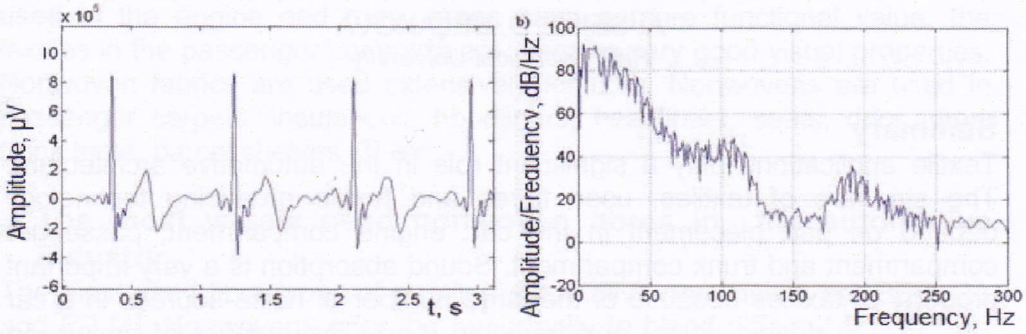

Fig.1. ECG signal a) and its periodogram b) after application of comb, low-pass filters and wavelet filter

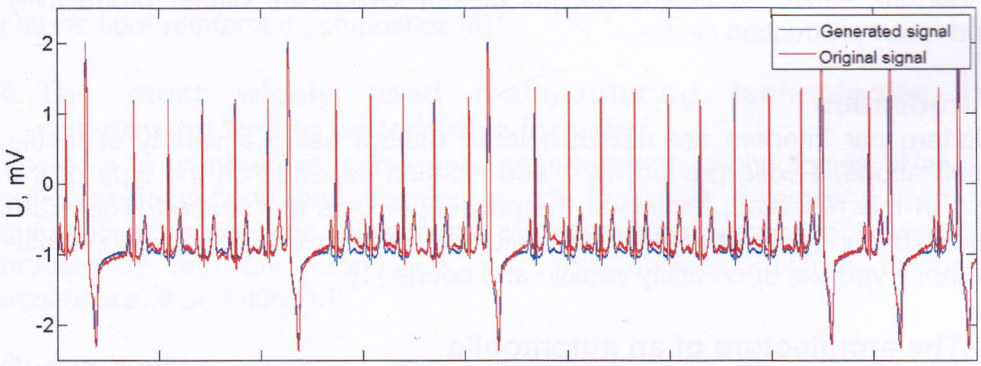

Fig.2. Comparison of generated and original abnormal ECG signals.

Conclusion

It is possible to filter out most of high frequency noise in ECG using various filters. However, high noise reduction leads to lower quality of signal details. New method of signal normalization for discrete ECG signals was developed and verified. Various decomposition methods were applied. Algorithm for the development of open source abnormal ECG signal generator was introduced and successfully applied to make another 3 different arrhythmic ECG signal generators based on the generator of the signal used in most of digital signal processing in this research.

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