ECG player – software and data for your own, easy artificial patient

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Introduction

On the market there are available simulators of ECG signals [1], which are used to control the quality and proper functioning of electrocardiographs. These artificial patients enable to perform such tests without need of participation of a living person, to avoid potential risk. Nevertheless, they produce synthetic signal, which is deformed and does not reflect the actual morphology of the ECG, thus are not sufficient for testing of more advanced functions of modern ECG equipment. Having standard ECG generator is associated with the cost about tens to hundreds of dollars. Collecting database of ECG signals is not the simplest and easily viable task, it often last too long. That makes having such device can be highly useful and could save not only money but also time.

Data

Our goal was to create an artificial patient which produces signals based on real ECG. To do this we needed a database containing these signals and the one that we used was a free, widely available MIT-BIH Arrhythmia Database [2] downloaded from PhysioNet website. It was create in a collaboration of Massachussets Institute of Technology and Boston's Beth Israel Hospital and includes 48 half-hour, two-channel ECG recordings of 360 Hz sampling with the 11-bit resolution. These recordings was made by using Holter monitoring and were obtained from forty-seven patients examined by MIT-BIH Arrhythmia Laboratory between 1975 and 1979 and were divided into two groups, first one represents variety of typical waveforms and artifacts of arrhythmia, another contains rare, less common but clinically significant arrhythmias. The format of downloaded files was not compatible with Matlab, thus they were converted into mat files by using WFDB package from the PhysioNet website.

Method

We prepared an alternative artificial patient based on the simplest possible assumption, which was using an easily accessible and cheap device (in our case it was a portable mp3 audio player).

Recordings from MIT-BIH Arrhythmia Database were recorded at 11-bit resolution, which means that an analogue to digital converter (ADC) was used. Then the received signals (already in digital form) have been exported to files with the mat extension. In order to create the ECG signal generator based on actual ECG recordings we needed a way to restore them as an analog signal, so that later it could be measured by using a recording device. For this purpose, there was a need to use a digital-to-analog converter DAC, working inversely to ADC which is used for measuring the ECG signal as an embedded component of the electrocardiograph.

We have noticed that DACs used in standard audio players fit our needs and produce signals of highly sufficient quality. According to that in order to create the ECG signal generator we used an audio player with built-in DAC. This allowed us to generate ECG signals as sound files and then play them back using the player. The signal coming from the sound file with the ECG signal is stored as digital data in the wave format.

We developed software for converting raw ECG signals into audio files using Matlab. Next we converted files from the MIT-BIH Arrhythmia Database to waveform audio file format in order to play these signals on audio player. The function which allowed us to do this is audiowrite, which is one of core Matlab functions. Resulting audio files have 8 kHz sampling, 16 bit resolution and have two channels (stereo). Then we checked compatibility of original and modified signals, especially checking if standard audio players are capable of preserving low-frequencies of ECG signal (audio signals are usually in the range from 20 Hz to 20 kHz whereas ECG is in the range from 0.15 Hz to 40 Hz [3]) and results were highly sufficient. Adjusting the volume of the player turned out to be adequate to receive signals with amplitude comparable to real ECG signals and there was no need to use voltage divider.

Results

The main goal of our work was to obtain signals which would be the most realistic without need for involvement of the patient. We have already used our solution to test highly advanced medical equipment, for which usage of the standard ECG simulator wasn't enough.

In order to precisely verify the accuracy of the output signal relative to the signal from MIT-BIH Arrhythmia Database, signals from audio files were recorded with the Holter and displayed using the included Sentinel software. Unfortunately, this software does not have a function which would allow to save raw ECG data to a file, because this option is usually not needed doctors to whom the software is dedicated. Therefore, the only comparison that could be carried out, is to draw one onto another two charts: fragment of ECG signal from MIT-BIH Arrhythmia Database displayed with the official PhysioNet Lightwave browser and from converted audio file registered by Holter-ECG recorder. For the best comparison axes of both charts have been standardized. These preliminary tests show that ECG signals from our generator are in a very good correspondence with real recordings (see Fig. 1 and Fig. 2).

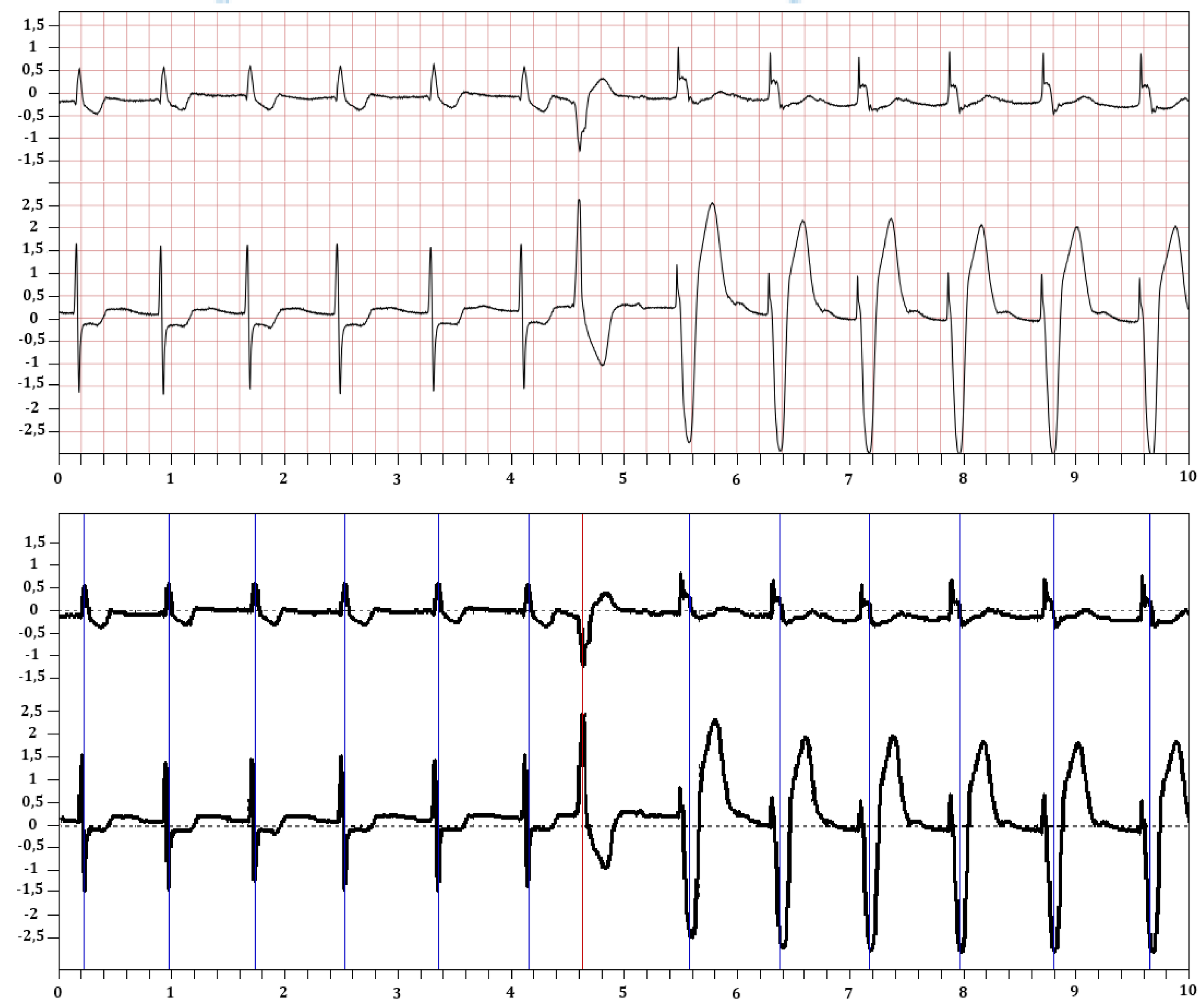

Fig. 1 Plots presenting fragments of ECG signals: on top – signal from the MIT-BIH Arrhythmia Database (102), the bottom: signal registered by Holter-ECG recorder from the audio player file (102.wav).

Fig. 2 Plots presenting fragments of ECG signals: on top – signal from the MIT-BIH Arrhythmia Database (104), the bottom: signal registered by Holter-ECG recorder from the audio player file (104.wav).

We have tried to make additional, numerical tests presenting agreement between reconstructed and real signals, but it occurred that the resolution of obtained signals (from Holter recorder) was too low to allow us making comparison of these signals. It was caused by limitations of equipment that we have and as soon as we achieve more suitable device we will make needed tests.

Our solution gives an opportunity to have an artificial patient, which may be used to scientific or industrial purposes and is available for anyone who has a reliable audio player (even this one in laptop can be used). Moreover, it offers very broad prospects for its application at zero cost and time of implementation.

References

[1] http://www.rigelmedical.com/products/simulators/ecg-patient-simulator

[2] Moody GB, Mark RG. (2001) The impact of the MIT-BIH Arrhythmia Database. IEEE Eng in Med and Biol 20(3):45-50.

[3] Clifford GD, Azuaje F, McSharry PE. (2006) Advanced Methods And Tools for ECG Data Analysis Artech House Publishing.