Compression of ECG and Breathing Signals

Whitepaper by OMsignal
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***Abstract*—Because of the limited amount of resources of the OMsignal hardware box, the only possibility to record and send the raw electrocardiogram (ECG) and raw breathing signals is to compress them. But compression creates a loss of signal quality that needs to be minimized. We present results of our compression algorithm where the percent root mean square error of the resulting decompressed signal compared to the original raw signal is less than 0.1 percent.**

***Keywords*—ECG, breathing, signal compression.**

I. Introduction

The OMsignal hardware box processes the various signals and transmits detected heartbeats, breathing inhales and exhales and various accelerometer data. For debugging purposes or for new applications, it would also be very useful to transmit the raw signal itself.

The box uses Bluetooth low energy (BLE) to transmit data to the phone and thus has limited bandwidth. It is also limited in CPU, battery and memory. There is not enough bandwidth to send raw ECG and breathing live over BLE. There is not enough memory to record raw data for hours. In order to be able to send live raw data to an application for display and to be able to record at least during one day, the signals need to be compressed while minimizing loss of quality. Furthermore, we need to select an algorithm that takes as little CPU and battery as possible.

Our goal is to be able to record the 250 Hz/32 bit ECG signal and 25 Hz/32 bit breathing signal within a block of 134 bytes per second. This size not only takes much less memory but is small enough to be able to be sent live over BLE.

The compression ratio within a block is around 7 times for the ECG and around 3 times for the breathing. The final algorithm runs in N * log(N) complexity and takes very little CPU (around 2000 multiplications and additions per second). Every second, the algorithm compresses the signal in real time, records it in the flash memory and sends the final result over BLE. There are no extra CPU peaks needed at the end except for sending over BLE.

Once on the phone, the compressed signal is sent to our servers via WiFi and can also be decompressed to be displayed. The raw ECG and breathing signals for all users can thus be recorded on our servers and retrieved for further analysis.

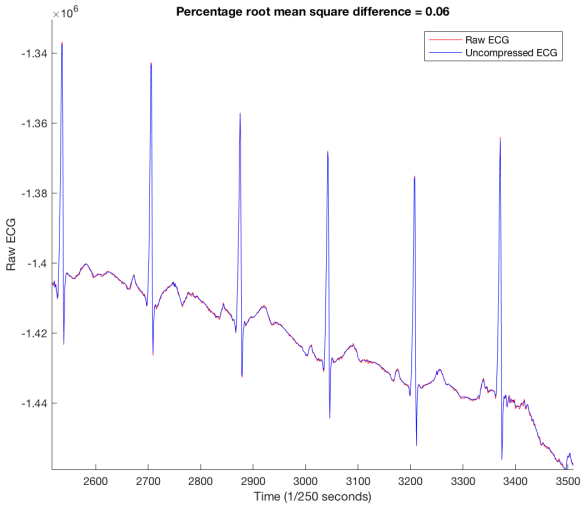
II. Results

We recorded raw 32 bit ECG and 32 bit breathing signals on the box. These signals were not compressed and were retrieved via USB cable.

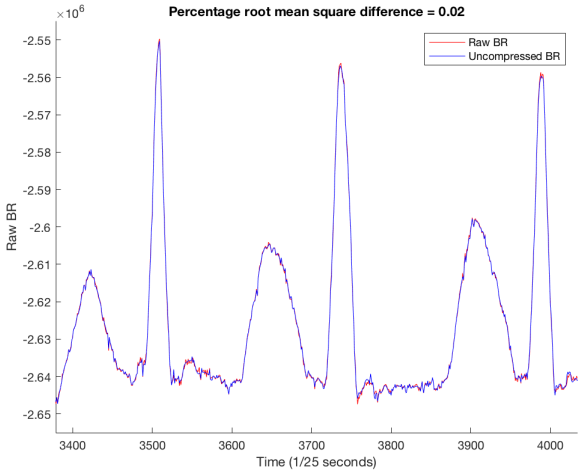
The recordings were then compressed and decompressed using our algorithm. We then computed the percent root mean square difference (PRD) of both signals:

$$PRD = 100 * \sqrt{\sum (O - D)^2 / \sum O^2}$$

where O is the original signal and D is the compressed then decompressed signal.



Here we show the result of the original ECG signal in red superimposed with the corresponding decompressed signal in blue. If the PRD was 0 (perfect decompression) then we would see only blue as it would perfectly superimpose the red signal. So we can thus see in red were the algo makes mistakes. The errors are mostly from smoothing very high frequency but low amplitude noise along the signal, there is no distortion in the most prominent signal features of the PQRST complex.



As for ECG, breathing compression and decompression preserve the most prominent features of the signal and smooths out high frequency noise.

III. Future Work

With our next generation of hardware, we will be able to compress and decompress in real time an ECG signal of up to 1000 Hz and a breathing signal of 40 Hz.