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Development of a Presentation Interface for Seismo- and Ballistocardiographic Data

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Abstract. Ballistocardiography is a method to gain detailed information about body movements imparted by the ballistic forces associated with cardiac contraction. We measured using different setups and sensor positions to gain information of a reference signal of healthy adults. We used two resting state recordings and two recordings under physical stress (ergometer and treadmill) with stepwise increasing load. Data was gathered from 34 subjects, which results in 72 data sets, overall, more than 18h of signal data. With these data we have created a first database for BCG reference. We started data analysis and created a first naive data representation prototype. Using this naive attempt, we created a user interface for the intuitive representation of live data as well as retrospective data.

Keywords. User Interface, Ballistocardiography, Seismocardiography, Data Management, Big Data

1. Introduction

Ballistocardiography (BCG) is a method to gain detailed information about body movements imparted by the ballistic forces associated with cardiac contraction and ejection of blood and with the deceleration of blood flow through the large blood vessels (see NLM Definition [1]). These heart-related movements are translated by a sensor device into an electrical potential which is suitably amplified and recorded (see [2]). Detailed information on cardiac physiology, for example on valve closures, primarily of the left atrium and ventricle, is measured using the special form of BCG, seismocardiography (SCG), on the thorax. The use of BCG technology can additionally, in combination with other non-invasive, diagnostic methods, such as pulse oximetry, determine the blood pressure over the pulse transit time (PTT) [3].

2. Method

In order to collect a first basic set of data from healthy subjects, we first measured 34 subjects (m = 21, w = 13), within different setups (M1-4), including two different

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accelerometer positions. For M1/M2, the tri-axle acceleration sensors (Kionix KX123-1022) are placed at positions on the sternum, the apex of the heart and the spine.
For the measurements M3/M4, two positions on larger vessels (temple, wrist), for a BCG setup, plus cardiac apex were used. This should allow comprehensive PTT investigations.

M1/M3 are resting state recordings, while M2/M4 are conducted under physical stress. M2 is recorded while using an ergometer (2 min at 40-60 W, 1 min at 70-100 W, 30sec at >=110W). M4 is measured while using a treadmill (2 min at 5 km/h, 1 min at 10 km/h, 30 sec at 15 km/h). For the data recording, we used a new, highly synchronous, scalable, modular measuring system with a Field-Programmable-Gate-Array (FPGA) core, some kind of a modular processor, and three tri-axial acceleration sensors, as well as a 6-channel ECG as a reference. The data output rate for the accelerometers was at 17.2 kHz and for the reference ECG at 12.4 kHz, as a result of the more complex communication [4]. We used split and compress methods to store the signal data within the database, every measurement was stored in four parts. Including meta data we stored about 800 GB for about 18 h of measurement signal data.

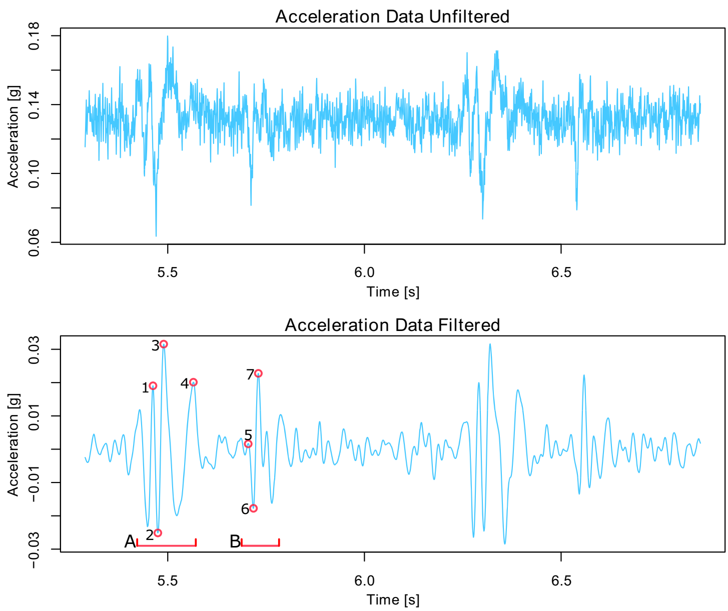

Figure 1. Presentation of the raw output date (top) of the measurement M1 (cardiac apex z-axis) and the first filtered data stream (bottom)

In Figure 1 two heartbeats can be seen in a raw calibrated acceleration data view, as well as in a first filtered and calibrated acceleration data stream. For the filtering we selected a third-order Butterworth bandpass filter with the limits 7 Hz and 40 Hz. In the bottom view we have annotated some features of the SCG signal. First, there are two intervals (A and B). Interval A represents the expulsion phase (contraction phase or systole) of the blood into the body circulation and B (relaxation phase or diastole) the refilling of the left ventricle. Basically, the left side cardiac physiology processes can be mapped with the SCG (see [5]). Interval A comprises four features, starting with the mitral valve closing (1), the isolating valve from the left atrium into the left ventricle, followed by the isovolumetric contraction (2). The isovolumetric contraction is the atrial systolic contraction. If the left chamber is filled, the aortic valve opens (3) and thus the path into the body circulation, the ventricular systole starts, represented by the rapid ejection (4) of the blood into the vascular tree. In B you can see the features aortic valve closing (5) and thus the start of heart's refilling, as well as the rapid filling (6). After the heart is refilled, the mitral valve opens (7) and thus the preparation for a new systole [5].

3. Results

As can be seen from the illustration in Figure 1, the evaluation of, e.g. the real-time display for medical diagnostics, is a challenge. For this reason, we decided to develop a first display version in the form of a serial data stream display, as shown in Figure 2.

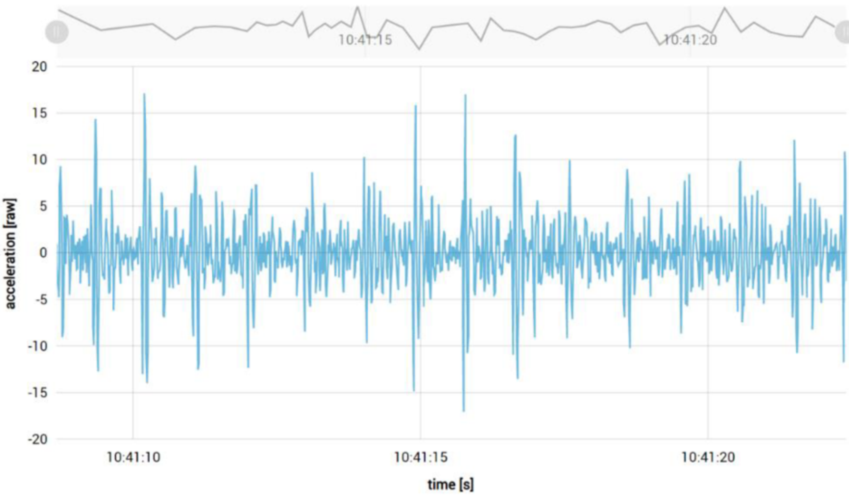

Figure 2. First visual representation attempt for the SCG live data

With this display prototype, we first implemented the option of the zoom function within the time axis (gray bar at the top of the figure). This attempt shows the common visualization. However, this form of presentation has proven to be unsuitable, since it is only possible to limited compare a small selection of heartbeats that are strongly dependent on time. Furthermore, no parameters or aggregations are used for visualization in this version. After consulting user interface (UI) experts, we developed the second concept prototype (see Figure 3). With this graphical UI, the last ten heartbeats can be displayed in filtered and calibrated form in an overlay with newest first, as well as the averaged signal curve. In addition, after consulting with medical experts, we also represented breathing as a separate signal feature of the SCG measurement in the lower area of the surface as a serial data stream over the entire measurement period. In addition, a selection of parameters (last pulse rate, mean time interval between heartbeats and last respiration rate) was shown on the right.

4. Conclusions

The current UI concept shows a first attempt for live BCG and SCG data visualization for upcoming diagnostic purpose. The layout, as well as the feature presentation will be

improved and further reviewed by medical experts. For the usage of the interface for the presentation of retrospective data the inclusion of meta data, as well as an advanced use of feature knowledge, for example by using box plot on several signal spots (e. g. SCG signal features), can be imagined. By providing a proper UI a further step to a diagnostic use of BCG and SCG and thus a practical benefit for medicine is made.
The collected data will be usable as open data soon and can be extended by research groups, e.g. data from sickened patients.

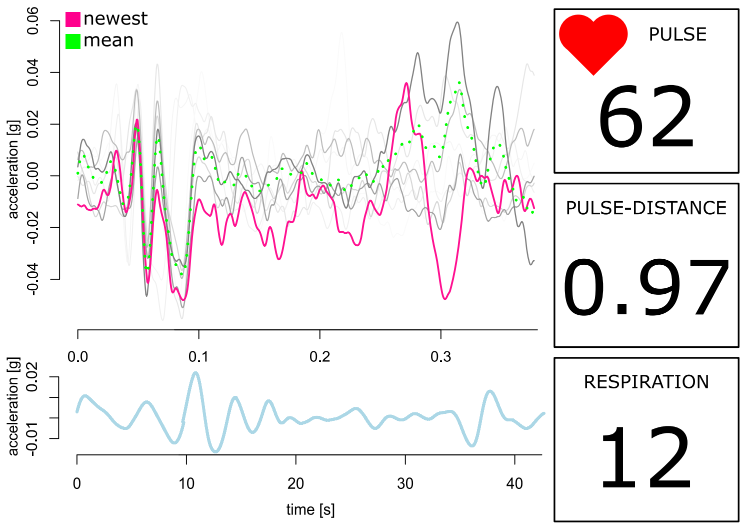

Figure 3. Advanced UI concept of SCG data of ten heartbeats in overlay on mitral closing point as anchor

Acknowledgement

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