An Arduino based heartbeat detection device (ArdMob-ECG) for real-time ECG analysis

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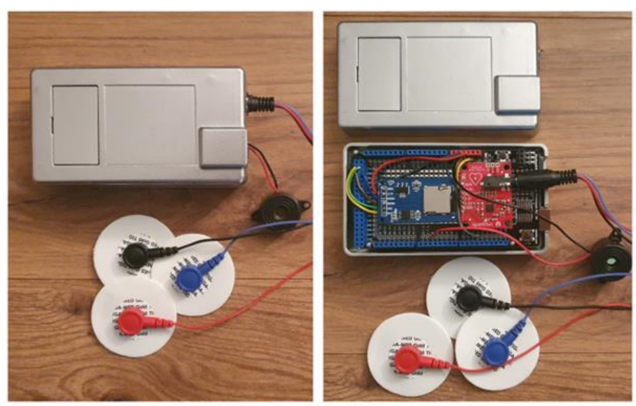
This technical paper provides a tutorial to build a low-cost (10-100 USD) and easy to assemble ECG device (ArdMob-ECG) that can be easily used for a variety of different scientific studies. The advantage of this device is that it automatically stores the data and has a built-in detection algorithm for heartbeats. Compared to a clinical ECG, this device entails a serial interface that can send triggers via USB directly to a computer and software (e.g. Unity, Matlab) with minimal delay due to its architecture. Its software and hardware is open-source and publicly available. The performance of the device regarding sensitivity and specificity is comparable to a professional clinical ECG and is assessed in this paper. Due to the open-source software, a variety of different research questions and individual alterations can be adapted using this ECG. The code as well as the circuit is publicly available and accessible for everyone to promote a better health system in remote areas, Open Science, and to boost scientific progress and the development of new paradigms that ultimately foster innovation.

The poster describes an Arduino-based heartbeat detection device (ArdMob-ECG) that integrates the AD8232 module for real-time ECG analysis. The ArdMob-ECG is easy to assemble, light-weight, small and transportable, inexpensive, yet reliable, and can be used without clinical personnel with simple instructions. This paper is meant as a guide for scientists to independently assemble the device for their own scientific studies. Utilizing an easy to use, inexpensive, lightweight, and reliable technical device for measuring heart rate and its components would advance the progress in scientific research. An ECG can monitor the heart activity of an individual and detect e.g. arrhythmias that can indicate heart problems. This has an immense meaning for monitoring the participants cardiac health.

The ArdMob-ECG described in this paper utilizes the AD8232 module, a small chip measuring the electrical signal of the heart that is then translated to an ECG waveform. It implements a simplification of the Pan-Tompkins algorithm to calculate the occurrence of heartbeats in near real time. Different data (e.g. timestamps, raw data) can be saved on a built-in micro SD card, while other data such as triggers can be sent directly to another device using a serial interface (USB-connection). Thus, triggers can be sent with minimal delay. The heartbeat analysis can already be calculated locally on the Arduino. The Arduino can also provide auditory feedback whenever a heartbeat is detected. This tone can also be easily adjusted to occur faster, slower or with a specific delay to the actual heartbeat, depending on the scientific paradigm (e.g. the widely used interoceptive sensitivity paradigm [1]).



(a) (b)

Figure 1. (a) The device how it is used. (b) The ArdMob-ECG inside the aluminium case showing the insides with the modules and all the relevant cable connections. The Piezo sound buzzer and the electrodes cable connected to the headphone jack of the AD8232 sensor can be seen on the right.

A major advantage of the ArdMob-ECG is that the variables can be easily modified, and additional triggers can be implemented, for example, directly playing the sounds faster or slower according to the last R-R interval [2][3][4].

To assess the quality of data obtained from the three channel ArdMob-ECG, data from 12 channel ECG from a clinical ECG machine (ZOLL X Series CCT Defibrillator) of a German ambulance and was recorded simultaneously for three seconds on one healthy 24-year-old participant. The ZOLL X Series CCT Defibrillator ECG-device is standard equipment and is routinely used in German ambulance vehicles. A trained medical expert compared both data outputs and assessed the validity of the heartbeat detection. Both devices managed to detect 100% of the heartbeats.

In light of growing development of sophisticated biofeedback methods in the health sciences, ECG data can provide valuable information about internal body states. Currently, the use of an ECG might be limited by expensive, heavy and rather immobile ECG machines, and difficulties in operating them with no technical training which might limit the overall progress in scientific biofeedback studies. Our mobile ECG device provides a solution to the aforementioned problems of high costs, transportability, and technical training required to operate a clinical ECG machine. Furthermore, the ArdMob-ECG allows for an easy way to save data and to send triggers through a direct interface with minimal temporal delay that can be of use for scientific paradigms.

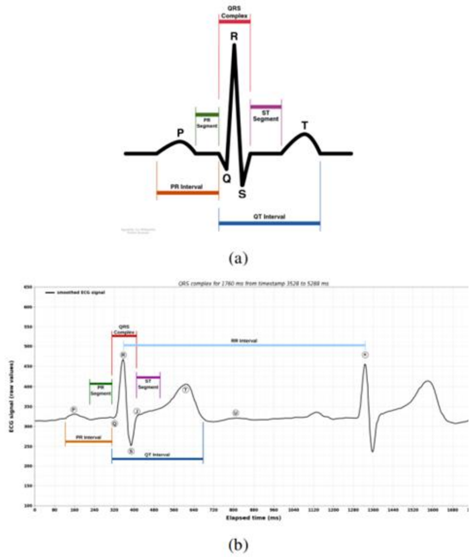


Figure 2. (a) a schematic representation of a normal ECG consisting of the components P, Q, R, S, T. (b) A recording from the ArdMob-ECG device with the different components.

ACKNOWLEDGMENTS

This research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – DFG – SPP – 2134. The pictures and the code for this device can be found in the GitHub repository [5]. The repository is licensed under the MIT license. Major sections of the Pan-Tompkins algorithm were adapted from an existing repository [6]. Some of the code contains elements from other available, open access, existing scripts, described in the Readme file in the GitHub repository. Author Contributions: T.J.M.: Conceptualization, software, validation, resources, writing original draft & editing, visualization; Y.K.G: Review & editing, visualization; M.V: Editing; L.K.: Editing.

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This poster summarizes a technical paper [1] which provides a tutorial to build a low-cost (10-150 USD) and easy to assemble Arduino-based mobile ECG device which integrates the AD8232 module (ArdMob-ECG).

Introduction

The ArdMob-ECG is **a mobile solution for Electrocardiogram recording** and has the following advantages:

- Small
- Lightweight
- Cost-efficient (~150 USD)
- 3 electrodes instead of 12 needed
- Can be battery-operated for mobile use
- Reliable detection algorithm with sufficient sensitivity and reliability
- Automatic saving on an inbuilt SD-card
- Different data types can be saved on a built-in micro SD card
- Other data such as triggers can be sent directly to other devices or software using a serial interface (USB connection) with minimal delay
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- Can be easily operated by non-clinical personell
- Open access Hard- and Software to promote open science and foster innovation

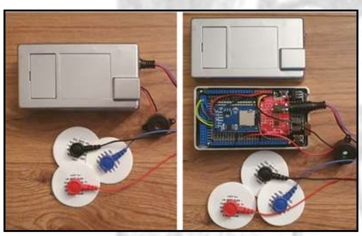

Figure 1: A picture of the ArdMob-ECG

Figure 1a: A picture of the ArdMob-ECG used in a VR study

Software & Hardware architecture

The ArdMob-ECG contains an Arduino that comes with its own software integrated development environment (IDE) and can be loaded via a USB cable to the Arduino board.

A variety of data types can be saved on a built-in micro SD card, while e.g. triggers can be sent directly to another device using a serial interface (USBconnection). The setup consists of an Arduino Mega 2560 board, an AD8232 heart beat monitor from which the cable for the electrodes connects, a 85 dB Piezo sound buzzer , and a micro SD memory card SPI reader.

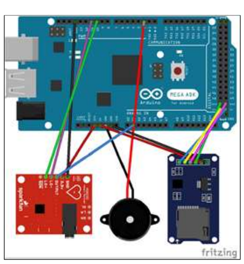

Figure 2: A schematic diagram of the ArdMob-ECG.

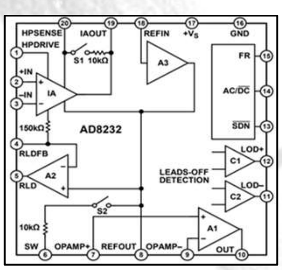

Figure 3: Functional block module of the AD8232 heart rate sensor

Algorithm & Validation

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The ArdMob ECG peak detection was compared to a professional ZOLL X Series CCT Defibrillator. Both devices managed to detect all the heartbeats, as evaluated by a trained paramedic. In Figure 4, an example peak, recorded by the ArdMob-ECG can be seen.

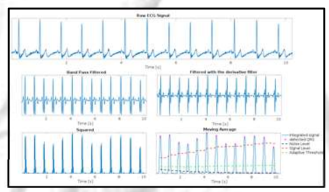
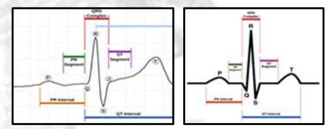


Figure 4: The different steps of the Pan-Tompkins algorithm [4,5,6]



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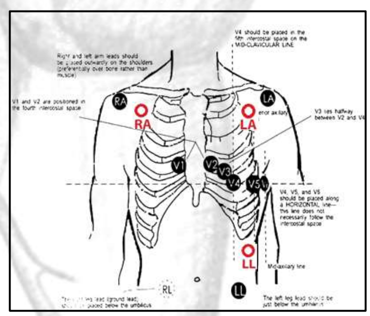

Figure 6: The classic ECG electrode setup marked in black dots. Depicted in red dots are the three electrode placements that are needed for the ArdMob-ECG.

Conclusion

The mobile ArdMob-ECG provides a solution to the aforementioned problems of high costs, transportability, and technical training required to operate a clinical ECG machine. It can also be battery-operated and only requires 3 electrodes instead of 12.

Furthermore, the ArdMob-ECG allows for an easy way to save data and to send triggers through a direct interface with minimal temporal delay that can be of use for scientific paradigms.

References

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AN ARDUINO BASED HEARTBEAT DETECTION DEVICE (ArdMob-ECG) FOR REAL-TIME ECG ANALYSIS

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03.12.2022

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BERLIN SCHOOL OF MIND AND BRAIN

HUMBOLDT-UNIVERSITÄT ZU BERLIN

CHARITÉ UNIVERSITÄTSMEDIZIN BERLIN

SPP The Active Self

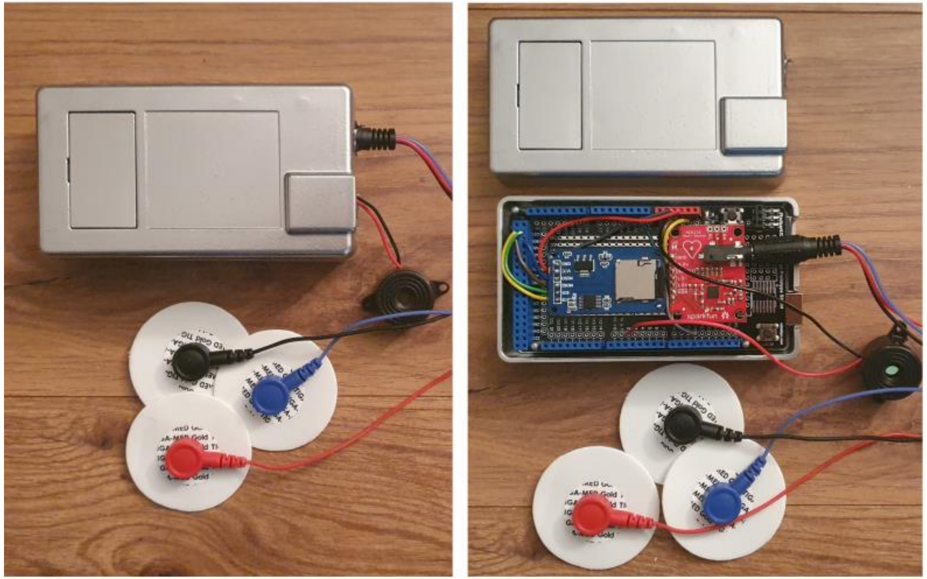
DFG Deutsche Forschungsgemeinschaft German Research Foundation

RTG 2386 Extrospection Humboldt-Universität zu Berlin

ArdMob-ECG

The ArdMob-ECG is **a mobile solution for Electrocardiogram recording**

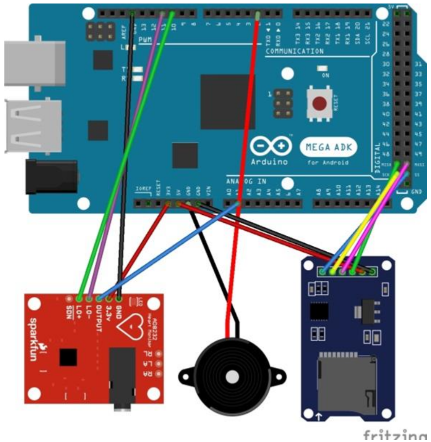
- Small
- Lightweight
- 3 electrodes instead of 12 needed
- Battery-operated for mobile use
- Reliable detection algorithm with sufficient sensitivity and reliability inbuilt
- Serial interface with minimal delay to connect to other machines and programs
- Automatic saving on an inbuilt SD-card



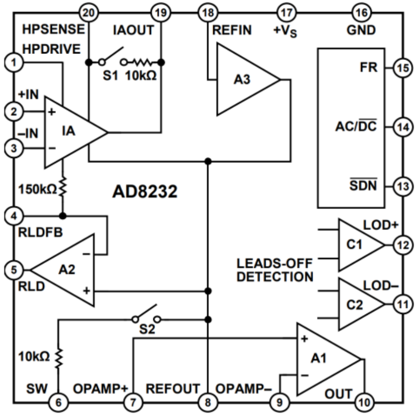
(a) (b)

ADVANTAGES

- Triggers sent with minimal delay
- Data like timestamps, raw data, etc. can be saved on a built-in micro SD card
- Other data such as triggers can be sent directly to another device using a serial interface (USB connection)
- C++ software adaptation allows for easy adjustments of the code. e.g. tones be played in synch or out of synch modified by length and pitch



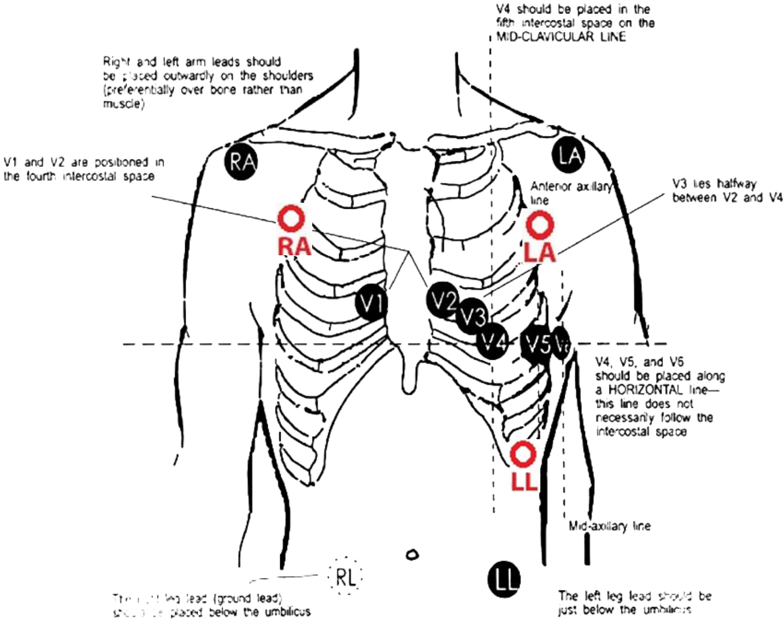
Schematic diagram of the ArdMob-ECG



Functional block module of the AD8232 heart rate sensor

Three electrode setup

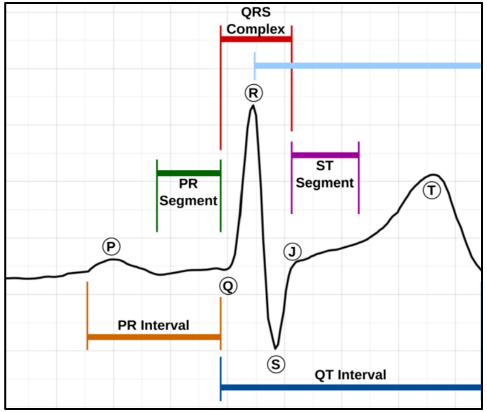
- Only 3 compared to 12 electrodes of medical ECGs are necessary.
- The classic ECG electrode setup is marked by the black dots. Depicted as red dots are the three electrode place that are needed for the ArdMob-ECG.



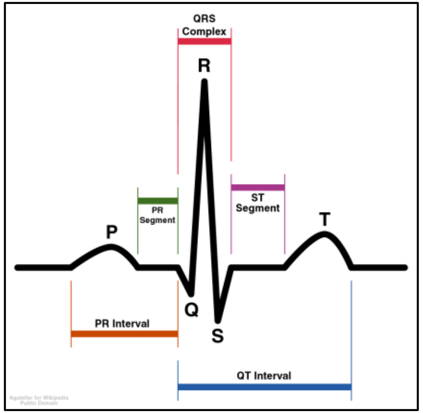
Depiction of the classic ECG setup in black, in red a possible ArdMob-ECG setup

VALIDATION

- The ArdMob-ECG captures the QRS heartbeat complex pattern
- The ArdMob-ECG peak detection results were compared to a medical ZOLL X Series CCT Defibrillator
- ArdMob-ECG detected all heartbeats, as evaluated by a trained paramedic



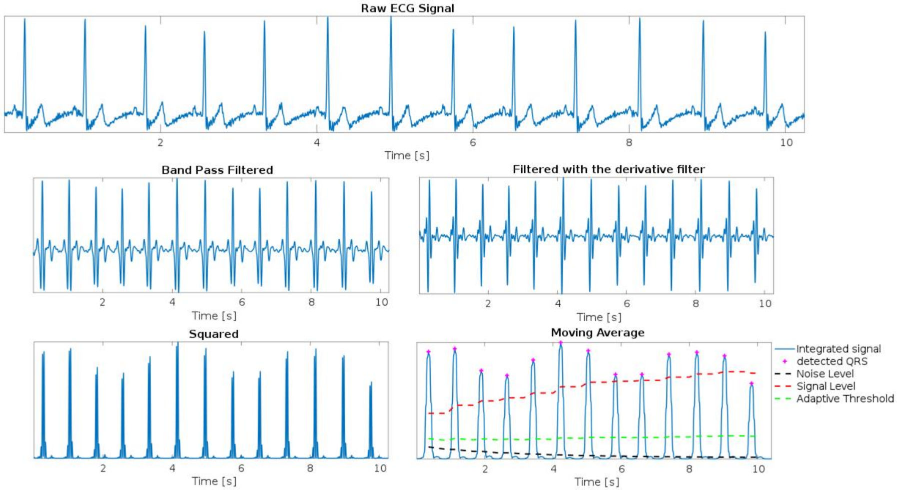
QRS complex recorded by the ArdMob-ECG



An ideal QRS complex

SOFTWARE

- The software utilizes a simplified version of the Pan-Tompkins algorithm
- **Future perspective:** Implementing further steps of the Pan-Tompkins algorithm to improve detection stability during body movement



The Pan-Tompkins algorithm

USE IN SCIENTIFIC STUDIES

- The ArdMob-ECG can be used for a variety of applications, e.g. scientific experiments using Virtual reality. On the right side, the ECG can be seen.
- In the video at the bottom, an example paradigm is shown. Whenever a heartbeat is detected by the ArdMob-ECG, the virtual hands shortly flash in a red color in this paradigm

ArdMob-ECG

DOCUMENTATION

Preprint:

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Subjects: **Signal Processing (eess.SP)**; Hardware Architecture (cs.AR); Systems and Control (eess.SY)
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ArdMob-ECG

POSTER

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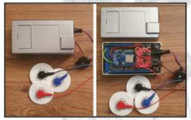

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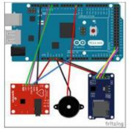

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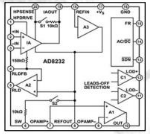

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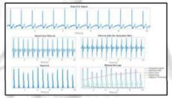

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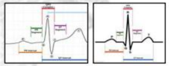

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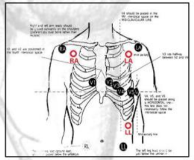

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Contact me for further information and collaborations!

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