Heart Rate Textile Sensing and Integration

Sports Technology, Heart Rate Monitoring

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Project Motivation

The Purdue Athletics department faces a problem with their heart rate monitor chest straps: Wrestlers and football players report the straps to be uncomfortable and slipping off, resulting in incorrect readings from the heart rate monitor. The goal is to prevent these problems from happening by creating a garment or practice jersey that implements the chest strap design, which is achieved by integrating the electrodes from the chest strap into the fabric of the clothing, allowing for an off-the-shelf heart rate monitor (Fig 1) to be attached. This will be done by comparing performance of electrodes to find suitable replacement material that can be integrated with clothes

Fig 1: Garmin Heart Rate Monitor

Existing Work

Electrodes are simply electricity transmitters that can detect electrical impulses coming from our body [1]. The signal of the electrocardiogram (EKG) detected by the electrodes can be seen in Fig 2. The most visible part of this signal is the QRS wave complex (the large amplitude spike), and the time between two QRS waves is the time of one heartbeat. Silver or copper fabric tends to be very popular for electrode material. Research similar to this project has already been done. Graduate student Lauren Taylor at Rice University was able to sew cardon nanotube fibers onto existing sports clothing (Fig 3) [3].

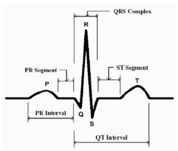

Fig 2: EKG Signal Example [2]

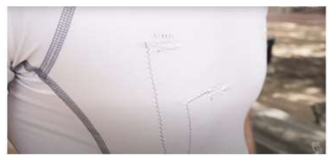

Fig 3: Rice University's Zig Zag Electrodes

Testing Method Overview

The performance comparison was done with a circuit setup (Fig 4/5). The main part of this circuit was the AD8232, a circuit board that can collect EKG signals from the body. A 3V 2232 battery was used to power the AD8232 and an Arduino Uno was used to collect the data from the AD8232 and process it onto a computer for a human to visualize and interpret. The main connections are ground to ground, power to power and the output of the AD8232 to the Arduino. Arduino and Processing 4 code was used to process the signals.

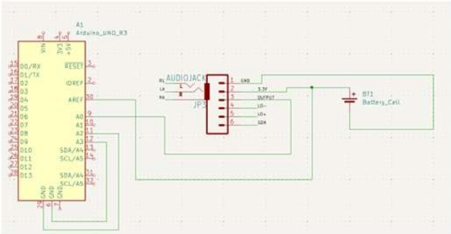

Fig 4: EKG Circuit Schematic

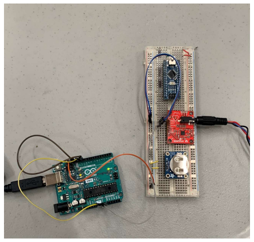

Fig 5: EKG Circuit Board

Testing Procedure

The Arduino code was able to process the signals from the circuit and translate those signals into data that is readable for humans. The Processing 4 code took the data processed by the Arduino code and illustrated it into a continuous looping graph that would display the EKG signals being collected by the AD8232 board. Three different configurations were tested: 3M Electrode Red Dot Cloth Pads (Fig 6), Knitted Silver Conductive Fabric, and Wahoo heart rate monitor chest strap pads. The audio jack on the AD8232 connects to the three pins that attach to the electrode configurations. The conductive fabric needed to be cut into squares and taped onto the body (Fig 7). The chest strap pad connection needed to be soldered with male pins so the two upper EKG pins could attach (Fig 8).

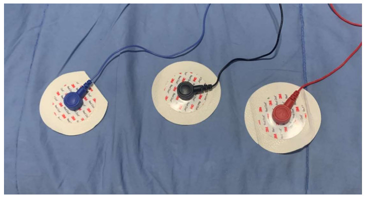

Fig 6: 3M Electrode Pads Setup (Baseline)

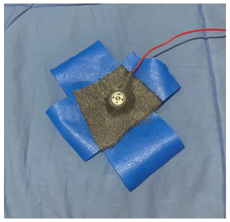

Fig 7: Silver Fabric Setup

Fig 8: Chest Strap Setup

Testing Results

Wahoo pads seem to have the most noise and inconsistency, while the baseline 3M pads have the least. For this project, the signal-to-noise ratio (SNR) was used, which measures the strength of the desired EKG signal against the background noise. Using MATLAB code, these ratios were calculated for each configuration (Table 1). The highest SNR was seen in the baseline configuration, while the lowest SNR came from the Polar chest strap pads. It can be concluded that the silver conductive fabric tested can be potentially used as a material for the garment that will be created. There are a few limitations to our testing, including the flimsy contact of the EKG pins with the body. This could cause inaccurate readings of the signals, leading to slight errors in SNR calculations.

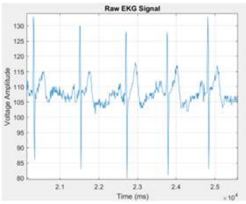

Fig 9: 3M Pads (Baseline) EKG

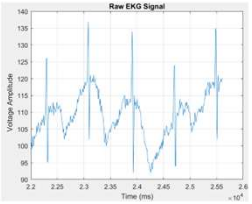

Fig 10: Knitted Silver Fabric EKG

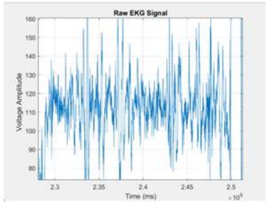

Fig 11: Wahoo Chest Strap EKG

Experiment Configuration	Signal To Noise Ratio (dB)
3M Electrode Pads (Baseline)	7.59
Knitted Silver Conductive Fabric	3.13
Polar Heart Rate Chest Strap Pads	-1.50

Table 1: Signal-to-Noise Ratios for Each Configuration

Next Steps

1. Figure out a way to decrease the noise in the signals being received using troubleshooting techniques
2. Confirm the SNR calculations are outputting expected values
3. Repeat the testing procedure with other potential electrode configurations, including both sewing and 3D printing onto fabric
4. Select a best performing configuration and implement into a garment or jersey

References

[1] Sikken, Jasper. "Electrodes: What Are They and What Are They Used For?" *Elitac Wearables*, https://elitacwearables.com/electrodes-what-are-they-and-what-are-theyused-for/. Accessed 19 Sept. 2024.

[2] Nataraj, Chandrasekhar. "The Components of ECG Signal. | Download Scientific Diagram." *Components of ECG Signal*, www.researchgate.net/figure/The-components-of-ECG-signal_fig1_224226027. Accessed 17 Nov. 2024.

[3] Taylor, Lauren. "Smart Shirt Keeps Tabs on the Heart." *Rice University News*, 2021, https://news.rice.edu/news/2021/smart-shirt-keeps-tabs-heart. Accessed 19 Sept. 2024.

[4] "Polar H10 Heart Rate Sensor – the Gold Standard of Heart Rate Measurement." *Polar Blog*, 4 Sept. 2020, www.polar.com/blog/new-polar-h10-heart-rate-sensor-2017/.

[5] *Amazon.Com: Garmin 010-12955-00 HRM-Pro, Premium Heart Rate Strap, Real-Time Heart Rate Data and Running Dynamics : Sports & Outdoors*, www.amazon.com/Garmin-HRM-Pro-Premium-Real-Time-Dynamics/dp/B085JKM9DR. Accessed 17 Nov. 2024.