Wellness: Stress Monitoring in Footwear

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Problem Description

Stress has many negative effects on the body and can interrupt the natural cycles of the digestive, immune and cardiovascular system. In the UK, approximately 44% of missed work days with regards to health were due to stress, depression and anxiety [1]. Not only does this have considerable financial impacts due to missed hours in the workforce, it also the affects health, happiness and wellbeing of individual. Monitoring stress and modifying daily habits to reduce stress could mitigate the negative effects of stress. Our device allows users to easily quantify and monitor their stress without hindering their day to day activities.

There are currently very few devices on the market that are similar to our prototype. The main competitors are stress trackers and health/fitness wearables. None of these wearables are implemented through footwear or use multiple physiological signals to quantify stress. For this reason, the system outlined in this report for monitoring, classifying and tracking stress over a user's lifetime is unique and novel.

Design Solution

Stress is determined from 4 physiological sensors; photoplethysmography (PPG) sensor to measure one's heart rate, galvanic skin response (GSR) sensor to measure the ectodermal activity, a temperature sensor and a 3-axis accelerometer to measure physical activity. In the current design, these four sensors are sewn on a band that is placed around the foot. The benefit of this device on the foot is that it doesn't hinder day to day activities. These signals are then sampled by a microcontroller and sent via Bluetooth Low Energy (BLE) to a mobile application for signal processing.

The custom designed mobile application provides data pre-processing, feature extraction and stress classification. The application was built for Android devices, using Java. Signal processing, feature extraction and classification are done locally within the application. The extracted features to classify stress are heart rate, skin conductivity, skin temperature, step count and calories burned for the day. These are presented as visual charts and graphs in the application so the user can deduce moments of the day in which they were stressed.

Application

Prototypes have been developed for both the hardware and software components creating a complete solution. The hardware prototype consists of a two adjustable bands to accommodate various users. One band is placed around the arch of the foot, containing all the physiological sensors, and another is placed around the users lower leg which contains preprocessing components, the microcontroller and the battery. Software was completed in Android Studio with original code, processing and functions. Graphing was done with open source software. Accuracy of classification results has not yet been completed in any rigorous method as clinical trials would be needed. However, testing of feature extraction accuracy has been completed, resulting in both high precisions and accuracy.

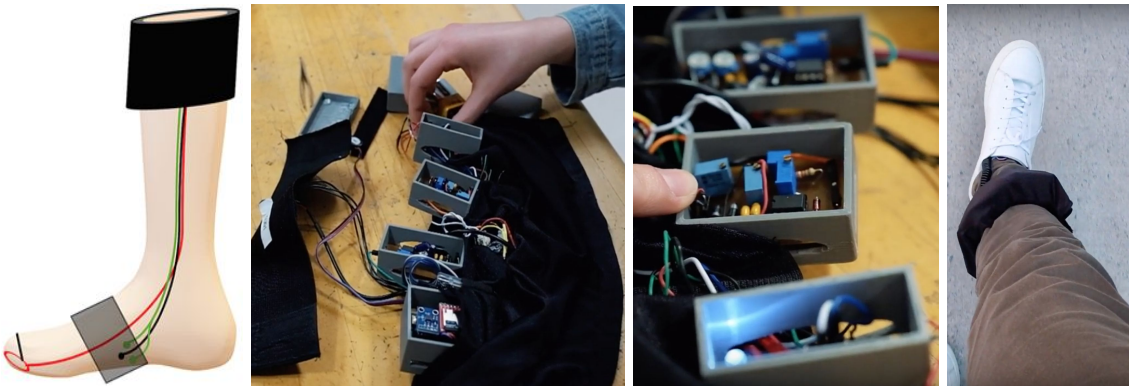

Figure 1: Implementation of device (far right). Pre-processing circuitry with controller (inner left and right). Device on user (far left).

Figure 2: Screenshots of mobile application. Login in page (far left). Main menu (inner left). Long term stress analysis (inner right) and heart rate trends (right).

A video highlighting our design solution can be found at: https://youtu.be/RwEzZW_Ekxw

Implementation

The next steps in the development of this product is the minimization of the hardware and improvement, by further testing, of the classification algorithm. Minimization of the hardware will be implemented through printing multilayer surface mounted printed circuit boards (PCBs). For further consolidation of hardware components, lithium ion batteries could be used to allow for a smaller design. Due to this reduction in size the processing device could be placed on the shoe or in a shoe sole.

In terms of the software, the next steps for the mobile application will be improving the classification of the stress results. Trials and studies with subjects will allow for high quality labeled data to be collected in order to help develop a machine learning model or verify the current decision tree used.

References

[1] “Work related stress depression or anxiety statistics in Great Britain, 2018,” *Health and Safety Executive*. [Online]. Available: http://www.hse.gov.uk/statistics/causdis/stress.pdf. [Accessed: 15-Apr-2019].