"A Modular Open-Source Stress Monitoring Garment"

Blake Hewgill, University of Vermont
AY 2019-2020 Progress Report

Background & Significance

The development of a low-cost and modular solution to health monitoring represents a transition in the evolution of wearable devices. The open-source and modular nature of the garment allows the same piece of equipment to perform as a viable monitoring solution across a variety of clinical interests by adding various sensor modalities without further hardware development. Stress and fatigue estimation hardware and techniques have been developed in the past, but generally rely on quantifying the subject's movement degradation across repetitive activities such as stocking shelves or loading equipment into vehicles. In a microgravity environment, the sensing modalities employed by many of these solutions become meaningless, as the absence of a gravity vector and the migration of bodily fluids confound sensor measurements. By implementing a solution which does not rely on specific movements or the presence of gravity, we may gain the ability to monitor stress and fatigue during astronaut deployment.

Project Goals

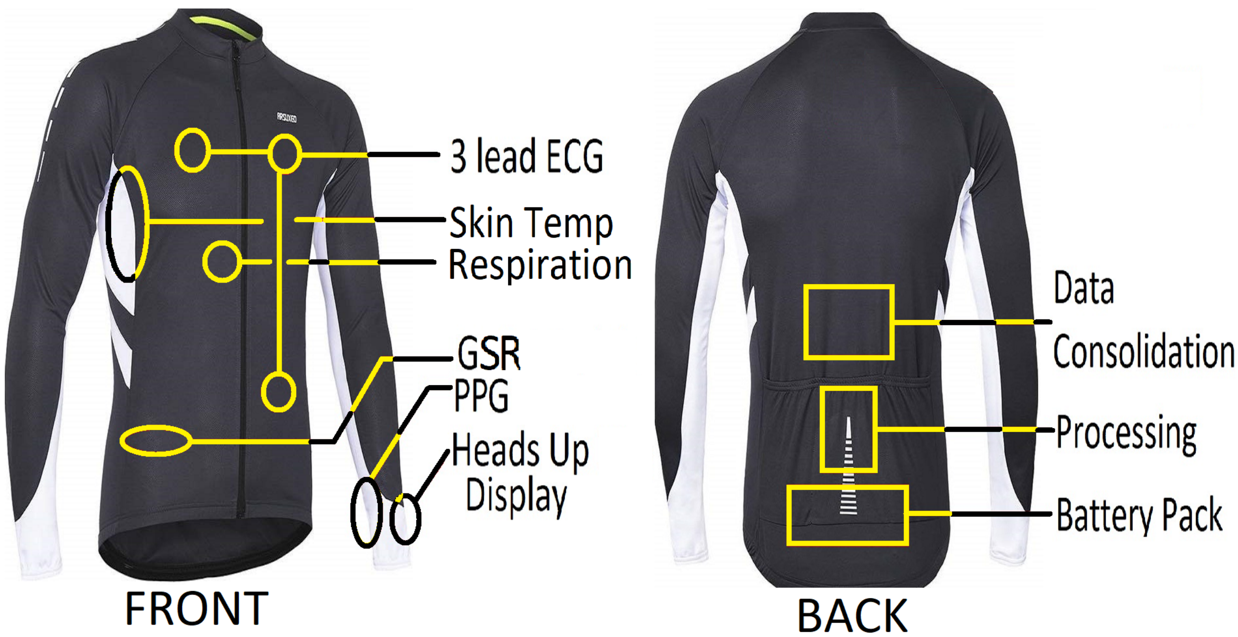
This project necessitated the completion of three major milestones: development of an open-source sensing garment, creation of a publicly available long-term dataset, and the analysis of collected data to estimate and predict mental stress levels. By developing an open-source solution to wearable sensing with a modular array of sensor modalities, correlations between different health parameters can be quickly evaluated. The generation of daily data collections over the course of several months allows analysis to be performed over an extended temporal window to detect changes and trends in physiological parameters measured by the garment over that period. Finally, the application of machine learning methodology enables the creation of predictive learning models to estimate and predict the level of mental stress associated with features of interest extracted from raw data collected by the garment hardware.

Summary of Key Findings

The wearable sensing garment, referred to as the Wearable Integrated Health Monitoring System (WIHMS) was developed on a form fitting polyester long sleeved shirt. WIHMS in its current configuration employs photoplethysmography (PPG), electrocardiography (ECG), galvanic skin response (GSR), respiration, and temperature sensing technologies at a 200 Hz sampling rate. A custom printed circuit board serves to interface communications between these sensors and logs data to an onboard microSD card. Any DC power source between 2.7 and 11.8 volts can be used to power the system for data collection. The complete cost of components used in the creation of the prototype garment was $169.38. Design documents including circuit schematics are publicly available in the project's GitHub repository, alongside all of the raw data used in the study.

Using the WIHMS garment, 80 corruption-free data collections were created from a 25 year old male subject between April 6th and June 25th 2020. 82 unique features were extracted from each of these files to characterize the recorded physiological responses and evaluate the relationship between measured biosignals and self-evaluated mental stress. Mental stress levels were evaluated using four individual self-estimation methods which have been utilized in clinical settings in the past.

It was found that a Cubic KNN algorithm was able to predict mental stress levels with an accuracy of 87.3% in when these levels are assigned to specific classes, or a mean error of only 7.56% on a continuous scale using a Bagged Trees method. Of the four stress estimation tests examined in the study, the most predictable self-evaluation was the overall score of the Stress Coping Resources Inventory test, introduced in 2003.



Hardware layout of the Wearable Integrated Health Monitoring System (WIHMS) platform developed during this effort