Using Mobile Environment Sensors for Wellness Monitoring

Madison McCarthy and Petros Spachos
School of Engineering, University of Guelph, Guelph, ON, N1G 2W1, Canada
E-mail: mmccar04@mail.uoguelph.ca, petros@uoguelph.ca

***Abstract*—The ever increasing demand on society can lead to detrimental human health consequences, if not properly managed. Although society is becoming more health conscious, mental health and wellness is still lacking in adequate resources, particularly with the student population. Wireless sensor technologies can alleviate the problem by providing an additional resource in the monitoring and self-assessment of wellness. Correlations between specific environmental settings and mood alterations can be made to improve an individuals wellness, by monitoring environmental conditions. In this paper, a novel wellness monitoring framework is proposed that enables long-term deployment of a mobile, energy efficient environmental sensor, with storage and retrieval options through a smartphone device. The framework can help produce positive improvements and awareness to mental health and wellness, while also providing a foundation for alternative applications to be developed. The extensibility of this framework can allow swapping of hardware components to provide additional data, as well as interconnect emergent technologies for additional functionality.**

***Keywords*—Mobile Sensor; Environmental Data; Mental Health and Wellness**

I. Introduction

One consequence of desiring a world with sustainable growth and development is the ever increasing demand that is thrust onto society. This increased demand can be detrimental to human health if not properly managed. Although society is becoming more health conscious, with efforts geared towards nutrition and workplace safety, there is still a stigma associated with mental health and wellness [1].

Some of the factors that affect the wellness of an individual include social interactions [2], traumatic events [3], demand in the workplace [4], and environmental conditions [5]. High levels of stress induced from heavy workloads in combination with poor environmental conditions can deteriorate one's mental health. Students in particular, are at risk for developing mental health issues due to the drastic changes in their daily environment, in combination with inconsistent workloads and societal expectations.

Many student associations exist to promote mental health awareness as well as provide tools to assist with management. Services such as online self-assessment quizzes and personal counselling are available, with aims of identifying at risk individuals or helping to cope with existing/ developing conditions. While these tools are effective at addressing wellness on a weekly basis, there are few tools that can address wellness on a day to day basis.

By taking advantage of progressing technologies with mobile sensors and smartphone technologies, we can now monitor and manage wellness on a daily basis. The abundance of Internet of Things (IoT) applications has resulting in very low power communication protocols and energy efficient sensors, all within cost efficient sensor development kits. Low cost, accurate and compact sensor nodes can be deployed for months at a time without requiring maintenance, while standard smartphones have the ability to act as the receiver.

In this paper, we propose a framework for monitoring and self-assessing personal wellness using emergent hardware technologies. First, we select a compact and energy efficient mobile sensor that uses a low energy wireless communication protocol. Second, we select a smartphone with an open-source development environment that uses the same low energy communication protocol. Third, we deploy the sensor in such a manner that it can collect the user's environmental data without hindering mobility, and store this data within the smartphone.

The rest of this paper is organized as follows: In Section II the related work is reviewed. The proposed framework is described in Section III, followed by Section IV which explains the experimental setup. In Section V, the results are discussed. Finally, in Section VI the concluding remarks for this framework are presented.

II. Related Work

In the recent years, there have been several different approaches to monitoring the wellness of an individual. The combination of biosensor data and environmental condition data can be used to identify an individuals wellness through pattern recognition techniques [6]. Other techniques that use additional wearable sensors are capable of determining stress levels based on Hemoencephalography (HEG) and Electrocardiography (ECG) signals to provide safe stress management techniques [7]. Although wearable sensors are capable of classifying health patterns when paired with the processing power of smartphones [8], they greatly restrict mobility, reducing practicality for a daily monitoring system.

Other approaches aim to objectify a mood assessment test while maintaining mobility for the user. MoodMiner is a platform developed in [9], which uses only mobile phone sensor data and events to objectify mood. This platform provides an accuracy near 50%, focusing on phone activity usage with some geographical data to identify an individuals frame of mind. Integration of sensors in the workplace to capture environmental data can also help to objectify conditions that result in greater productivity [10]. With the aid of periodic feedback surveys, a pilot study was conducted to correlate comfort to productivity. The drawback of the system in this study is its limited sensor mobility, only capable of providing environmental data from a fixed location.

Another approach focuses towards the back-end infrastructure of cloud computing and storage, which has given way to IoT applications. In [11], a framework for body area networks is described, that take advantage of cloud processing, in order to give advantage to e-health applications. Typical sensor data from the body network is transmitted to a mobile device with internet capabilities to act as a gateway to the cloud. The data is then stored, processed, and finally presented visually to a health professional. Experimental models, such as in [12], follow this framework. The vastness and complexity of body sensor information requires the offline processing power that the cloud offers. For easily processed environmental data, this framework proposed requires additional unnecessary resources, lacks immediate feedback, and still restricts the user mobility based on the types of sensors.

The framework proposed in this paper differs from current frameworks on several fronts. By allowing for both mobility in the user and in the sensor, a wide range of data from multiple environments can be collected. The proposed framework requires minimal resources and is capable of providing feedback for self assessment without offline processing. Moreover, the low energy profile of the sensor results in potential long term deployment with minimal user intervention.

III. System Framework

In this section, the introduced system framework is presented. The hardware components consist of both the sensor and smartphone device, with a communication link connecting the two together. Figure 1 illustrates the proposed system framework with the different components.

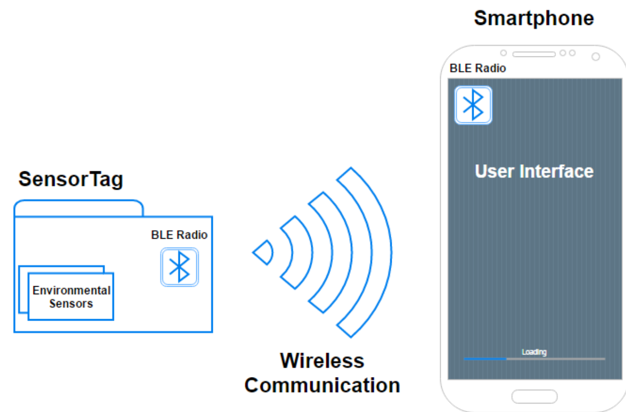

Fig. 1: Proposed System Framework.

Fig. 2: CC2650 SensorTag.

A. Hardware Components

The two hardware components chosen for this system are the CC2650 SensorTag from Texas Instruments [13] and the Samsung Galaxy Note II smartphone. The SensorTag collects environmental data, while the smartphone provides a user interface as well as internet connectivity.

The CC2650 SensorTag, shown in Fig. 2, is a compact ($5 \times 6.7 \times 1.4$ cm) development kit with 8 integrated low-power sensors and Bluetooth Low Energy (BLE) wireless capabilities. These qualities ensure that it is highly portable, can gather a wide range of environmental data for analysis, all while being very energy efficient. Out of the 8 available sensors (infrared temperature sensor, relative humidity sensor, ambient temperature sensor, optical sensor, barometric pressure sensor, gyroscope, accelerometer and magnetometer), the ambient temperature and humidity sensor were selected for use, as these environmental readings can easily be interpreted for wellness self-diagnostics.

The Samsung Galaxy Note II smartphone utilizes the Android operating system and comes equipped with a Quad-core CPU, 2 GB of memory, as well as both Wi-Fi 802.11 and BLE. The Android operating system ensures ease of application development through the open-source Android Software Development Kit (SDK). The two mentioned wireless radios provide internet connectivity and enable a communication link between the SensorTag and the smartphone without additional hardware.

B. Communication Link

Bluetooth Smart, alternatively known as BLE, provides a common communication link between the two hardware components. As the name suggest, BLE can consume less power than alternative low power communication configurations such as ZigBee [14], making it ideal for low power, IoT applications. One drawback of BLE is a small data rate of 0.27 $Mbit/s$, limiting the potential of high bandwidth applications. The smartphone's WiFi capabilities also allow for a communication to a remote server, if long-term storage of information is required.

IV. Experimental Setup

In this section the experimental procedure is described along with the developed User Interface (UI) on Android.

A. Bluetooth Low Energy Profile

In order to enable BLE communication between the hardware components, a client-server relationship must be established. The SensorTag acts as both the peripheral and the server, advertising itself for communication and providing data to be sent to the client. The generic attribute profile (GATT) server contains an array of services that offer functionality changes and access to sensor data. The smartphone acts as the central while the client, establishing a connection to the advertised SensorTag, and then requesting service changes and sensor data through the GATT client. The SensorTag comes factory shipped with software enabling this client-server relationship described.

The client software was developed using the Android SDK, a highly supported open-source application development tool. Source code providing a BLE server skeleton is available for the SDK on git, quickly enabling a reliable connection to BLE enabled devices. The client must then enable the desired services, in this work the temperature and humidity, on the SensorTag before data is available for reading. Once these services are enabled, the client enables periodic data retrieval from the SensorTag, using a predefined 1 second interval. This interval enables the SensorTag's automatic sleep cycle to be engaged, reducing the overall power consumption.

B. User Interface

Using the Android SDK, an interactive UI was developed for the smartphone, which can be seen in Fig. 3. This application includes the client software previously described, and allows for sensor data to be logged for each activity that the user enters. Activities entered can range from busing to campus, sitting in lecture, or even sleeping at the end of the day. A prompt appears to the user at the start and end of each activity to log data for future reference. Among the entered data is a self-assessed mood score scaling from 1 - 10, with 1 representing the negative extreme and the latter representing the positive extreme. The user then has access to the stored data for a future self-assessment.

C. Self-Assessment Scale

In order to extract quantifiable data regarding the user's current frame of mind, a subjective mood scale was created. As previously mentioned, this scale ranges from 1 - 10, with each bound representing an extreme in negative or positive disposition respectively. As well, each value is restricted to whole numbers to better reflect major mood changes within the individual. The user is required to enter their current mood at the start and end of each activity. By doing so, the user's change in mood can be measured and reflected upon.

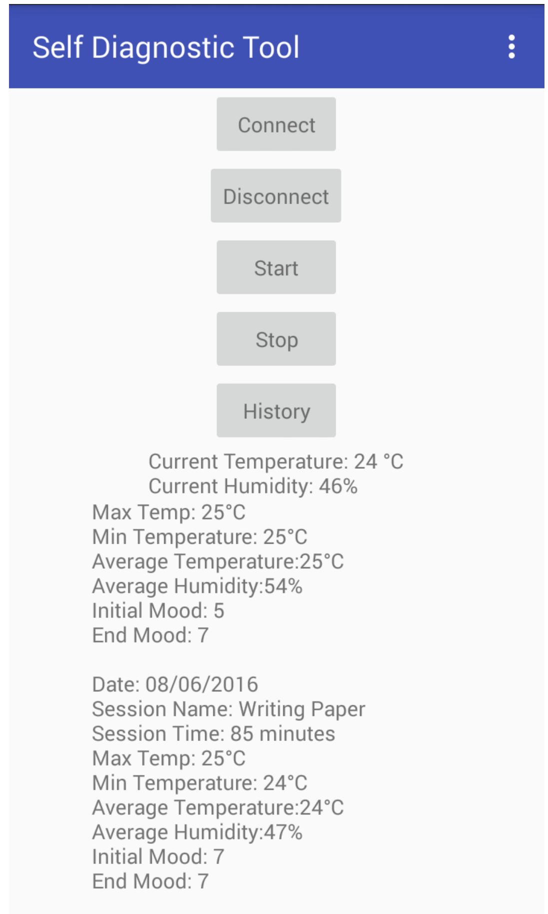

Fig. 3: Custom User Interface for Self Diagnostic Tool.

D. Sensor Placement

The proposed setup is to attached the SensorTag to a student's backpack. This location allows for unrestricted access to environmental conditions, traveling with the student without hindering mobility. The student is then able to control the sensors and monitor their personal wellness through with the environmental data. Before beginning an activity, the SensorTag is enabled via the UI and a description of the event as well as an initial self-assessed mood are entered. Once the activity is completed, the student then disables the SensorTag and inputs a second self-assessed mood. The sensor's statistical data, event activity, mood scores, and a time stamp are then stored for future retrieval. After several activities have been completed, this tool can be used for reflection on personal wellness with correlation to environmental data.

V. Results

The purpose of this tool is to provide an additional resource for mental health and wellness self-assessment. Individuals must make a conscious effort to evaluate their own current mood, bringing awareness to this often forgotten aspect of health. By tracking daily environmental conditions in congruence with the individual's mood, the user can better generate a correlation between the two. Avoidance of activities or

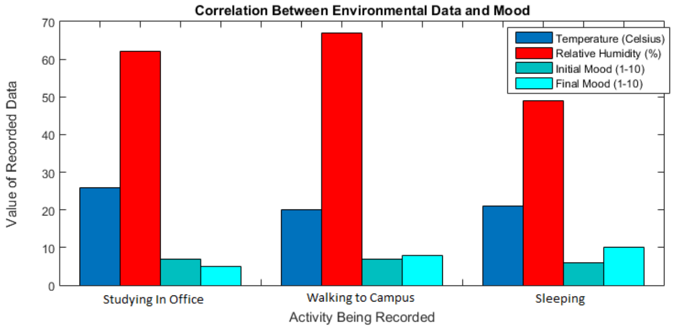

Fig. 4: Comparison between environmental data and mood.

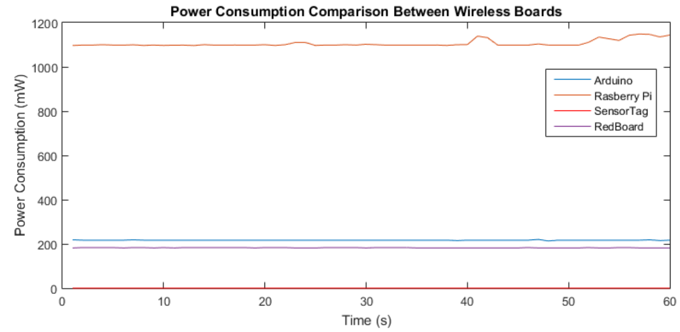

Fig. 5: Power consumption comparison between wireless boards.

environmental conditions, such as a room too humid for studying, can help improve the user's frame of mind, allowing them to actively better their mental health.

Figure 4 shows a comparison between three sample activities. The average temperature, average relative humidity, initial mood, and final mood are grouped together based on the activity completed. This comparison allows for a quick correlation between environmental conditions and the user's change in mood. The user can then self-asses their daily activities to better improve their personal mental health and wellness.

Many resources exist currently that address a student's wellness such as personal counselling sessions, stress management workshops, and online assessment modules. However these resources often lack empirical data, making it a challenge to monitor specific events or environmental conditions that trigger mood changes. By combining these current resources with the framework proposed, access to self-assessed data could become available for review by health professionals.

Previous issues of mobility are also addressed with this framework. Due to the compact nature of the SensorTag and limited hardware components required for this setup, the user's mobility is not restricted. The SensorTag is capable of traveling along with the user through an attachment to their personal belongings (backpack), while the smartphone is already an assumed possession by the user. Once the SensorTag is fixated, no further adjustments are required, allowing this device to be with the user 24 hours of the day.

If so desired, the energy efficiency of this framework allows for continuous use throughout the day and night with minimal battery replacement. Figure 5 shows a comparison on power usage between the SensorTag and three common development boards with wireless capabilities. The Arduino's, Raspberry Pi's, and Redboard's power range from $180\ mW - 1150\ mW$, while the SensorTag's power ranges from $0.03\ mW - 0.09\ mW$ during an active cycle. Long-term deployment of the sensor can be achieved without requiring an additional power supply or energy harvesting device. It should be noted that currently the smartphone application remains unoptimized, and does pose a power consumption issue. Typical smartphone devices do however require charging on a daily basis, resulting in only a minor implication.

This framework is also extensible to a wider range of applications and sensors. Variations in smartphones and BLE enabled sensors can further allow for Global Positioning System (GPS) location tracking, accelerometer based step counting, as well as microphone information to better reflect environmental conditions. An extension of a cloud-based server can provide data analysis to better depict user trends and highlight activities with significant mood alterations. All of this can be accomplished with this simple framework, maintaining individual mobility and sensor deployment lifetime.

VI. Conclusion

In this paper, a simple framework is proposed to better help address mental health and wellness self-assessment. First, we selected the appropriate hardware capable of collecting environmental data. This hardware not only has to ensure user and sensor mobility, but also must be capable of communicating with an energy efficient protocol. After this, a communication link is established with an appropriate client-server relationship assigned. Next, a UI capable of displaying and storing both environmental and user data must be developed. Then the sensor can be placed in in a location that allows for dynamic, long term deployment, without hindering the user.

With this framework in place, we were capable of providing an additional resource for the monitoring of a student's wellness. By providing empirical data that can be reflected upon, the user is capable of correlating environmental conditions to their mood changes. Avoidance of key activities or environmental conditions can then help improve the user's frame of mind.

The proposed framework is also extensible, which allows for a variety of applications to be explored. By selecting alternative smartphones and sensors, additional information can be collected to better improve the assessment of the environmental conditions. As well, additional hardware and emergent technologies can be assimilated, such as the cloud, further improving the functionality of this framework.

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