Smart Wearable Band for Stress Detection

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***Abstract*— Sometimes mental stress needs to be control as it results in different dangerous suffering. Timely mental stress detection can help to prevent stress related health problems. The aim of this paper is to design an IoT base wearable, cost effective and low power smart band for health care that detect mental stress based on skin conductance. This band can monitor user's mental stress continuously and transmit the stress related data wirelessly to user's smart phone. It not only help the users in better understanding their stress patterns but also provide the physician with reliable data for a much better treatment. Inputs to this device are various signals from different sensors. By intelligently analyzing the correlation between these signals using machine learning algorithm, this band predicts that whether the subject is suffering from stress or not.**

Keywords—Skin conductance, wearable device, smart band

I. Introduction

Mental stress is one of the growing problems of the present society. The number of people experiencing mental stress is increasing day by day. Stress is a response of our body to prepare itself to face difficult situations. When a person goes under stress, his nervous system responds by releasing stress hormones. These hormones make our body ready for emergency actions. In certain situation it become dangerous and can put a person in serious mental disorder. Long term effects of stress can be chronic. Chronic effect of the stress causes health problems like hypertension [1], cardiovascular diseases [2] and memory problems. The sense of loneliness and hopelessness may lead people to suicide. People may be less likely to notice whether they are under high stress or may be generally less sensitive to stress. Stress detection technology could help people better understand and relieve stress by increasing their awareness of heightened level of stress that would otherwise go undetected.

For this objective we have designed a smart band device in order to detect different conductance levels of the skin and predict whether the person is under stress or not. But skin conductance alone cannot accurately predict the stress level in everyday activities. Physiological responses caused by stress can also be provoked by physical activities like running, lacking of sleep etc. In order to accurately measure the stress level, classification should be made. This band will be capable of detecting stress by analyzing different parameters in accordance with skin conductance like activities tracking, sleep quality etc. The collected data is then transmitted to user's smart phone via Bluetooth and upload to web from where it can be accessible by doctor or family members.

II. State of the Art

There exist several technologies for recognition of stress level. There are also several reports on physical effects and on the detection of physical changes occurring as a result of mental stress. Parameters that can be used for stress detection are, muscle tone, pupil diameter [3], heart rate variability [4], Electroencephalography (EEG) to measure stress related brain waves [5] and cortisol [6], skin conductance [7 8]. IOT based wearable health care devices and fitness bands are available that uses heart rate variability to measure stress level. The heart rate can show variation in most cases. For example, people may have higher heart rate when standing than when sitting. Hence using heart rate as an indicator to detect mental stress may lead to misclassification.

Heart rate, HRV and blood pressure can be used to monitor the activity of sympathetic and para-sympathetic nervous system. Vrijkotte demonstrated the process of evaluation of work stress using blood pressure, heart rate and HRV [9]. Dishmen et al. Showed distinction between different emotional situations using heart rate variations [4]. Skin conductance is another parameter used for stress detection. The sweat secretion in stress condition decrease the skin resistance and increase skin conductance. This type of fluctuation in skin conductance can be used to measure stress level. Setz et al. accurately classified different responses of skin conductance automatically from cognitive load and stress very efficiently [8]. Hermandaz et al. differentiated stressful and non-stressful calls at the call center environment using skin conductance feature [7]. Mokhayeri et al. classified stressed and relax conditions by using multi-modal physiological signals like pupil diameter, electrocardiogram and photoplethysmogram [3]. Skin conductance has also other medical applications such as epilepsy control because sweaty hands may be a symptom of epileptic attack. Skin conductance in combination with skin temperature can also be use to develop truth meter [10] because when a person lies his hands become cold and is skin resistance become low.

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Besides this, the design and development of wearable sensor based system for health monitoring has acquired great attention in the scientific community and industry during last year [11]. These devices provides low cost unobtrusive solutions for continuous any time, any place health monitoring by comprising of different types of physiological sensors, transmission modules and processing capabilities. A lot of manufacturers like Philips, Nellcor, Nonin and Egilent etc are providing small wearable health care devices. For example Polar and Omron uses a chest worn belt for heart rate monitoring and wrist watch for measurement display [11]. Blufitbottle is a water bottle that keeps records of drinking water while keeping the user healthy and hydrated. Aircasting is a platform for recording, mapping and sharing health and environmental data using smart phones and custom monitoring devices.

III. METHODOLOGY

A. Skin Conductance

Skin conductance is considered as a biomarker for stress in which eccrine sweat activity that is controlled only by sympathetic nervous system is measure. Variation in skin conductance is in relation with sweat secretion. When a person is under stress, this stress puts the sympathetic nervous system into actions. Since sweat glands are controlled by sympathetic nervous system so it activates the activity of the sweat glands. Sweat secretion from sweat glands reduce the skin resistance and increase the skin conductance level. Thus skin conductance acts as indicator for sympathetic activation due to stress reaction and can be used for stress measurement. Along with SC, heart rate and skin temperature can also be used as indicator for sympathetic nervous system activities as shown in figure1.

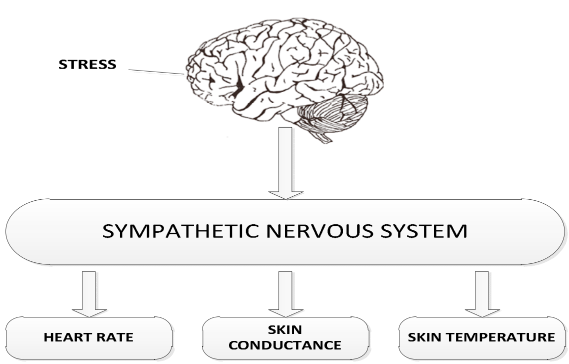

Fig.1 Sympathetic nervous system activities

B. Design

The Hardware of the smart band includes skin conductance sensor, 3-axis accelerometer, Bluetooth and microcontroller. Smart band skin conductance sensor measure the conductance fluctuation from the underside of wrist by applying a constant DC voltage to two silver (Ag) electrodes that are in contact with skin. The skin conductance signal is an indication of the short term fluctuation of the skin conductance. An accelerometer significantly helps in classifying activities such as sitting, running etc [12]. Physical activities also stimulate sweat glands which can bring variation in skin conductance. Therefore an accelerometer is planned to put in smart band to maximize the stress detection efficiency. Complete design is given in figure 2.

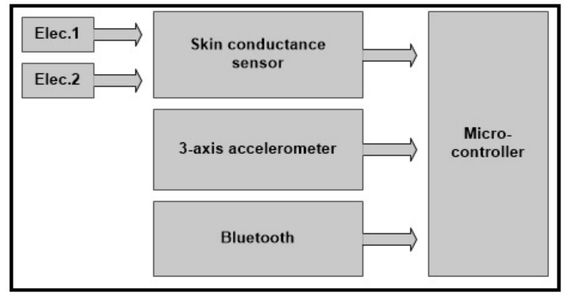

Fig. 2 Smart band design

C. Architecture of skin conductance sensor

Human skin acts as a resistance to the flow of electrical current. In order to measure the skin conductance, a small current is passed through a pair of electrodes placed on the surface of skin. The measure value can be in the form of conductance, resistance or voltage value. The range of the skin response is between 10kΩ and 10MΩ.To find out this value we use one resistance in series with skin resistance. This device uses a voltage divider as shown in the figure 3.

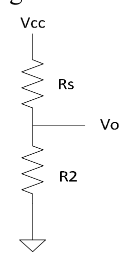

Fig. 3 Voltage divider

Rs is the resistance of the skin and R2 is 890kΩ. Vo is the output voltage which is obtained by

$$Vo = \frac{R2}{Rs + R2} Vcc$$

It can be observe that the Vo output is inversely proportional to the value of skin resistance. The more stressed the person is, the more sweat his hands will be. So his resistance will decrease. Thus we can conclude that for more stress the output voltage will be high. A low pass filter made by a capacitor and a resistor is also included to filter out the high frequency.

D. Data analysis

The data used for the prediction of stress was collected based on experiment consisting of extracting SC signals from 12 individuals [13]. These individual have ages from 23 to 56. The sampling rate was 4 Hz. This data was acquired from these individuals knowing their mental condition (stressed or unstressed) and physical activities. The data was organized in two groups, with efforts and without efforts. The output voltage averages for these individuals are mentioned in the table 1.

a. *Logistic Regression*

Logistic regression is use for analyzing data in which there are one or more independent variables that determine an outcome. In logistic regression there are only two values to predict, 1 or 0. In our case logistic regression will predict the probability whether the subject is under stress (1) or not (0) based on the reading of the skin conductance. For a specific training set the cost function for logistic regression are given as follows.

$$J(\theta) = \frac{1}{m}\sum_{i=1}^{m}\mathrm{Cost}(h_\theta(x^{(i)}), y^{(i)})$$

$$\mathrm{Cost}(h_\theta(x), y) = -\log(h_\theta(x)) \qquad \text{if y = 1}$$

$$\mathrm{Cost}(h_\theta(x), y) = -\log(1 - h_\theta(x)) \qquad \text{if y = 0}$$

The analysis of the data presented in table was carried out using logistic regression. The training accuracy was found to be 91.66% and 100% with and without regularization respectively.

Table 1: Difference in relaxed and effort situation

Users	Without effort(V)	With effort(V)	Stressed
User 1	1.7396	1.6118	Yes
User 2	1.5379	1.6309	Yes
User 3	1.6153	1.6153	Yes
User 4	1.3839	1.6711	Yes
User 5	1.1266	1.1431	Yes
User 6	1.1388	1.0186	Yes
User 7	1.0011	1.0943	No
User 8	0.8238	0.9581	No
User 9	1.101	1.123	No
User 10	1.060	1.0971	No
User 11	0.7096	0.7931	No
User 12	1.0529	1.0811	No

E. *Operation*

This smart band having the potential of continuously monitoring, measures the skin conductance of the user via two electrodes. These electrodes are present on the inner side of the band. Being in direct contact with the skin, these electrodes pass a small DC voltage through the skin and receive the response. The band records the output voltage and after analyzing by different algorithms while keeping other parameters under consideration predicts the stress condition of the user. The band is also connected to user's smart phone through Bluetooth. Mobile receives data from the band wirelessly and let the user know about stress level. The mobile application also enables the user to upload data manually or automatically to specific website from where this data can be use by doctor for medical assistance. The whole operation is summarized in the figure 4.

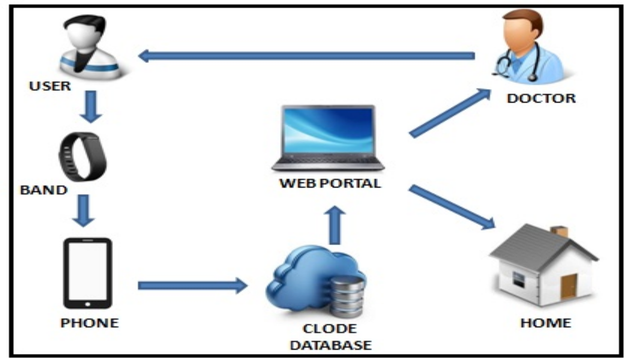

Fig. 4 Operation

IV. Conclusion

To overcome the problem of stress we demonstrated the procedure of a wearable smart band that efficiently detects the user mental stress. This band has the capability of monitoring stress level continuously in everyday activities. It not only send alerts to users via smart phone but allow him to manage stress and to share health data with doctors and family members. Remote patient monitoring using this device may increase access to efficient caring and decrease healthcare delivery cost.

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