

Stress Detection Using Smartphone and Wearable Devices: A Review

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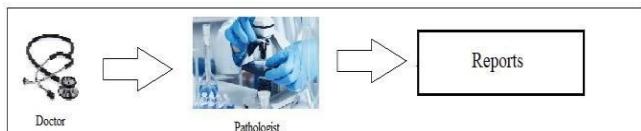


Figure 1. Traditional Stress Detection System

Abstract—Stress is the mental condition of the human body that causes its dis-functioning. It affects adversely on body parts resulting in health disorders. Traditional method of stress detection includes lab tests done by doctor. Besides traditional techniques, sensors are used to measure physiological signals, as these signals make it easy to detect stress. Based on techniques of data collection, this paper is divided into two types, one for In-lab experiment, in which participants wear various sensors on their body which is invasive for real time application while in second, data was collected from sensors which are already available in the handy devices of participant such as smartphone, wearable devices etc. Different types of sensors and their uses are explained in this paper. Automatic real time stress detection systems can be developed. This paper lists various algorithms used to gain more accuracy in detecting stress. This paper is helpful for the fellow researchers who will be working on automatic stress detection. Various studies in this domain have been reviewed and this is a primary effort in summarizing the highlights of the previous research done in stress detection domain.

Keywords—*Stress detection, Physiological signals, Fitbit, E4*

I. MOTIVATION

According to World Health Organization (WHO), the count of people suffering from depression is nearly 350 million. Stress can lead to depression and further leads to suicide. Count of suicide is almost 1 million per year [31], so it is necessary to detect stress at primary level. Positive stress is like a motivation while negative stress badly affects human health as it is long lasting [34]. Being a long term it adversely affects human body, so it is necessary to detect negative stress. It is mostly seen in the people at working areas where the workload is more, along with deadlines and pressure of completion of the work.

II. STRESS DETECTION SYSTEM

A stress detection methodologies studied here can be divided into three types as follows.

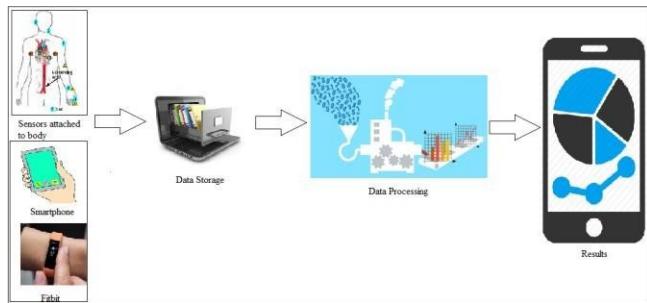


Figure 2. Automatic Stress Detection System

A. Traditional Methods

Following are few traditional methods to detect stress. Medical Tests – These can be done to know each physiological signals which reflects stress clearly for e.g. heart rate, galvanic skin response etc. [16], as shown in Figure 1.

Facial expression - In our day to day life, we come across many people. Some are known to us while some are not. We can easily detect the changes in behavior or the emotions of a person which are very well known to us. We can tell whether he/she is tensed by observing his/her behavior. But same thing doesn't happens with the person which are not known or very less known to us. Because

Few are explained in Table II below. By considering these two ways, let's start with stress detection using sensors.

B. Using Sensors for Stress Detection

When an individual is stressed, there are few fluctuations (depending on how much the person is stressed) in physiological parameter values [16]. Various physiological parameters used are explained in Table I. Sensors are attached to different body parts as shown in Figure 2. Autonomic nervous system manages various functionalities of a human body [16]. Sympathetic nervous system and parasympathetic nervous system are the categories of ANS. SNS controls the reactions occurred when person is stressed while PNS controls resting activities of body [17]. To calculate these parameters, various sensors are available. These physiological parameters are calculated using various sensors and used for stress detection as follows.

To record brainwaves, a device which is an interface between brain and computer is kept on head and later divided into different bandwidths [1]. EEG (Electroencephalography) is used to record signals of brain activities. Neurofeedback technique, which is the modern way to reduce stress is also used. i-care stress is an android application in which data is taken in two ways, one from emotive device which records brain activities and other from questionnaire to know the state of stress. This raw data is processed, and stress level is calculated. To reduce the

knowing someone's behavioral changes happens only when the person is known to you.

Hormone analysis – During stress, level of various hormones gets changed [33]. So by testing level of these hormones stress can be detected.

As stress is becoming one of the major risk factor to the health, it needs to be detected and reduced. To know whether the person is stressed or tensed, there should be some way that will detect their daily behavioral patterns and will detect changes in that patterns.

To know these patterns, system needs to collect required data of each user, analyze it and make inferences accordingly.

The main challenge in detecting stress is that it varies from person to person i.e. although same work is given to all, it shows different levels of stress for every other person [11]. Stress of a person can be detected by examining the changes in emotions, daily routine etc. But this cannot be applied for everyone. For this we need to collect all the data of an individual and reveal all the changes in the regular behavior. Collection of data can be done in two ways, one is using medical tests and other using sensors in those devices handled by the user. These devices include smartphones, smartwatches, Fitbit etc., which have many sensors in it,

calculated stress three actions are provided, user is free to choose one of them. Actions include concentration, music therapy, and relaxation. In concentration user has to control his/her mind, and by doing so, stress can be reduced. In relaxation, deep breathing technique is used, which makes user calm. Third technique is music therapy, which requires entire mind to work simultaneously, hence relaxes mind. Stress levels, before and after applying above actions are recorded and are shown graphically, so as the user can observe the changes.

TABLE I. PHYSIOLOGICAL PARAMETERS USED

Physiological Signals/ parameters	References
Electrodermal Activity of skin (EDA)	[17,18,20,22,25,29]
Blood Volume Pulse (BVP)	[17]
Electrocardiography (ECG)	[17,18]
Electromyography (EMG)	[17,25]
Heart Rate Variability (HRV)	[7]
Heart Rate (HR)	[18,20,22]
Respiration Rate (RR)	[20,25]
Systolic Blood Pressure (SBP)	[20,29]
Electroencephalography (EEG)	[26]

Sioni R discussed how different physiological signals are affected during stress and various techniques to measure these signals such as Electrodermal activity of skin, Blood Volume Pulse, Electrocardiography, Electromyography etc. To measure these, various sensors and equipment are required which needs to be kept on particular area of body. Also it is recommended that these sensors should be

included in the wearable devices. Also, heart rate variability (HRV), is considered as one of the important factor deciding stress, as it is a non-stationary signal. Various operations like preprocessing, analysis, feature extraction are performed on ECG signals. Feature extraction is done on the basis of time domain analysis as well as frequency domain analysis [7].

TABLE II. VARIOUS ALGORITHMS USED

Algorithms	References
Random Forest	[11]
Support Vector Machine (SVM)	[18,2,21,24,11]
K-nearest Neighbor (KNN)	[18,2]
j48	[8,11]
Naïve Bayes	[8,21,24]
Linear discriminant function (LDF)	[21]
Bagging	[11]
DBSCAN	[15]
k-means	[15,26]

Feature extraction of Heart Rate, Galvanic Skin response, Heart Rate Variability is done using time and frequency as parameters, in which 92.75% accuracy is achieved. K-nearest neighbor and Support Vector Machine algorithms are used for classification. Using different sensors, physiological data is taken from working people and dataset is generated (SWELL-KW dataset) [18].

To develop a real time system, neural networks are trained using signals like Respiration Rate, Heart Rate, and Systolic Blood Pressure. These proved most effective for accuracy [20]. The sensors capture data continuously resulting in more energy consumption, to avoid this, first data of galvanic skin response is taken and analyzed. If it shows symptoms of stress then level of above mentioned physiological signals is taken. Stress detection process takes place only when these signals show the symptoms of stress. The study in which devices or machines are trained such that it recognizes human emotions and stimuli like artificial intelligence [5].

Instead of using various sensors to know stress, a single sensor i.e. Electro-dermal Activity sensor is used in [21]. For this, MIT Media lab 'stress database' is used. Model is trained, tested and then used. 81.82% accuracy is achieved [21].

Using just two signals i.e. Heart Rate [22] and Galvanic Skin Response [29,22] an accuracy of 99.5% is achieved. In-Lab experimentation is done. To collect data, sensors were worn by the participants [22].

Electroencephalography signals of a patient are continuously taken for medical diagnosis. EEG detects the change in brain activities which can be noticed by their frequency changes. These signals are used in [6,26]. Using k-means clustering [26], and deep learning methodology [6], patients are divided into different categories of stress. Just EEG signal is used, therefore consumption of human efforts and time is reduced. Dataset is obtained from Matrix Radiotherapy from Kolhapur [26].

C. Automatic Sensing Methodologies

Almost everyone uses smartphone frequently. It has various inbuilt sensors for different purposes as explained in Table

III. Less or more of these sensors are available in wearable devices like Fitbit, E4 etc. Uses of these sensors is explained in the

table. Also no special handling of these sensors is required. Pattern of using smartphone and sensing data impacts a lot on person's stress [14]. Along with this, sleeping pattern and social interaction is also taken for better results [4]. Data

But when smartphone is motionless (kept somewhere during sleep, meeting etc.) creates obstructions in collecting physical activity data. Same issue doesn't occur when wearable devices like smartwatches are used because same sensors are available in smartwatch also. Here smartphone and smartwatch are used for data collection [13].

Orientation and placement of these sensors in smartphone or other wearable devices greatly influence the success of this system. But in real time application the variability in the placement and orientation of these devices should be handled properly. Fusion of sensors is a technique in which data from sensors is analyzed together to get more accurate results [13]. According to Thapliyal H., using IoT, various devices can be developed for automatic stress detection. Various sensors that collect different types of data required to detect stress are explained. A mobile application is necessary to function these sensors and analyze data.

Here five wearable devices are taken for this study, these are HeartMath Inner Balance, Spire, WellBe, Zensorium Being, Zensorium Tinke. All these devices are attached with at least one, either android or iOS application having access to the location and calendar with the users permissions. According to this study, HRV method is important to detect stress.

TABLE III. SENSORS AND THEIR USES

Sensors	Uses
Accelerometer	Gives Activity Data. To detect activity of a person such as whether he/she is stationary, walking or running [11]
Microphone	To detect audio surrounding of a person (silence, voice or noise) [11]
Conversation data	To detect if person is near conversation [11]
GPS data (GPS Chip)	To know the location of person [11]
Call log data	Information about time and duration of calls [11]
Light sensor data	If the phone is in dark, charging or locked for a longer period of time(battery charging and locking data) [11]
Optical Sensor	Variations in blood volume and heart rate are detected using LED light that reflects off the skin. Available in Zensorium Being device [9].
Infrared Blood Flow Sensor	Using IR light, blood flow speed in ear is calculated [9].
Heart Rate Monitoring Sensors	Using Heart Rate Variability, heart rate is taken [9]

Gjoreski M., proved that using only smartphone creates many challenges. Though the work profile is same for the people, stress observed is different for each person. Here person wise different model worked better using random forest. Along with the use of sensors that detects physiological signals, voice

obtained from these sensors is used for stress detection by various researchers, as explained below. Accelerometer sensor in smartphone collects physical activity of the user.

permission of user to his/her highly private and sensitive contents. Data from sensors of smartphone such as microphone, accelerometer, electronic compass, light sensor and app usage history is taken from user for this study. Mood-Explorer is an android app which collects sensing information. This app sends notifications to user and reports their emotional state. Around 76% accuracy is taken from ML model [14].

Jin Lu's combination of smartphone and Fitbit along with questionnaire data are used. In the beginning of this study, clinical diagnosis of each participant is done. From smartphone, location and physical activity of the user is taken. For clustering DBSCAN is used. Activity data, heart rate, sleeping patterns are extracted from Fitbit. Here multi-task learning is a proposed method [15].

III. DISCUSSION

According to World Health Organization (WHO), in future one individual among four will be suffering from mental disorder [32]. As we saw in above studies, to know the person's stress, it is important to know all the activities of a user along with their physiological parameters. Data is captured in two different forms, one in constrained environment, taking few participants for particular period of time (having some restrictions) for the purpose of study and second in unconstrained environment i.e. participants were free to do anything without any restriction.

Some studies captured this data using sensors. But to develop a system as a real time application, user will be in unconstrained environment.

Now to capture data, few studies used special sensors which were attached to the user's body, and some took data from the devices which user uses daily such as smartphone and various wearable devices.

But having these sensors attached, user's body created disturbance in their daily routine. So capturing data from devices which user uses daily will be more comfortable. Various algorithms and techniques are applied as shown in Table II.

analysis can also be done [11]. Person specific model works better [12], but for this, more labelled data is required and in case of general model, no labelling is required. Garcia-Ceja only accelerometer is used for sensing data.

Even for mood prediction, blood pressure, heart beats, blood pressure etc. can be considered. SMS, Email contents also gives basic idea of the mood of a person, but it requires

IV. CONCLUSION

World Health Record of World Health Organization, mentioned that among four individuals, one will suffer from mental disorder. 450 million people around world are suffering from stress [32]. Although much of study is done in the area of stress detection, more accuracy in unconstrained environment is needed. As we have seen above, no extra handling of sensors will be preferred by a user. It is fruitful to take data using sensors which are already present in the devices handled by user frequently.

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Combination of various sensors will result in better accuracy.

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