RESEARCH ARTICLE

Stress Monitoring Using GSR in People with Anxiety Disorder and Analysis Using Optimization Algorithms

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ABSTRACT

Purpose:

Anxiety disorder is a serious issue that leads to depression, which in turn causes various physical and mental health problems. Monitoring the level of stress in people with anxiety disorder is very important, considering they often fall into panic attack episodes when anxiety levels increase.

Methods:

In this work, a study is conducted among eleven people by assigning a critical task and monitoring the level of stress using a GSR V 2.0 sensor and an Arduino microcontroller. The obtained EDA signals are processed and analyzed using a convex optimization-based algorithm (cvxEDA) for decomposing the GSR signal and a Trough-to-Peak algorithm for measuring the number of peaks in the SCR.

Results:

The findings indicate an increase in stress reactivity when subjected to critical tasks. Stress levels are categorized based on the number of peaks in the SCR.

Conclusion:

The proposed work can aid clinical psychologists in assessing human stress levels non-invasively and is also very cost-effective.

Keywords: cvxEDA, EDA, GSR, Stress, SCR, TTPAT

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1. INTRODUCTION

Stress is most dangerous factor that affects human life. Stress occurs due to food and other things in working life. Stress detection is significant because it shows how the brain reacts to inputs during the neuronal activity-related conceptual processing (10,18). Stress often leads to a Panic Attack where people often worry about their health and other things regularly. Even when the doctor reports are normal the people will not accept it and keep on worrying. Example of panic attack is people often feels they have symptoms of heart attack, stroke, other major diseases and keep on checking their body by monitoring heart rate, Blood pressure and some people taking number of ECG and other blood tests.

When the anxiety level increases Panic attack occurs in episodes. During panic attack period people are so anxious and in the worst case feeling like they are about to die any moment. Hence it is very important to monitor the level of stress. In general researchers used to measure stress by measuring HRV, Blood Pressure and temperature (1,3,19). Measurement of Stress using Electro dermal activity is a new concept for researchers. A person level of stress is determined using Skin temperature with the help of GSR skin current sensor V2.0. Number of GSR peaks in the output of GSR sensor is an indication of person level of Anxiety.

Electrical conductivity of the skin is measured using GSR sensor. Galvanic Skin Resistance (GSR) also called by name Electrodermal Activity (EDA). The sympathetic

nervous system controls how the body reacts to specific stressors, and as a result, sudomotor nerve activity causes the sweat glands to fire (4,13). This results in a shift in the skin's conductivity. Skin conductivity can be measured by two electrodes placed in the surface of skin. A mechanism in the signal chain for EDA measurement allows current to be injected between the two electrodes; the voltage that is detected serves as an indicator of skin conductance.

Sweat activity changes in accordance with emotional excitement. GSR is measured using electrical characteristics of skin. **Skin conductance** is **directly proportional** to sweat gland activity. Conductivity of the skin increases with the increase in sweat gland activity (12,14).

The main advantage of EDA is its noninvasive approach. EDA has mainly two components.

SCL -Skin conductance Level

SCR – Skin Conductance Response

The tonic component (Skin conductance level) is associated with slow-changing signals and the signal's background features. The signal's phasic components (Skin conductance Response) are those that change quickly. Skin conductance response is used to gauge how the sympathetic nervous system responds to specific stimuli and is used to measure Cognitive stress intensity (14).

Skin conductivity response is measured in Micro siemens (μS). The palmar and plantar areas of the hands and feet have the highest density of eccrine glands (16). The two electrodes on any two fingers are connected with GSR Sensor. The current flow between the electrodes is measured as a continuous signal and is proportionate to skin conductance. In this proposed work the people with anxiety disorder are subjected to a critical task of reading an article about a specific disease like a heart disease and filling a form about their own symptoms related to the specific disease.

Increased anxiety levels can affect the patient confidence in taking critical task assigned to them (7). With minimal preparation times and cleanup, skin conductivity is recorded non-invasively using two electrodes placed on the fingers. This renders GSR measurements a lot more comfortable for respondents compared to other methods such as fMRI or EEG, where longer preparation and calibration phases are quite common.

The four important performance metrics of GSR measurement are listed in Table 1.

Table 1: Performance Metrics in GSR Measurement

S.No	Performance metrics	Description
1	Latency	The time delay in producing a Event-Related Skin Conductance Response once the stimulus is given
2	Peak amplitude	The amplitude difference between onset and peak.
3	Rise time	The time required for the Event related skin conductance response to reach its peak value from the onset
4	Recovery time	The time it takes for the Event related skin conductance response to recover and reach the offset value from its peak value

2. LITERATURE SURVEY

In order to calculate heart rate, heart rate variability, and pulse-related metrics, PPG and ECG feature extraction intrinsically rely on peak identification (R-peaks in ECG, systolic peaks in PPG). The earlier works uses peak detection methodology as a preprocessing step (2).

In recent years, wearable sensing devices (smart electronic gadgets) worn on the body as implants or accessories have garnered a lot of attention from researchers. Thanks to advancements in manufacturing and sensor technologies, they are developing quickly in terms of technology, functionality, size, and real-time application capabilities (6).

Autonomic Bio signals has the Potential for Effective Monitoring of Stress. Wearable devices integrated with such system for assessment of stress in Real Time (5). EDA Readings Collected using sensor are often has motion artifacts and noise. Hence Suitable Optimization algorithms should be employed to extract useful information from GSR Data (9).

Removing noise component and motion artifacts from the raw GSR Signal can significantly improve accuracy level in prediction of anxiety level (11).

In general, it is difficult to analyze GSR signal, Hence measuring the peak count and its amplitude can give

useful information from the GSR signal rather than simply analyzing it (8).

3. MATERIALS AND METHODS

GSR Sensor V 2.0 is used here for the measurement of skin conductance. V 2.0 is known for high precision, higher accuracy, and better stability. Electrode pair connected to two fingers is used to pick up the electrical skin conductivity and transfer it to the GSR sensor. The experimental setup is illustrated as block diagram in Figure 1.

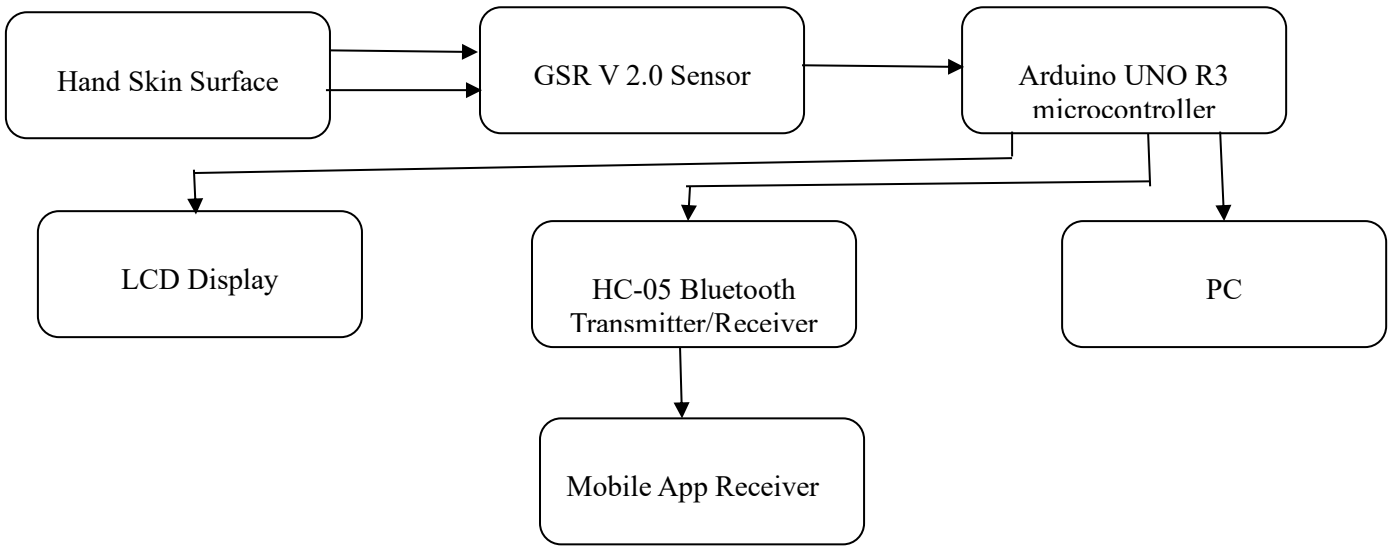


Fig. 1. Experimental Setup Block Diagram

The raw GSR data measured using the V 2.0 sensor is fed to the Arduino UNO R3 microcontroller. The board has 20 I/O pins (14 digital and 6 analog), and it offers a USB-to-serial communication interface. Arduino 1.8.19 version software is used in this study.The HC-05 Bluetooth Transmitter/Receiver module is used here to transmit the Arduino board GSR output value to the smartphone. The device can be used within the distance of 8m.

16x2 LCD display is used for displaying the raw GSR voltage value. It receives the output GSR value from the Arduino microcontroller. The same output can be either plotted or observed in the PC via COM4. The readings are taken at a baud rate of 9600. The real-time experimental setup is shown in Figure 2.



Fig 2. Real-time Experimental setup

GSR activity is typically measured in micro-Siemens (µS) and normal human skin conductivity (GSR) ranges from 1 to 20 (µS). The reason GSR is such a valuable biometric signal in assessing emotional behavior is that it leverages unconscious behavior not under cognitive control. Skin conductance (EDA) is exclusively regulated by autonomic sympathetic activity (17). By leveraging suitable algorithms, it is possible to identify patterns and classify stress states with greater accuracy than traditional methods

The collected data were analyzed in the time domain by computing the number of GSR peaks for each signal. The results of the time domain analysis show a growth of the GSR peaks number as the intensity of physical effort increases. When subjected to stress, sweat glands become more active, consequently the concentration of sodium and chloride ions in the skin increases and causes a rise in conductivity of skin. The coding for serial plotting and printing of GSR value on PC via COM4 is shown in Figure 3.

GSR | Arduino 1.8.19

File Edit Sketch Tools Help

GSR

```
#include <LiquidCrystal.h>
#include <SoftwareSerial.h>

// LCD Pins
LiquidCrystal lcd(2, 3, 4,5, 6, 7);

// HC-05
SoftwareSerial BT(11, 10);    // RX, TX

// GSR
const int gsrPin = A0;

void setup()
{
  lcd.begin(16, 2);

  Serial.begin(9600);
  BT.begin(9600);

  lcd.setCursor(0,0);
  lcd.print("GSR Monitor");
  delay(1500);
  lcd.clear();
}
  lcd.print("       ");          // Clear old value
  lcd.setCursor(0,1);
  lcd.print(gsrValue);

  // Serial Monitor
  Serial.print("GSR: ");
  Serial.println(gsrValue);

  // Bluetooth
  BT.print("GSR Value: ");
  BT.println(gsrValue);

  delay(500);
}
```

Fig. 3. Coding for Plotting and Printing GSR Value

4. GSR SIGNAL PROCESSING

Skin conductance and skin resistance are reciprocals, and most GSR sensors output a raw ADC voltage value rather than conductance directly. Human Skin resistance calculated from the raw sensor voltage output using the formula

Human skin resistance R_{SR} = ((1024 + 2 x V_{GSR}) X 10000) / (512- V_{GSR})

Where V_{GSR} is raw voltage output of GSR sensor.

Skin conductivity is measured as reciprocal of Human Skin Resistance

Skin Conductivity = (1 / R_{SR}) X 1000000

The unit of Skin conductivity is Micro siemens (µS)

The various steps in GSR signal processing is illustrated in Figure 4.

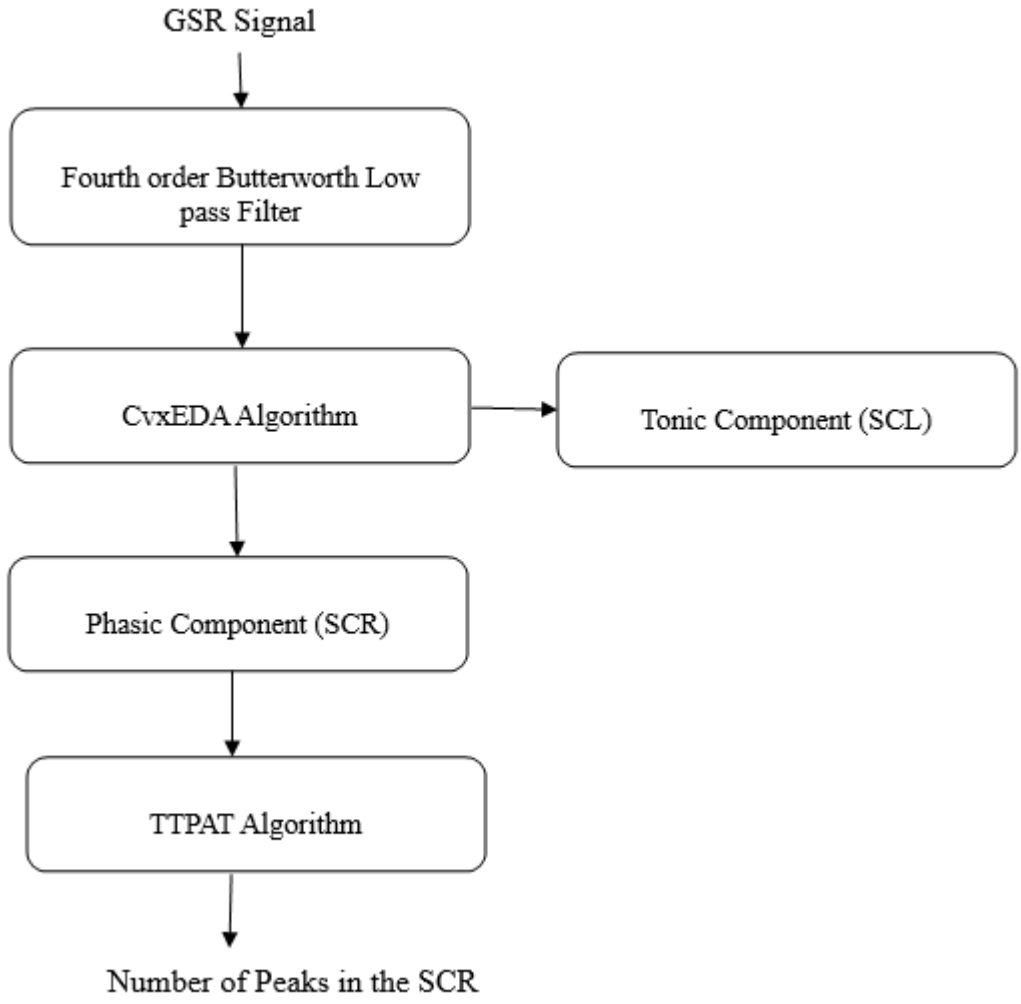


Fig.4. Steps in GSR Signal Processing

In the pre-processing stage, the conductance signal is resampled into uniform time grid and the high-frequency noise component and motion artifacts are removed using 4^{th} order Butterworth low pass filter. The preprocessed GSR signal is decomposed into tonic and phasic components using the Convex optimization based algorithm (cvxEDA). The third step in GSR signal analysis is to find out the number of peaks in Phasic Component (SCR's). Stress level is determined based on the number of peaks in Phasic component. Number of peaks in the phasic component are determined using Trough-to-peak (onset-to-peak) amplitude-threshold algorithm (TTPAT).

4.1 Decomposition of GSR Signal

In this work GSR signal is decomposed using cvxEDA algorithm. cvxEDA takes EDA decomposition as an optimization problem. A convex method always guaranteed to provide the best solution. Skin conductance response (SCR) has a known shape as it has characteristics of rising quickly and decaying slowly, most importantly SCR peaks are produced occasionally, Since the sympathetic nervous system release pulses sparsely. This algorithm focusses mainly on these sparse sequence of pulses. The phasic components are reconstructed using these sparse pulses into a known shape. The mathematical expressions for optimization algorithm are presented below.

GSR output, $g(t) = x(t) + y(t) + n(t)$

Were,

$g(t)$ = GSR output signal

$x(t)$ = Tonic component

$y(t)$ = Phasic component

$n(t)$ = Noise component

The phasic component, $y(t) = s(t) + b(t)$

Where,

s(t) = Sparse driver and b(t) = Bateman impulse response

The value of s(t) is chosen in such a way that it needs to satisfy the following conditions

a) Minimize the mismatch between observed signal g(t) and the reconstructed signal as close as possible to zero value

b) Keep the driver Sparse

c) The tonic component should be a smooth one

d) The driver value should not goes to negative

4.2 Determination of Peaks in SCR

After the phasic component is determined using the cvxEDA algorithm, the number of peaks in the phasic component are determined using TTPAT algorithm. Trough to peak Amplitude Threshold (TTPAT) algorithm is used to find out meaningful events in a continuously varying noisy signal by determining the size from onset to peak. This process continues for each and every Trough and Peak.

1 SCR count = Minium Amplitude of 0.01 to 0.05 µS

The algorithm is preferred over other peak detection algorithms because of its low computational cost, its ability to handle baseline drift and it is best suited algorithm for non stationary signal like GSR.

5. RESULTS AND DISCUSSION

The Raw GSR value is transmitted from GSR sensor to the PC through serial communication port. The data has been displayed in PC via COM port 4(Serial Monitor) as shown in Figure 6. The same port can also plot the graph between raw GSR value and time (Serial Plotter). The raw GSR output is shown in Figure 7.

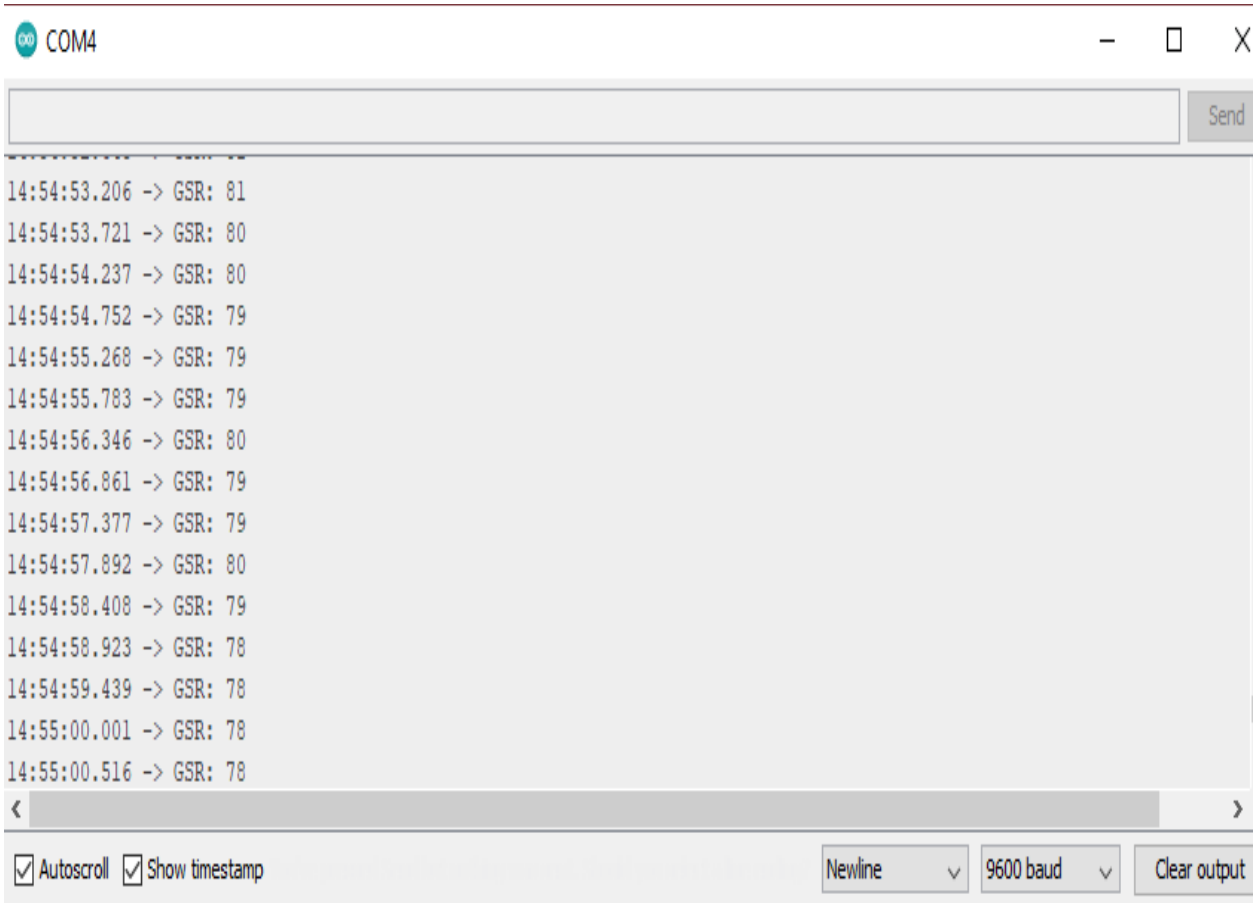


Fig.6. Raw GSR value displayed in PC

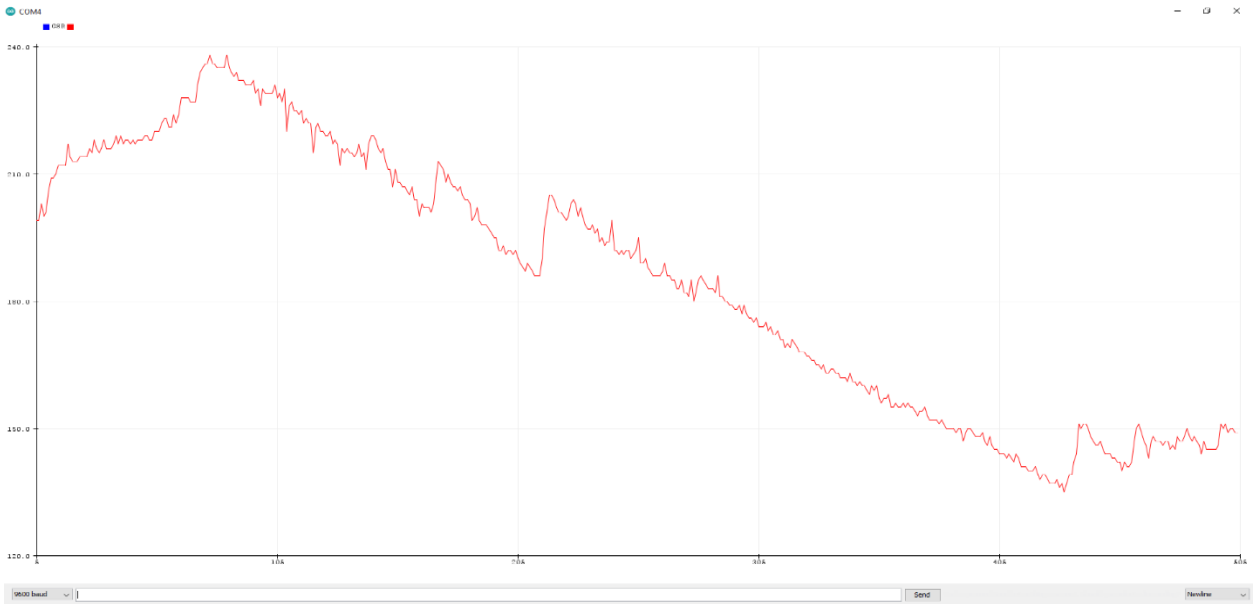


Fig.7. Raw GSR output signal

In general the output of GSR sensor v 2.0 is voltage V_{GSR}, the skin conductance can be calculated from V_{GSR}. Conductance value is displayed in Figure 8.

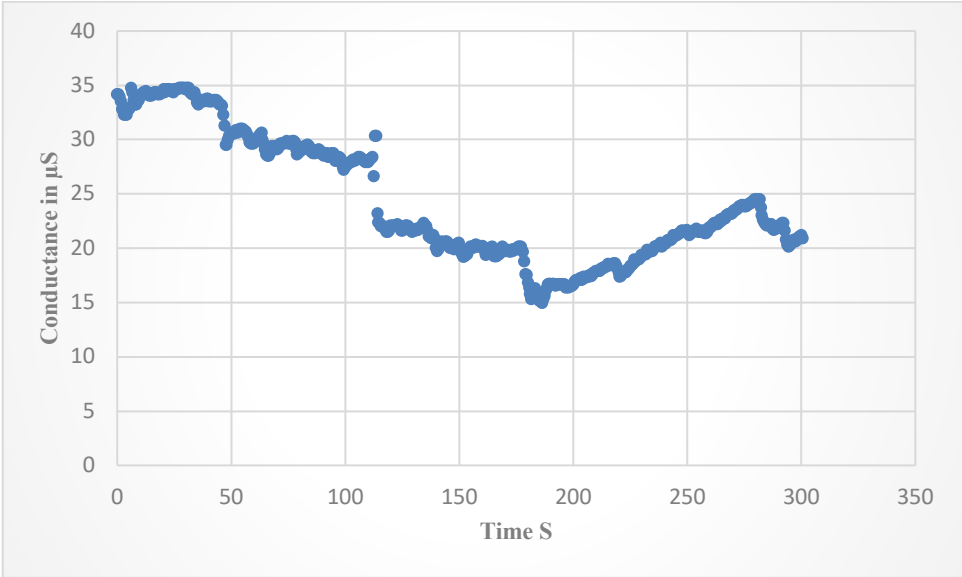


Fig. 8. : Skin Conductance output

Fourth order Butterworth low pass filter is used to remove the high frequency Nosie and motion artifacts. The preprocessed conductance signal is shown in Figure 9.

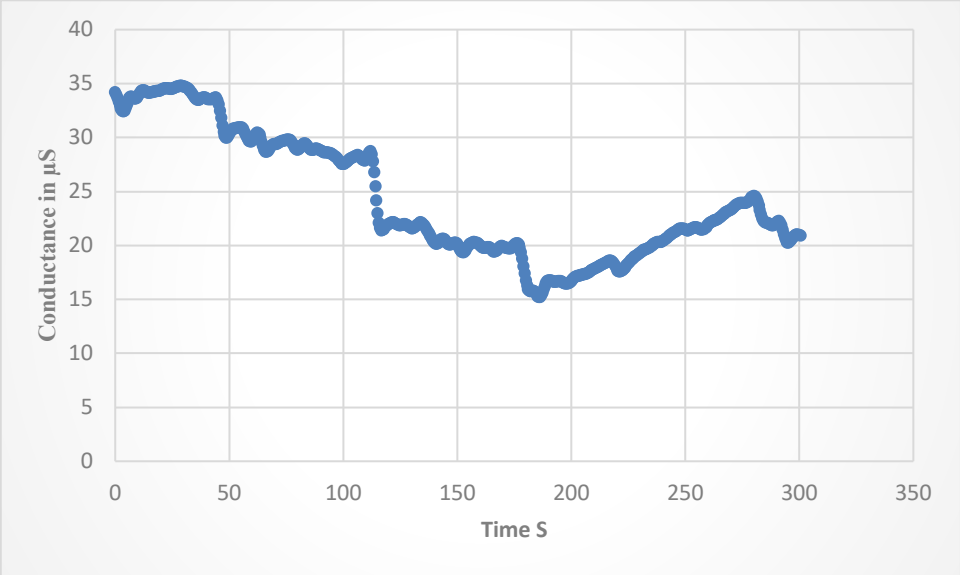


Fig. 9. Pre-processed Conductance signal Output

The preprocessed signal is decomposed into Tonic and Phasic component by convex optimization algorithm. The tonic component is associated with slow-changing signals and the signal's background features. The signal's phasic components are those that change quickly. The phasic component is the Skin Conductance Response (SCR), and it plays a vital role in determining Stress levels. The tonic and Phasic component outputs are shown in Figure 10 and 11 respectively.

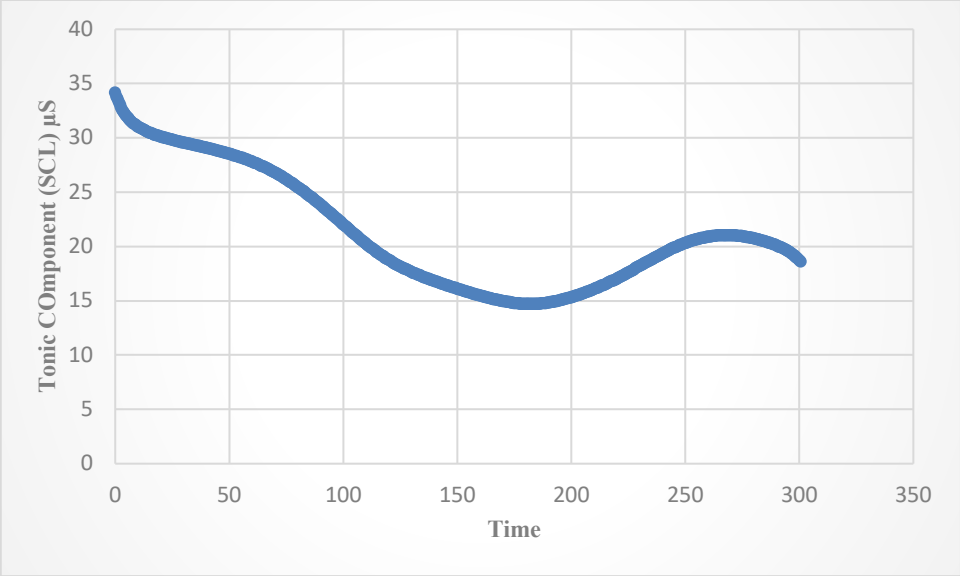


Fig.10.Tonic component output signal

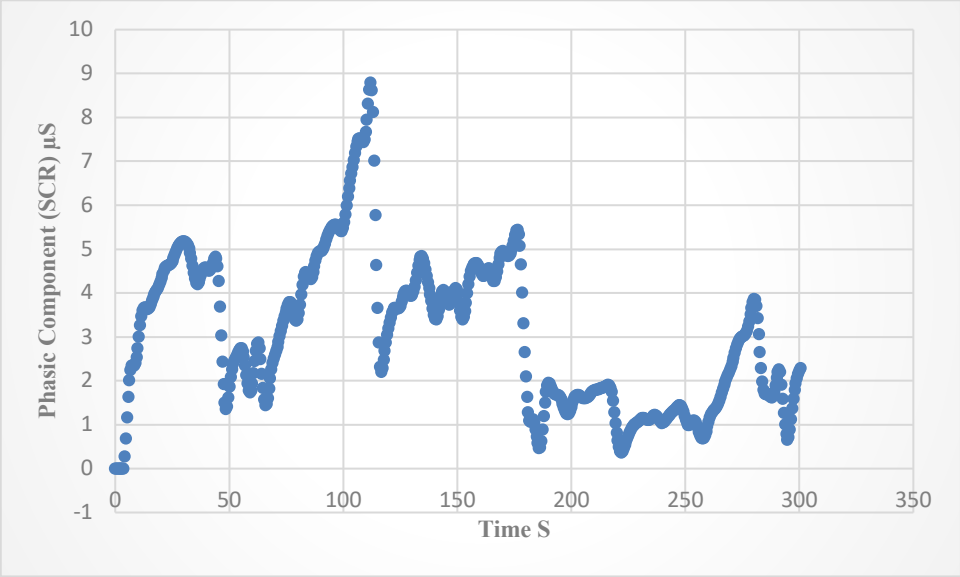


Fig. 11. Phasic Component Output signal

The person stress level is calculated based on the number of Peaks in Phasic Component. If the number of peaks are high then stress level also high. Phasic component with highlighted peaks are shown in Figure 12.

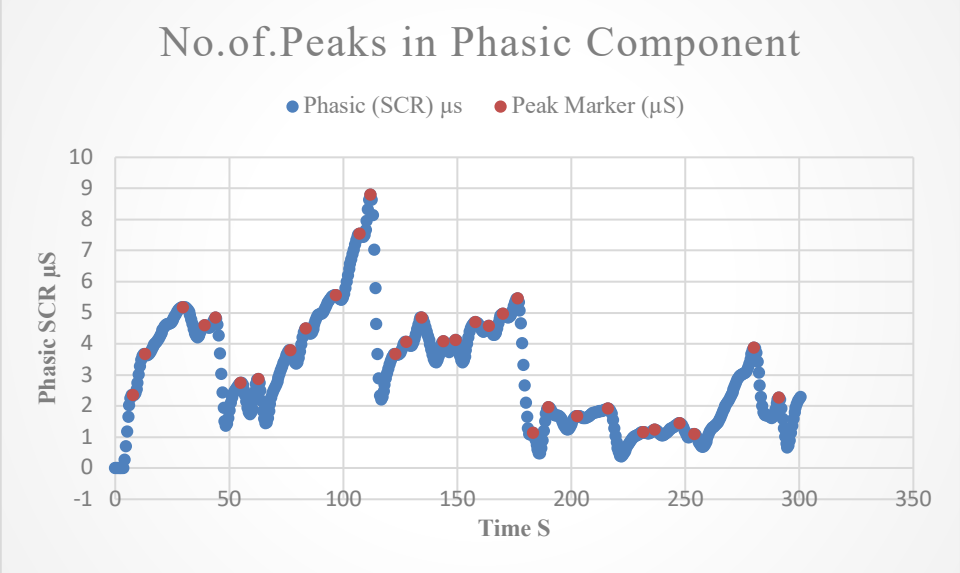


Fig.12. Phasic Component with Peaks

In this proposed work 11 people with anxiety disorder are subjected to a critical task of reading an article about a specific disease like a heart disease and filling a form about their own symptoms related to the specific disease. EDA data are recorded for a uniform period of 5 minutes for all eleven participants. In this research work peak count is taken as a measure of Anxiety level. The level of anxiety among the participants are categorised based on number of peak count during the 5 minute period as shown in Table 2. SCR peaks for all eleven participants are plotted in Figure 13.

Table 2 Anxiety level categorisation

Anxiety Level	Peak Count

People with severe anxiety	≥ 23
People having medium anxiety	17 – 22
People with mild anxiety disorder	≤ 16

Anxiety levels are categorized as mild when peak range is ≤ 16, Moderate when peak count is between 17 to 22 and as High when peak count is ≥ 23. From the results, there are 4 participants each in mild and high category of Anxiety level. There are 3 participants in the Moderate anxiety level category. Peaks per minute for each of the three categories are illustrated in Table 3.

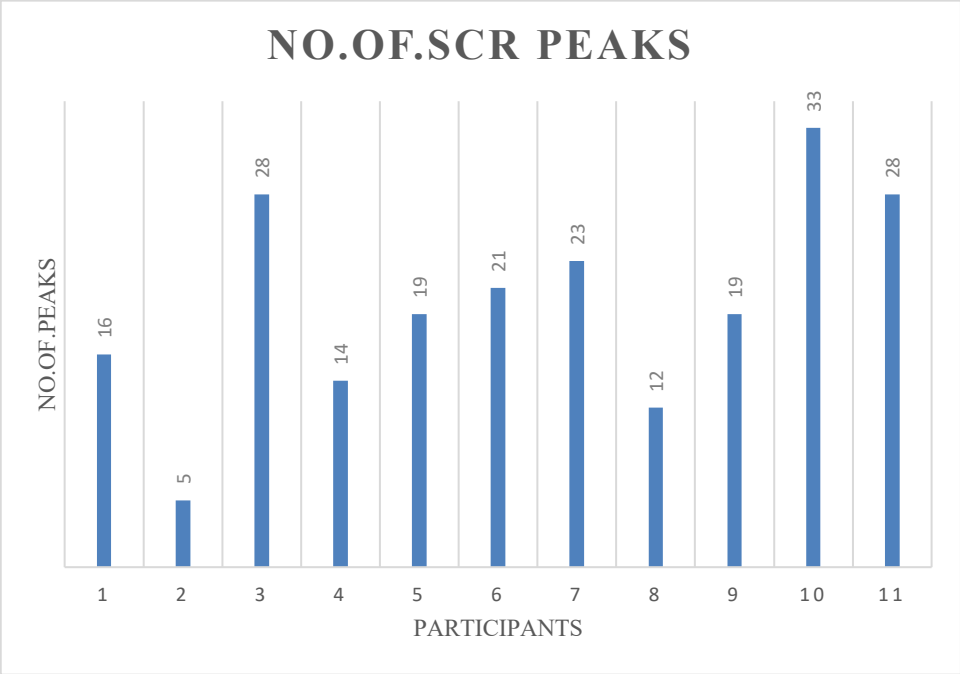


Fig.13. Number of SCR peaks for Each Participant

Table 3: Average Peak per minute vs Anxiety Level

Anxiety Level	Peaks per Minute
Mild	2.4 to 3.2
Moderate	3.8 to 4.2
High	4.6 to 6.6

6. CONCLUSION

Anxiety disorder is a serious issue that leads to depression which in turns causes various physical and mental health problems. Monitoring the level of stress in people with anxiety disorder is very important considering that they often fall to panic attack episode when anxiety level increases. The obtained EDA signals are processed using algorithms cvxEDA and TIPAT. The level of anxiety is often determined by counting number of peaks in the Phasic component. The observed results indicate that anxiety level increases when people with anxiety disorder are subjected to critical tasks.EDA data are recorded for a period of 5 minutes commonly for all eleven participants. Anxiety level categorised based on the Peak count. The study will be a good tool for doctors treating patients in identifying the level of anxiety and give treatment accordingly.

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Competing Interests

"We the authors have no relevant financial or non-financial interests to disclose."

Author Contributions

"All authors contributed to the study conception and design. Hardware setup like gathering GSR sensor , arduino board and other essential devices and components is done by [Suneetha). [G.Nalinashree] has contributed in the use of cvxEDA optimization for decomposition of EDA signal. Extensive literature review on stress measurement, recording the GSR signal, analyse of GSR signal and finding the number of peaks using TIPAT algorithm are performed by (V.Karthikeyan). All authors read and approved the final manuscript."

Ethics approval

"This is an observational study. Hence no ethical approval is required."

Consent to participate

"Informed consent was obtained from all individual participants included in the study."

Consent to publish

"We the authors affirm that we have collected only the experimental data and any specific (individual details, images or videos) hence we are declaring that there is no need for obtaining consent to publish".