STRESS DETECTION FROM HEART RATE VARIABILITY

MINI PROJECT

Submitted by

ARUL KUMAR.V(411620104001)

SURYA.S(411620104020)

In partial fulfilment for the award of the degree

of

BACHELOR OF ENGINEERING

IN

COMPUTER SCIENCE AND ENGINEERING

PRINCE Dr K VASUDEVAN COLLEGE OF ENGINEERING AND TECHNOLOGY, PONMAR, CHENNAI-600 127

ANNA UNIVERSITY:: CHENNAI 600 025

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BONAFIDE CERTIFICATE

Certified that this project report **"STRESS DETECTION FROM HEART VARAIABLITY"** is the bonafide work of **"ARUL KUMAR.V "** and **"SURYA.S"** who carried out this project work under my supervision

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Submitted to the Viva voce Examination held on _ _ _ _ _ _ _ _ _ _ _ _ _ _

NTERNAL EXAMINER **EXTERNAL EXAMINER**

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ABSTRACT

In today's modern society, stress is a huge problem. Although stress is a psychological response, it affects several physiological processes in the human body. Such as imbalance in hormones, increased tension in neck muscles, and change in heart rate (HR), and heart rate variability (HRV). According to Hans Selye, "stress is a response to change in order to maintain the state of stability or homology that the body has maintained against the stimulus to break the mental and physical balance and stability of the body". Being able to measure stress can be a huge help to treat and maintain stress in today's world. When the body is stressed, HRV decreases. From the acquired ECG from a stressed person, HRV is calculated using the Time-Domain method and compared to the HRV acquired from a person at normal/relaxed state. The decrease in HRV proves the increase in stress and can be used for diagnostic and treatment purposes.

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LIST OF SYMBOLS AND ABBREVIATIONS

ECG	-	Electrocardiogram
HR	-	Heart Rate
HRV	-	Heart Rate Variability
Mean RR	-	Mean of RR-interval Mean of heart
Mean HR	-	rate standard deviation of the RR-
STD HR	- -	intervals
Min HR	-	Lowest heart rate
Max HR	-	Highest heart rate
	-	Root Mean Square of Successive Differences
		The number of pairs of successive RR-intervals that differ by

RMSSD more than xx ms

NNxx - The proportion of NNxx divided by the total number of RRintervals

pNNxx - Laboratory Virtual Instrument Engineering Workbench - Student Data Acquisition Device

LabVIEW
myDAQ

CHAPTER 1

INTRODUCTION

1.1 NEED

In today's modern world, stress has become a part of our lives. Stress is a psychological response that causes several physiological processes in the human body such as metabolism, increase tension in neck muscles, bowel dysfunction, insomnia, changes in heart rate, and heart rate variability.

Students and employees are the ones mostly affected by stress. Statistical reports from the UN (United Nations) show that excessively-long working hours and disease, contribute to the deaths of nearly 2.8 million workers every year, while an additional 374 million people get injured or fall ill because of their jobs. To prevent such tragedy, management of stress can be achieved by diagnosing and treating stress.

To diagnose and treat this psychological pressure, measuring stress by calculating the changes caused by the HRV parameters, is used as an indicator for stress. When a person is stressed, HRV is decreased from the normal range.

1.2 STRESS

Stress is basically the "fight or flight" response to a perceived threat. This activates the amygdala, or the "fear center" of the brain, and causes a cascade of events. Stress factors can be classified into four types: physical stress, psychological stress, psychosocial stress, and psychospiritual stress.

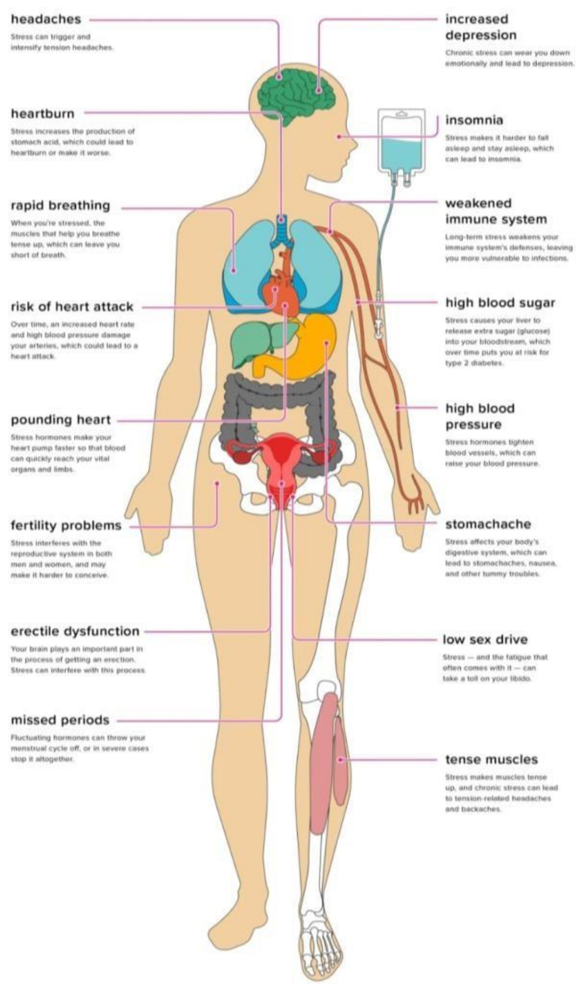


Fig 1.1: Effects of Stress

Harvard Health Publications of Harvard Medical School explains, “When someone experiences a stressful event, the amygdala, an area of the brain that contributes to emotional processing, sends a distress signal to the hypothalamus, this area of the brain functions like a command center, communicating with the rest of the body through the nervous system so that the person has the energy to fight or flee.”

1.3 HEART RATE VARIABILITY

Heart rate variability (HRV) is simply a measure of the variation in time between each heartbeat. Heart rate variability is where the amount of time between your heartbeats fluctuates slightly. These variations are very small, adding or subtracting a fraction of a second between beats. HRV value for an average healthy adult is from 60 to 200 milliseconds.

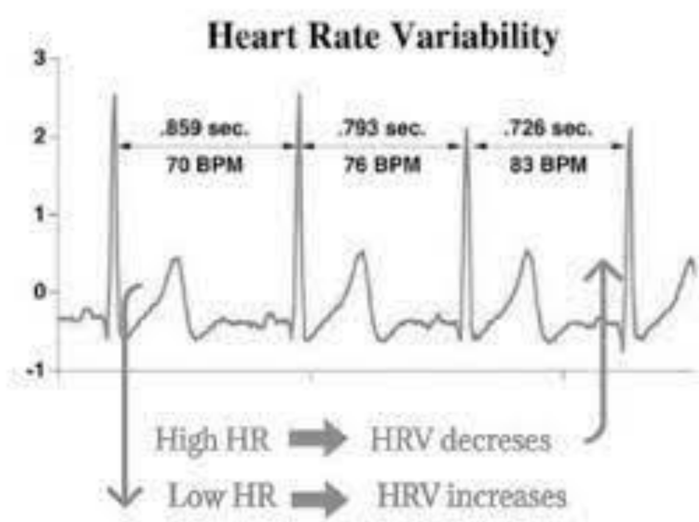


Fig 1.2 Heart rate variability

High heart rate variability usually indicates less stress and a low heart rate variability indicates that the body is under stress, which may be caused by exercise, psychological events, or other internal or external stressors.

1.4 HRV FROM ECG

Heart rate variability (HRV) is the fluctuation in the time intervals between adjacent heartbeats. HRV indexes neurocardiac function and are generated by heart-brain interactions and dynamic non-linear autonomic nervous system (ANS) processes.

By using the Time-Domain method, HRV can be calculated from ECG. To analyze HRV by a time-domain method called RMSSD. This is the Root Mean Square of Successive Differences between each heartbeat. It is relatively simple to calculate (important for large-scale computation) and provides a reliable measure of HRV and parasympathetic activity.

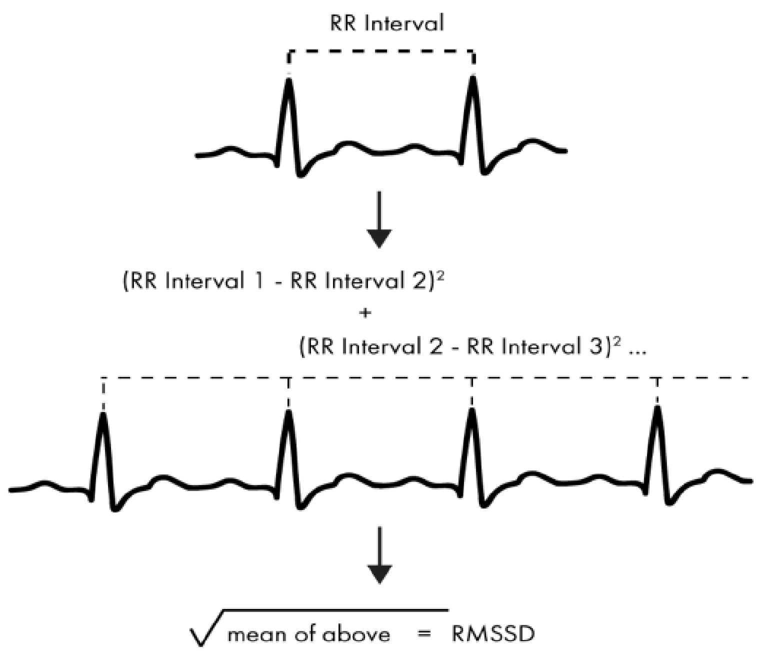


Fig 1.3: R-R interval calculation from ECG

Studies show that, from HRV parameters, stress levels with respect to changes in the ECG of a person can be derived more accurately. The HRV parameters used here are SDNN (Standard Deviation of NN intervals, RMSSD (Root Mean Square of Successive Differences)

1.5 RELATION BETWEEN STRESS AND HRV

An increase in heart rate (HR), is a physiological response to stress which decreases heart rate variability (HRV). When a threat or stressor is perceived, this cognitive inhibition is removed triggering the default stress response which results in physiological activity. When the stressor has ended, the stress response is again inhibited and physiological activation returns to 'normal' values.

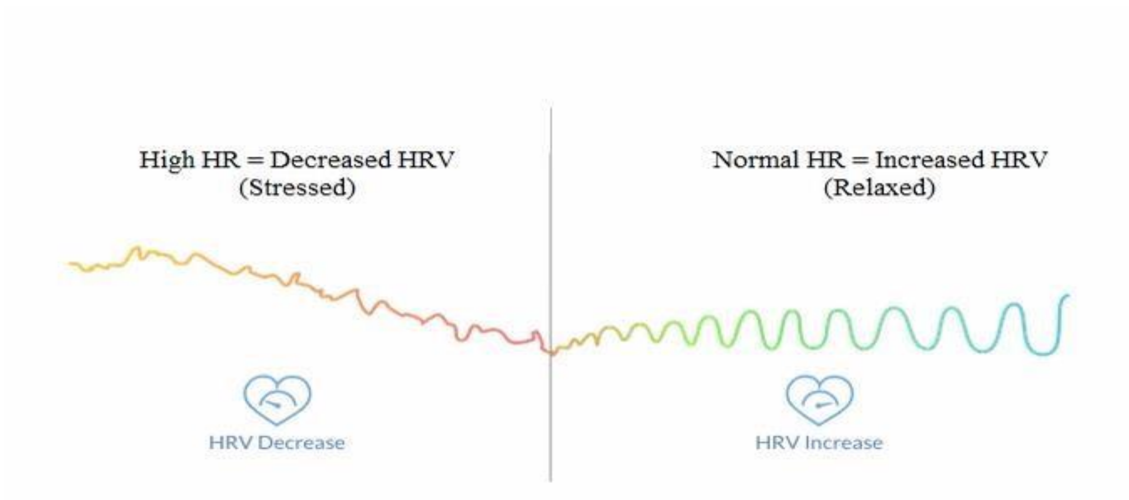


Fig 1.4: Relation between stress and HRV

Stress can cause an increase in heart rate (HR), hence the heart rate variability decreases. During a normal state, the heart rate variable value is higher than the heart rate variable when stressed.

CHAPTER 2

REVIEW OF LITERATURE

2.1 ECG SIGNAL ACQUISITION USING LABVIEW

ECG signals are acquired using LabVIEW. Akshay Kumar Sharma and Kyung Ki Kim in 2020 have used the myDAQ data acquisition device and LabVIEW software to acquire ECG signals in real-time with ECG monitoring electrodes.

2.2 TIME-DOMAIN METHOD TO MEASURE HRV

The heart rate at any point in time or the intervals between successive normal complexes are determined and in a continuous ECG record, each QRS complex is detected, and the so-called normal-to-normal (NN) intervals, the instantaneous heart rate is determined. And the standards of measurement of HRV are set by Marek Malik et.al. in 1996 using the Time Domain Method. The time-domain method is a commonly used approach to measure heart rate variability (HRV), which provides valuable insights into the functioning of the autonomic nervous system and cardiovascular health. This method involves acquiring an electrocardiogram (ECG) signal, which records the electrical activity of the heart. By identifying the R-peaks in the ECG signal, which correspond to each heartbeat, the time intervals between consecutive R-peaks, known as R-R intervals, can be extracted. Various statistical measures are then calculated based on these R-R intervals to assess HRV.

The time-domain HRV measures obtained include the mean RR interval (MeanNN), which represents the average duration of all R-R intervals, and the standard deviation of NN intervals (SDNN), which reflects the overall HRV. Additionally, the root mean square of successive differences (RMSSD) provides insight into short-term HRV by analyzing the differences between adjacent R-R intervals. Other measures such as NN50 and pNN50 indicate the number and percentage of R-R intervals that differ by more than 50 milliseconds, highlighting high-frequency HRV.

By interpreting these time-domain HRV measures, valuable information can be gained about the adaptability and flexibility of the cardiovascular system, as well as the overall autonomic nervous system function. Lower HRV values may suggest reduced adaptability or increased stress levels, while higher HRV values often indicate better cardiovascular health and increased resilience. However, it is important to consider factors such as age, gender, physical activity, and overall health conditions when interpreting the results, as these factors can influence HRV analysis. Overall, the time-domain method provides a quantitative assessment of HRV and serves as a valuable tool in understanding the cardiovascular health of individuals

2.3 INFLUENCE OF MENTAL STRESS ON HRV

Mental stress i.e., psychological stress can influence heart rate and heart rate variability is proposed by J. Taelman et.al in 2008 by recording the HR & HRV changes in a group of 28 subjects at rest and with a mental stressor. Mental stress has a significant impact on heart rate variability (HRV), indicating the intricate connection between the mind and the cardiovascular system. When individuals experience mental stress, the autonomic nervous system responds by activating the sympathetic branch, commonly known as the "fight-or-flight" response, and suppressing the parasympathetic branch, which promotes relaxation and recovery.

This autonomic response to mental stress has a direct effect on HRV. Typically, mental stress leads to a decrease in HRV, specifically in the high-frequency (HF) and total power (TP) spectral bands. HF power reflects parasympathetic activity, while TP represents the overall HRV. Therefore, reduced HF and TP values indicate a shift towards sympathetic dominance and a decreased ability of the cardiovascular system to adapt and regulate.

Furthermore, mental stress can also manifest as an increase in low-frequency (LF) power and the LF/HF ratio. LF power is influenced by both sympathetic and parasympathetic activity, but during stress, sympathetic modulation becomes more prominent. The LF/HF ratio, derived from the ratio of LF to HF power, is often used as an indicator of sympathovagal balance. An elevated LF/HF ratio suggests a shift towards sympathetic dominance.

It's important to note that the impact of mental stress on HRV can vary among individuals. Factors such as coping mechanisms, resilience, and psychological well-being can influence how individuals respond to stress. Additionally, chronic or prolonged mental stress can have a cumulative effect, potentially leading to decreased overall HRV and an increased risk of cardiovascular problems.

By analyzing HRV during mental stress, researchers and healthcare professionals gain insights into the individual's physiological response and their ability to adapt to stress. This information can be utilized in various fields, including stress management, resilience training, and assessing cardiovascular health in high-stress occupations. Ultimately, understanding the influence of mental stress on HRV contributes to a comprehensive understanding of the mind-body connection and the importance of maintaining a healthy balance between mental well-being and cardiovascular health.

2.4 STRESS RECOGNITION USING HEART RATE VARIABILITY

Kostas Marias et.al. in 2019 investigated reliable heart rate variability parameters in order to recognize stress. Using HRV to acquire accuracy as well as to estimate the importance of the involved HRV parameters to recognize stress.

The usage of only ECG recordings could serve efficiently in stress detection. Stress recognition using heart rate variability (HRV) has emerged as a valuable tool for objectively detecting and assessing stress levels. HRV refers to the variation in time intervals between consecutive heartbeats and serves as an indicator of autonomic nervous system activity, including the sympathetic and parasympathetic branches.

When individuals experience stress, the sympathetic nervous system becomes more active, leading to increased heart rate and decreased HRV. This alteration in HRV patterns can be leveraged to recognize and quantify stress levels. Various HRV measures are utilized for stress recognition:

1. Time-Domain Measures: Parameters like the standard deviation of NN intervals (SDNN) and the root mean square of successive differences (RMSSD) can be employed. Decreased SDNN and RMSSD values are associated with reduced HRV and higher stress levels.
2. Frequency-Domain Measures: HRV analysis can be conducted in different frequency bands, such as low frequency (LF) and high frequency (HF). Stress is typically characterized by decreased HF power (reflecting parasympathetic activity) and increased LF power (representing sympathetic and parasympathetic influences). The LF/HF ratio can also serve as an indicator of sympathovagal balance during stress, with an elevated ratio indicating sympathetic dominance.
3. Nonlinear Measures: Nonlinear HRV parameters, including approximate entropy (ApEn) and sample entropy (SampEn), offer insights into stress recognition. These measures assess the complexity and irregularity of HRV patterns, with lower values associated with higher stress levels.

By employing machine learning algorithms and pattern recognition techniques, HRV data can be analyzed to develop stress recognition models. These models are trained on labeled datasets that consist of HRV recordings during both stressful and non-stressful conditions. By extracting relevant HRV features, the models can identify patterns indicative of stress.

HRV-based stress recognition has practical applications in various domains, such as stress management, occupational stress assessment, and biofeedback interventions. It provides objective and real-time measurements of stress levels, enabling individuals and professionals to monitor and manage stress more effectively. By understanding an individual's physiological response to stress through HRV analysis, interventions can be tailored to reduce stress and promote overall well-being.

2.5 HEART RATE VARIABILITY IS A STRESS INDICATOR

Hye Geum Kim et.al in 2017 investigated studies to survey providing a rationale for selecting heart rate variability (HRV) as a psychological stress indicator. That the change in HRV (decrease in HRV) when psychologically stressed can be used as a stress indicator. Heart rate variability (HRV) serves as an informative indicator of stress levels. HRV refers to the variation in time intervals between consecutive heartbeats, which is regulated by the autonomic nervous system. When individuals experience stress, the sympathetic branch of the autonomic nervous system becomes more active, leading to increased heart rate and decreased HRV.

The link between HRV and stress is rooted in the intricate interplay between the mind and body. Stress triggers physiological responses that affect the autonomic nervous system's balance, resulting in alterations in HRV patterns. Reduced HRV is commonly observed during periods of stress, indicating a shift towards sympathetic dominance and a decrease in parasympathetic activity.

By analyzing HRV, valuable insights into stress levels can be gained. Various HRV measures, including time-domain, frequency-domain, and nonlinear parameters, can be employed to assess HRV patterns associated with stress. These measures encompass factors such as the standard deviation of NN intervals (SDNN), low frequency (LF) and high frequency (HF) power, and nonlinear indices like approximate entropy (ApEn) and sample entropy (SampEn).

The practical implications of HRV as a stress indicator are significant. It provides an objective and quantifiable measure of stress levels, allowing individuals, healthcare professionals, and researchers to monitor and manage stress effectively. HRV-based stress assessment can be utilized in various contexts, such as stress management programs, occupational stress evaluations, and biofeedback interventions. By understanding the relationship between HRV and stress, individuals can develop strategies to mitigate stress, enhance well-being, and promote overall cardiovascular health

CHAPTER 3

METHODOLOGY

3.1 R-R INTERVAL EXTRACTION

To determine the stress level from the heart rate variability parameters, the HRV parameters from both normal and stressed states are compared.

These HRV parameters are extracted using Time-Domain from ECG signals acquired when the subject is at normal and stressed state.

3.1.1 SIGNAL ACQUISITION

ECG signals are acquired from the subject at both normal and stressed states. ECG signals are acquired using LabVIEW.

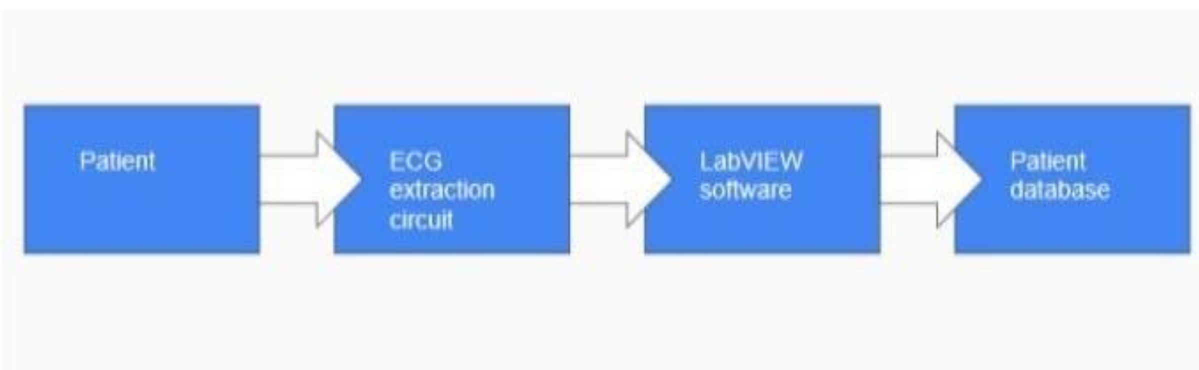


Fig 3.1: Block diagram of the system

The ECG signals are acquired and then amplified. Designed to block the undesired frequencies and only bypass the desired range of frequencies. The captured signal is converted into a suitable form to be processed using LabVIEW.

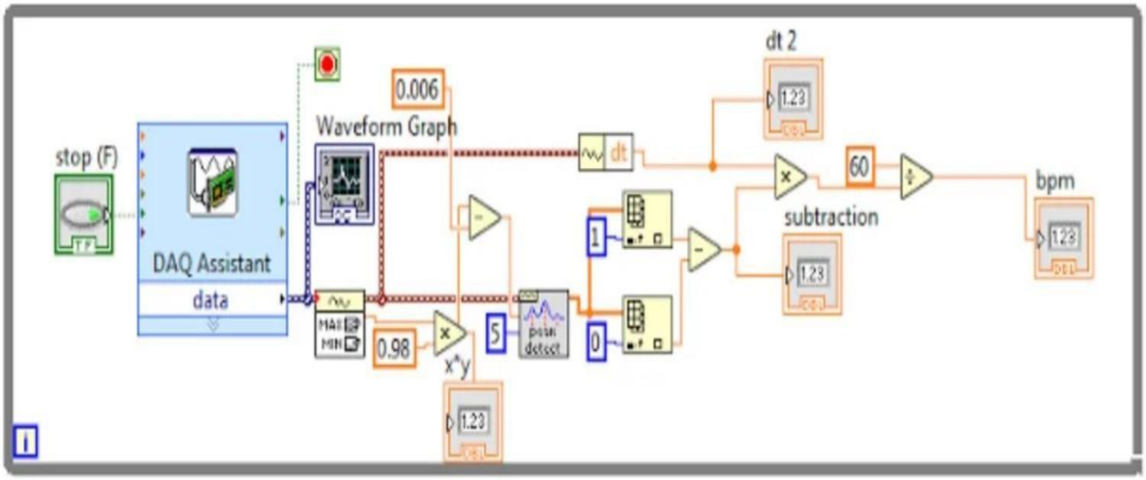


Fig 3.2: Circuit diagram for ECG Acquisition using LabVIEW

The desired ECG signal is then imported into python for HRV analysis of the acquired ECG signal of both the stressed and normal state of the subject. The imported signal into python is then preprocessed for the extraction of HRV parameters.

3.1.2 SIGNAL PREPROCESSING

From the acquired ECG signal, HRV parameters are extracted using the Time-Domain method with the help of python software. The python is saved in 'Atom' software and is executed. And the Parameters are extracted.

ECG is acquired when both stressed and at normal states of the subject have been recorded and extracted the HRV parameters using the python code. From the recorded ECG signal, it is given as the input. From the given input, the signal is plotted.

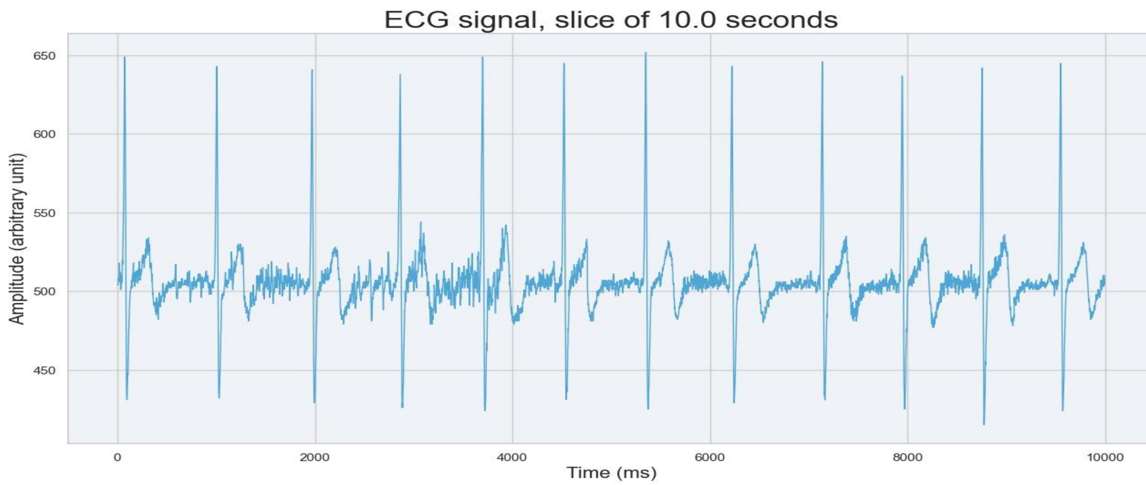


Fig 3.3: ECG signal, a slice of 10.0 seconds

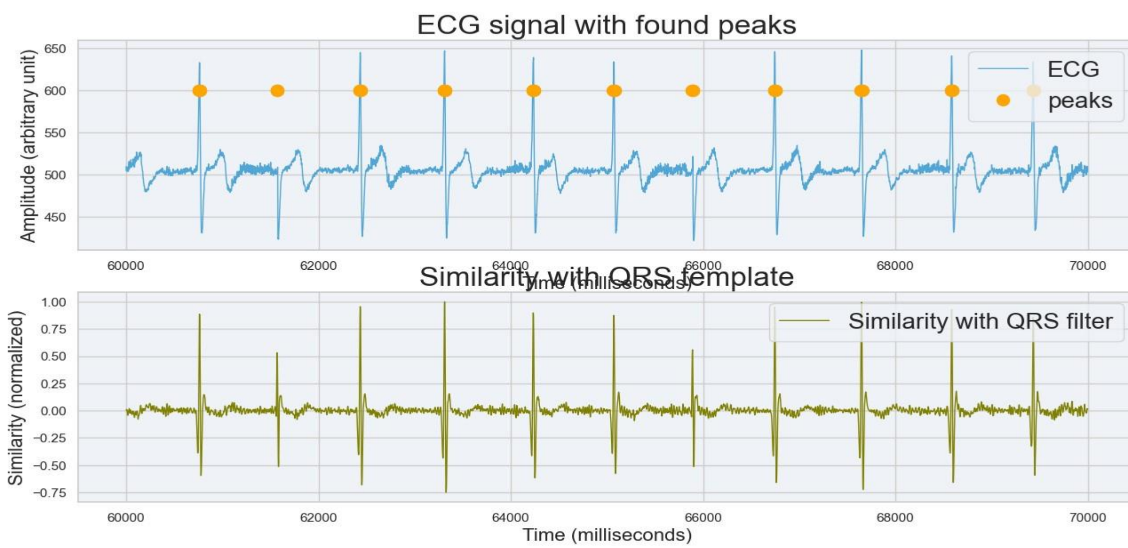


Fig 3.4: ECG signal with found peaks and Similarity with QRS template

From the plotted signal, peaks of the ECG signals are detected for the first 10 seconds. From the detected and plotted ECG, the similarities of the peaks are detected and grouped. Then, from the ECG signal R-R intervals are calculated and plotted in milliseconds. ECG signal and the R-R intervals, and group peaks are plotted.

3.1.3 R-R INTERVAL EXTRACTION

R-R intervals are the difference between successive peaks of the QRS wave of the ECG. From the grouped peaks from the ECG, the difference between the peaks is found as R-R intervals. These calculated R-R intervals may have some small errors, which can be corrected by replacing them with the median value of the R-R intervals. The correction of these intervals is manually corrected, and the input of corrected R-R values is loaded.

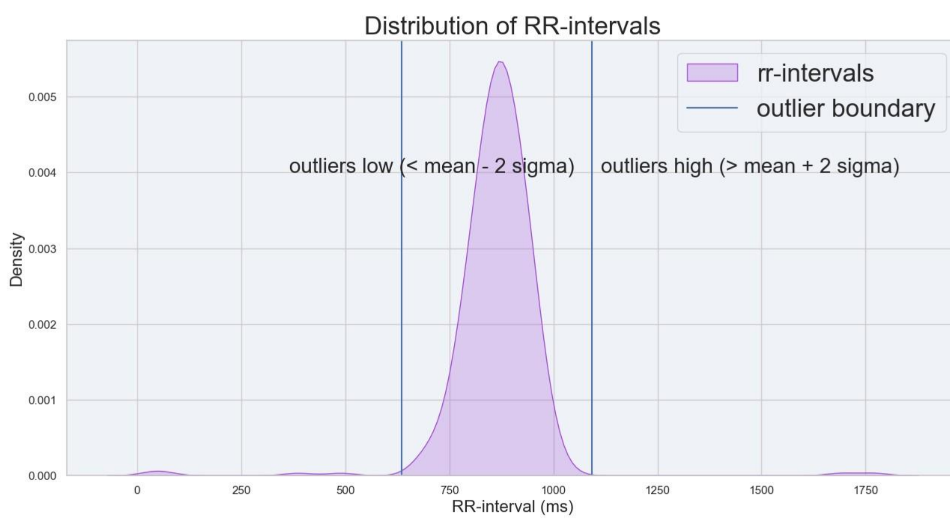


Fig 3.5: Distribution of RR-intervals

And the manually corrected R-R intervals of the ECG are plotted. And the main HRV parameters are extracted from here using the Time-Domain method.

3.2 TIME-DOMAIN METHOD

Time domain methods use RR-intervals and measure a whole range of metrics, from which HRV parameters can be extracted. These metrics were standardized in a special report of the Task Force of ESC/NASPE in 1996.

In a healthy heart, there is a natural variation, which is due to a balance between the sympathetic nervous system (SNS) and parasympathetic parts (PSNS) of the Autonomous Nervous System. If the body experiences, stress then the sympathetic system will activate, to prepare for fight or flight behavior, and the heart rate will increase.

The PSNS controls the body's "rest and digest" responses and is associated with recovery. Parasympathetic activation conserves energy, constricts pupils, aids digestion, and slows the heart rate. These two parts of the nervous system are normally in a healthy balance, causing a natural variation in the heart. If this balance is disturbed for any reason, this variance will change.

RMSSD (Root Mean Square of Successive Differences) is one of the HRV parameters. It is a measure of how much variation there exists in the heart rate. A lower RMSSS is associated with stress and various illnesses. It is often used as the score that represents 'HRV'.

List of metrics used for Time-Domain Analysis:

- **Mean RR:** Mean of RR-interval
- **SDNN:** Standard deviation of RR-intervals
- **Mean HR:** The well-known mean heart rate, measured in beats per minute
- **STD HR:** Standard deviation of the Heart rate
- **Min HR:** Lowest Heart rate
- **Max HR:** Highest Heart rate
- **NN50:** The number of pairs of successive RR-intervals that differ by more than 50 ms.
- **PNN50:** The proportion of NN50 divided by the total number of RRintervals

These values which are acquired by time domain analysis from both normal and stressed ECG shows the difference between the HRV and how the HRV values of a stressed state are lower than the HRV values of a normal state of the subject.

CHAPTER 4

RESULT AND DISCUSSION

4.1 PARAMETERS EXTRACTION

The HRV parameter of both normal state and stressed state ECG are extracted which are used for the determination of stress. The parameters are extracted and compared to determine stress as the HRV decreases when stressed.

These HRV parameters are extracted from the preprocessed signal which we acquired from LabVIEW is imported and the parameters are calculated using Python by the Time-Domain method.

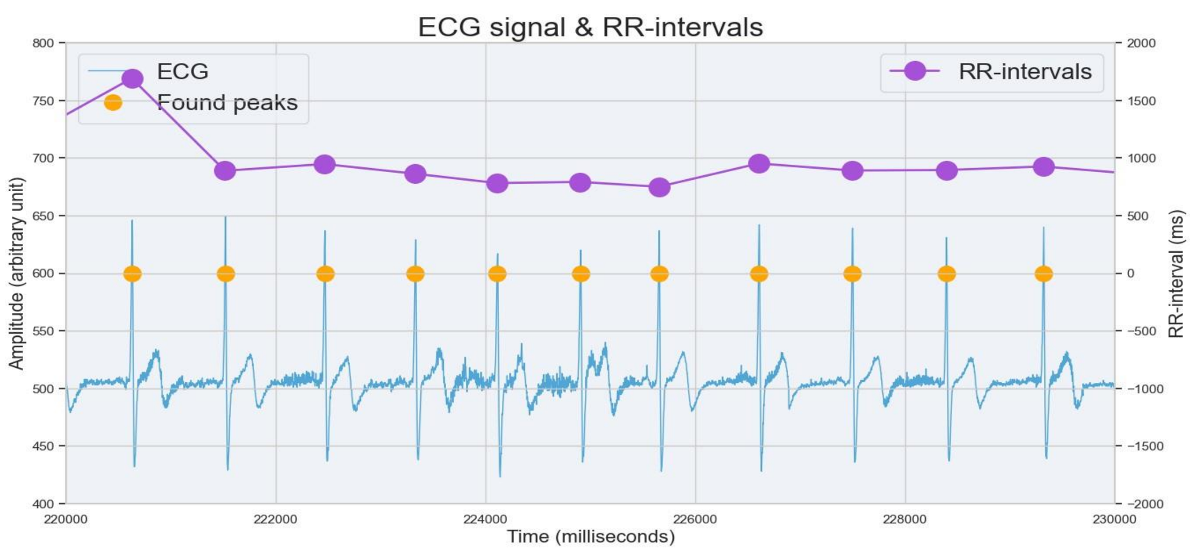


Fig 4.1: Peaks detected and RR-intervals

From the ECG signal, the peaks are detected and similarities grouped. From here, RR-intervals are calculated. By acquiring ECG there may be some errors present, those errors are removed my correcting them manually by loading the corrected data by selecting a mean threshold value.

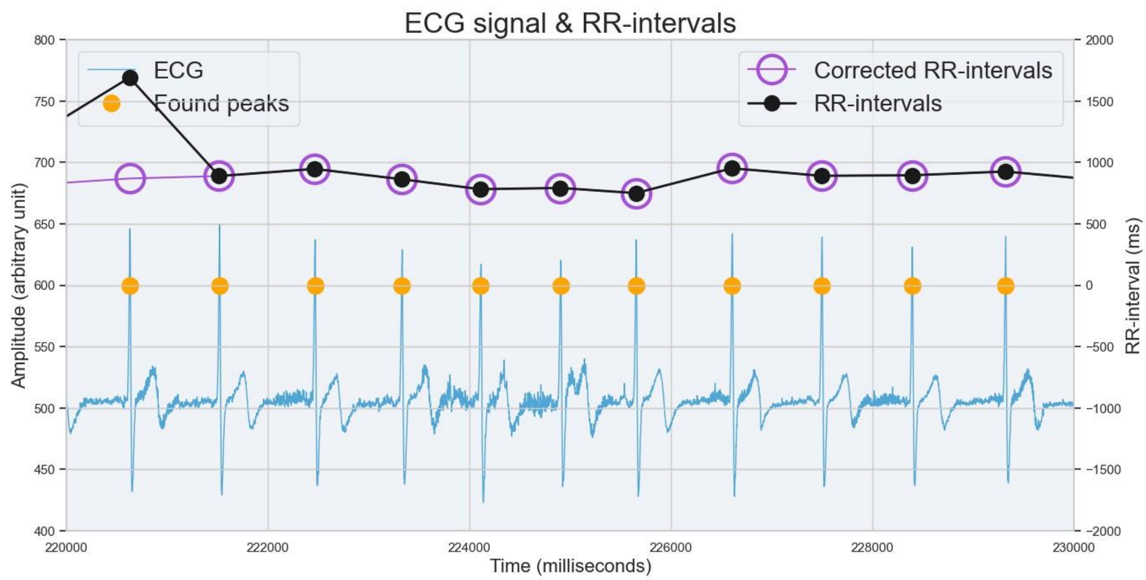


Fig 4.2: Manually corrected RR-intervals

From the corrected RR-intervals calculated from the normal state and stressed state ECG, HRV parameters are extracted using Python code and compared.

4.2 COMPARISON OF HRV PARAMETERS FOR STRESS DETECTION

To detect stress from HRV, HRV parameters extracted from both normal state and stressed state values are compared. A decrease in the HRV value of the stressed state shows, that stress can influence HRV, and HRV parameters can be used to detect stress in a non-invasive method.

From the table below (table 4.1), the HRV parameters of the stressed state are lesser than the HRV parameters of the normal state (relaxed state).

HRV PARAMETERS TIME-DOMAIN METHOD	NORMAL STATE	STRESSED STATE
Mean RR (ms)	866.81	657.08
STD RR/SDNN (ms)	62.58	48.21
Mean HR (beats/min)	69.60	81.95
STD HR (beats/min)	5.24	9.53
Min HR (beats/min)	58.37	80.34
Max HR (beats/min)	88.76	123
RMSSD (ms)	60.37	46.66
NN50	122.00	153.03
pNN50 (%)	35.26	57.99

Table 4.1: Comparison of HRV parameters

Mean RR, STD RR/SDNN, and RMSSD values of the stressed state are lesser than the normal state. And Mean HR, STD HR, Min HR, and Max HR values of the stressed state are greater than the normal state which shows that, heart rate increases and heart rate variability decreases during the stressed state.

From this derived output, we can conclude that during stressed state, Heart Rate (HR) increases and Heart Rate Variability decreases. Therefore, by calculating HRV parameters from the ECG signal, we can determine the stress level in real-time and by a non-invasive method.

APPENDIX

SAMPLE CODE:

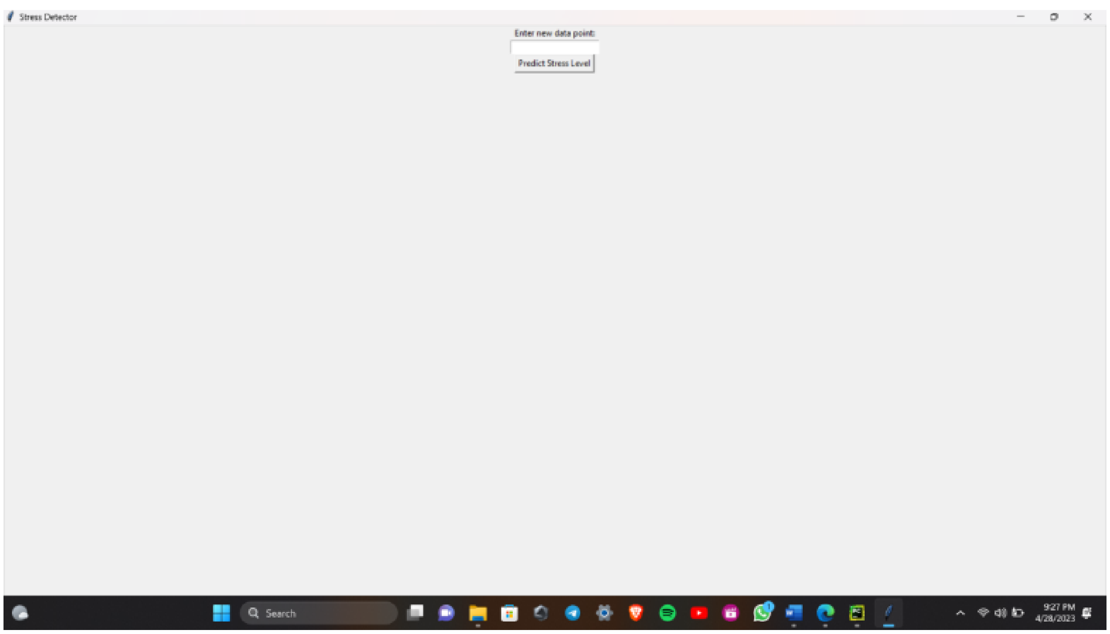
```
import pandas as pd

import tkinter as tk

from tkinter import messagebox

from sklearn.ensemble import RandomForestClassifier

from sklearn.model_selection import train_test_split

from sklearn.metrics import accuracy_score


# Load the HRV dataset

hrv_df = pd.read_csv("hrv_dataset.csv")


# Split the dataset into training and testing sets

X = hrv_df.drop(columns=["datasetId", "condition"])

y = hrv_df["condition"]

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)
```

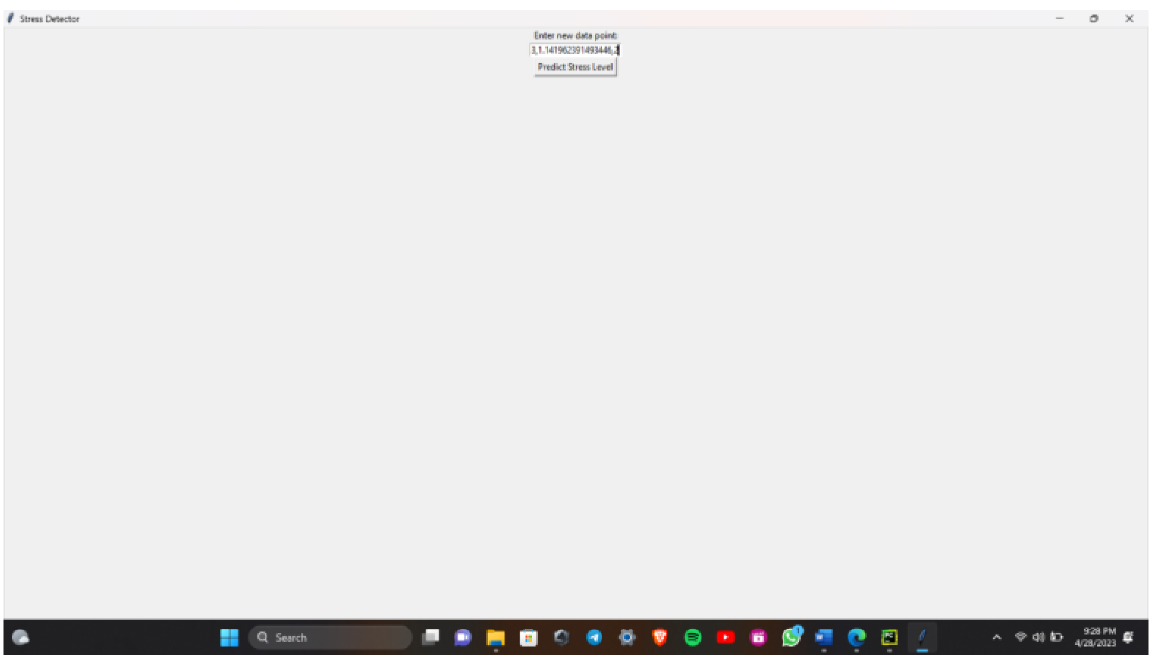
```
# Train a random forest classifier on the training set
rfc = RandomForestClassifier(n_estimators=100, random_state=42)
rfc.fit(X_train, y_train)


# Define a function to handle button click event
def predict_stress_level():
    # Get the new data point from the user input
    new_data_point_str = new_data_point_entry.get()
    new_data_point_list = new_data_point_str.split(",")
    new_data_point = []
    for val in new_data_point_list:
        try:
            new_data_point.append(float(val))
        except ValueError:
            messagebox.showerror("Error", "Invalid input")
            return

    # Create a DataFrame with the new data point as a single row
    new_data_point_df = pd.DataFrame([new_data_point], columns=X.columns)
```

```
    # Use the trained model to perform stress detection on the new data point
    predicted_stress_level = rfc.predict(new_data_point_df)[0]
    messagebox.showinfo("Result", f"Predicted stress level: {predicted_stress_level}")

# Create the GUI
root = tk.Tk()
root.geometry("300x300")
root.title("Stress Detector")

# Add a label for the user input
new_data_point_label = tk.Label(root, text="Enter new data point:")
new_data_point_label.pack()

# Add a text box for the user to input the new data point
new_data_point_entry = tk.Entry(root)
new_data_point_entry.pack()

# Add a button to trigger the stress level prediction
predict_button = tk.Button(root, text="Predict Stress Level", command=predict_stress_level)
```

```
predict_button.pack()


root.mainloop()
```

OUTPUT




Stress Detector
Enter new data point:
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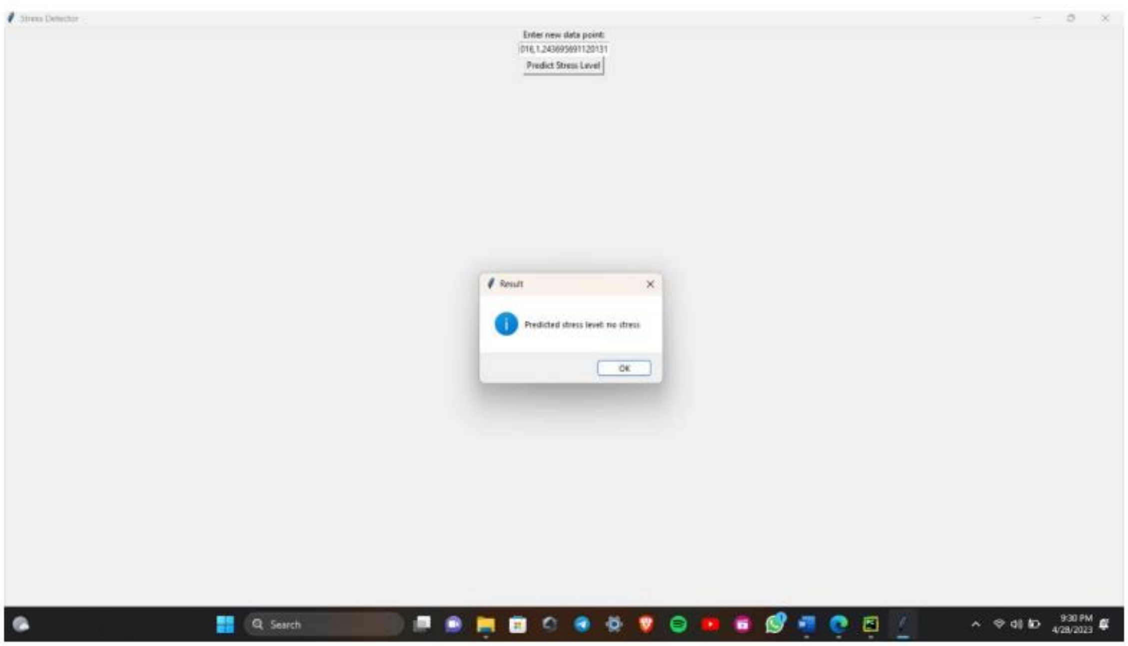
Predict Stress Level
Search


Stress Detector
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Predict Stress Level
Result
Predicted stress level: no stress
OK
Search
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CHAPTER 5

CONCLUSION AND FUTURE WORK

CONCLUSION:

In this paper, we instigated that stress can be determined using HRV parameters which is a non-invasive, real-time method. By the comparison of HRV parameters of normal and stressed states, stress causes HRV variation when stress and can be used as a parameter to determine stress. Decrease of HRV is a response caused by stress is determined. By HRV parameters, the stress level determined is more accurate and can be helpful in diagnosing, treating, and management of stress can be achieved which is much required in today's modern world of stressful students and employees.

FUTURE WORK

To improve the use of HRV parameters to determine stress in everyday life as stress is a factor that changes every day according to the person's lifestyle, A wearable stress monitoring device with built-in memory to have long recording of ECG record and stress monitoring capabilities for a long period of time for the management of stress respect to the person who uses it. To achieve this, electrodes for ECG acquisition and programmed controller to perform the algorithm to obtain ECG and stress level.

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