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A Smart Biomedical Healthcare System to Detect Stress using Internet of Medical Things, Machine Learning and Artificial Intelligence

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Abstract: Stress is a widespread issue in today's fast-paced world, affecting millions of individuals globally. Although stress can have adverse impacts on physical and mental health, identifying and managing it in real-time can be challenging. Advanced technologies such as Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Medical Things (IoMT) have the potential to revolutionize the way we live and work and address this challenge. A recent study, "A Smart Biomedical Healthcare System to Detect Stress using IoT, Machine Learning and Artificial Intelligence," proposes a machine learning-based approach coupled with IoMT to detect stress in individuals using physiological sensors such as heart rate, temperature, and moisture (sweat) sensors, as well as facial expressions. The proposed method can monitor and classify individuals into "stressful" or "non-stressful" situations. Our classification findings show that our method is a better one for identifying stress in real time. The prototype's primary aim is to introduce an innovative approach to detecting initial stress in workplace, educational, and organizational settings to promote the well-being of staff members, students, and others, ultimately enhancing productivity.

Keywords: *Stress, AI, mental health, IoMT, biomedical, ML*

1. Introduction

Stress is a widespread condition that impacts people of all ages and socioeconomic backgrounds. Although it is a natural response to challenging situations, chronic or frequent stress can have detrimental effects on physical and mental health. As a result, there is a growing need for effective stress detection and management systems. Recent advancements in IoT, machine learning, and Artificial Intelligence (AI) have opened up new possibilities for stress detection and management, allowing for real-time monitoring of stress levels. AI contains various subsections with Machine Learning, Conventional Neural Networks, Deep Learning, speech recognition with unique skills and functionalities [1-2]. To address this need, this paper outlines a paper work that aims to develop a reliable stress detection system that utilizes IoT, machine learning, and AI. The proposed system employs a combination of physiological sensors and facial expression recognition to detect stress and classify it as either "stressful" or "non-stressful". The physiological sensors measure various parameters, such as body temperature, heart rate, and sweat production, which are indicative of stress levels. The highest statistics of new cases have been reported in Brazil (522 298; 3% increase), India (351 318; 13% increase), Colombia (204 123; 4% increase), Russian (134 565; 23% increase), Argentina (121 824; 9% increase) [3-4].

If any of these physiological indicators surpass their threshold values, the facial emotion recognition system analyzes the user's facial expressions using Haar cascade and convolutional neural network algorithms to determine whether the individual is stressed. IoMT is a most emerging era of IoT, exponentially gaining young researchers' consideration with every transient day because of wide applications in SHS [5-6]. IoMT plays a crucial role in the healthcare business to increase accuracy, productivity and reliability. The proposed system provides real-time stress detection and notification, enabling individuals to take appropriate action to manage their stress levels. In addition, some techniques are emerged in literature to determination of some challenges of NB-IoT systems [7].

However, some research activities to the enhancement of NB-IoT resource supervision is continue in the next decade, high data speed, scalable etc., NB-IoT conditions can release for calibration and commercialization. The system can be instigated in several settings, such as

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healthcare, education, and workplace environments, to monitor stress levels and provide timely interventions [8]. The paper also includes a review of existing stress detection approaches and their limitations, highlighting the need for a reliable and non-invasive stress detection structure that can be implemented in real-world settings. The present procedure has selected as a use circumstance, since it involves a distributed network through a manufacturing ability [9], [10]. To improve recognition quality of fault analysis, hybrid DL method is presented to select the most typical sensors.

The testing methods employed in the paper work include functional testing, non-functional testing, unit testing, integration testing, system testing, and manual testing, ensuring the system's reliability and accuracy in stress detection. In summary, this paper work proposes an innovative approach to stress detection and management that utilizes IoT, machine learning, and AI to improve the well-being of individuals and organizations [11]. The proposed system has the potential to revolutionize stress detection and management by providing real-time monitoring and personalized interventions to mitigate the negative impacts of stress on health and productivity [12]. The practice of AI in healthcare [13],[14] is start to alter present procedures in prevention, analysis, treatment, improvement, additional physical and mental stress.

2. Literature Survey

The paper [15] proposed a stress recognition algorithm that utilizes face images and face landmarks. Previous research on stress recognition has primarily focused on biological signals or thermal images, which require specific devices for information acquisition. To overcome this limitation, the proposed algorithm can identify stress from images captured using a standard camera. Additionally, a deep neural network was designed to process facial landmarks as input, taking advantage of the fact that eye, mouth, and head movements differ from normal situations when an individual is stressed. The author Asha *et. al*[16], Islam, and Khan proposes a cost-effective technique to perceive mental stress using a heart rate sensor and machine learning. The authors highlight the significance of heart rate changeability as a stress indicator, which can be measured using a simple sensor. They collect heart rate data and use it to train a machine learning model to predict stress levels [17]. The authors demonstrate that their proposed approach can effectively detect stress levels using a low-cost sensor and machine learning, thereby having potential applications in healthcare and other related fields. This paper could be a valuable addition to a conference on innovative technologies for healthcare or machine learning applications.

Develop a stress detection mechanism and a stress level indicator circuit for measuring the stress level of human brain using the Electroencephalogram (EEG) Signal. Signals coming from the frontal lobe of human brain have been used for the measurement of stress [18]. The cerebral indications of thirty individuals are documented during the process of tackling five sets of mathematical questions that progressively become more intricate. The research presumes that the individuals experience five distinct levels of tension, namely 'Calm', 'Slightly Anxious', 'Moderately Anxious', 'Highly Anxious', and 'Exceedingly Anxious' throughout the problem-solving activity. Subsequently, the collected EEG data is analysed and distinctive attributes are extracted. This endeavour constructed a feedforward artificial neural network to classify the level of stress in the human brain.

A case study emphasizing the importance of detecting high-level stress at early stages to prevent negative impacts. The researchers utilized wearable devices that have become increasingly popular in people's lives to detect extreme stress levels during daily routines [19]. To resolve this problem, the study proposed a technology that automatically detects stress that uses physiological signals obtained from smart wearable devices in an unobtrusive manner. The system successfully discriminated between contest stress, using different machine learning methods based on heart activity, skin conductance, and accelerometer signals relatively higher cognitive load (such as during a lecture), and relaxed time activities by using different machine learning methods based on heart activity, skin conductance, and accelerometer signals.

A facial expression recognition system [20] based on Convolutional Neural Networks (CNNs). Humans have many types of Facial expressions but usually we consider 7 basic facial expressions (happy, sad, anger, surprise, neutral, disgust, and fear) and this was used to classify human emotions. The application uses image processing and machine learning techniques, image is taken from a webcam/camera and compared with the trained dataset, which is stored in the application and this will display the emotional state of the image. The paper [21] presents a stress discovery system that uses non-invasive and non-intrusive detectors to cover physiological signals. The development of this emotion recognition system involved three stages trial setup for physiological seeing, signal preprocessing for the birth of affective features, and affective recognition using a literacy system. The system monitors four signals Galvanic Skin Response (GSR), Blood Volume palpitation (BVP), Pupil Diameter (PD), and Skin Temperature (ST) to separate affective countries in a computer stoner. A Support Vector Machine is employed for prophetic modeling.

The author Cana *et. al* [22], "Stress Detection in Daily Life Scenarios Using Smart Phones and Wearable Sensors" by

Cana et al. (2019) reviews recent works on stress detection using smartphones and wearable devices in daily life scenarios. Stress has surfaced as a significant contributor to colorful ails in ultramodern society. The frequency of smartphones, smartwatches, and smart wristbands has led to their expansive operation in our diurnal lives, raising the question of whether stress can be detected and averted using this bias. In this check, the authors review recent studies on stress discovery in diurnal life that employ smartphones and wearable detectors. While multitudinous studies have examined stress discovery in controlled laboratory settings, there's a limited number of studies exploring stress discovery in real- life conditions. The authors classify and dissect the studies grounded on the physiological modality employed and the targeted terrain, similar as office, lot, auto, and diurnal life settings. The authors also bandy promising ways, managing strategies, and exploration challenges.

The development of an ambulatory device that enables the measurement of heart rate, electrodermal activity, and skin temperature with non-invasive sensors [23]. To unobtrusively obtain physiological information under real-life conditions, it is necessary to simultaneously measure multiple physiological signals using small, discreet, mobile devices. Hence, the authors have developed an ambulatory device that can measure heart rate, electrodermal activity, and skin temperature consuming non-invasive sensors [24]. With the aid of wireless connectivity and local data storage on a memory card, the device may be employed during in-situ investigations for the analysis of autonomic nervous system function [25]. The researchers used this device in a study to objectively evaluate stress in the blind while walking in urban areas, by analyzing the electrodermal activity of blind pedestrians who followed a charted course involving various urban conditions independently [26].

The authors [9] present a wireless healthcare system created on Galvanic Skin Response (GSR) for monitoring stress levels. The system consists of a wireless sensor device for collecting physiological data and a central monitoring station for data analysis and display. The GSR sensor measures changes in skin conductance, which is a reliable indicator of emotional arousal and stress. The collected data is wirelessly transmitted to the central station where it is analyzed and displayed for healthcare professionals to interpret. The system is designed to be non-invasive, easy to use, and cost-effective. [10]A review of studies focused on stress detection using Galvanic Skin Response (GSR) [10] and its impact on human health. The paper examines different methods of GSR measurement and signal processing techniques, as well as the potential health risks associated with chronic stress. The authors conclude that GSR can be a useful tool for stress detection and prevention, but further research is needed to fully recognize its effect on human health.

The authors conducted a study to explore the possibility of sensing stress with a wearable device by measuring HRV. The study involved 24 healthy individuals who wore a wrist-worn device for 24 hours to collect HRV data [11]. The participants reported their stress levels at regular intervals using a smartphone app, and the authors analyzed the HRV data using time and frequency domain analysis. They also developed a machine learning-based algorithm for stress detection. The results of the study demonstrated a significant correlation between HRV parameters, such as SDNN and RMSSD, and the reported stress levels. The authors found that machine learning algorithms, including random forest and support vector machine, were effective in detecting stress based on HRV data. These findings suggest that wearable devices that measure HRV can be useful for real-time stress detection and timely interventions to prevent negative health outcomes.

The goal of this study was to develop a reliable method for recognizing seven distinct emotional states using EMG signals from facial and forehead muscles. The researchers recruited 12 participants and used wearable EMG sensors to record data while they produced facial expressions for each of the seven emotions: joy, sadness, anger, surprise, disgust, fear, and neutral. The study utilized a two-phases recognition approach, with the first phase involving the removal of features from the EMG signals through time-domain, frequency-domain, and time-frequency-domain analysis [12]. The second phase elaborate the use of a random forest classifier to recognize the seven emotional states. The researchers discovered that a combination of features derived from the facial and forehead muscles was the most successful in recognizing the seven emotions, achieving an accuracy rate of 75.83%. The study also found that the frequency-domain analysis of EMG signals was particularly effective in distinguishing the seven emotions.

From the above study, stress is a prevalent issue in today's fast-paced world, with serious negative impacts on individuals' physical and mental health. The existing methods of stress detection suffer from limitations such as subjectivity, invasiveness, and lack of real-time monitoring, necessitating the need for a reliable and non-intrusive stress detection system. This paper aims to develop such a system using IoT, machine learning, and artificial intelligence [27]. The proposed system combines physiological sensors and facial emotion recognition to detect stress and classify it into 'stressful' or 'non-stressful' situations [13]. The system's goal is to provide real-time stress detection and notification to the user and can be implemented in organizations, institutes, and IT sectors to monitor the stress state of their employees. By providing timely feedback and intervention, the system can help individuals manage their stress levels effectively and prevent the negative consequences of chronic stress. This paper has significant implications for the field of health and well-being, and its successful implementation can positively impact individuals' lives and organizations' productivity.

3. The Proposed System and Methodology

The idea behind the suggested stress detection system is that changes in body temperature, sweet production, and heart rate may be transformed into analogue voltage levels and then digitally analysed to determine the levels of stress. The system uses a heartbeat sensor, a temperature sensor, and a sweat sensor to degree the heart rate, body temperature, and electrical conductivity of the skin, respectively. Changes in these physiological parameters are measured by the sensors, which are then inspected to determine if an individual is stressed or not. The subject may be in a condition of stress if the analysed values above the threshold values defined, and in addition to the physiological sensors, the suggested system also makes use of facial expression recognition to validate the state of stress. The system classifies the facial expressions of the individual into basic emotions such as anger, disgust, fear, happiness, sadness, neutral, and surprise. A deep neural network is used to analyze the facial landmarks of the individual, taking into account eye, mouth, and head movements that are different from normal situations when a person is stressed.

The system analyzes both the physical parameter values received from the sensors and the stress levels detected by the facial images. If both values match the stress thresholds, the system classifies the individual as stressed. The system utilizes the Haar Cascade and Convolutional Neural Network to detect the facial expression. The suggested stress detection system aims to provide real-time stress detection and notification to the user and can be implemented in organizations, institutes, and IT sectors to monitor the stress state of their employees.

- The proposed system requires the following hardware components:
- Arduino Uno board
- LCD display
- Heartbeat sensor
- Temperature sensor
- Sweat sensor

The proposed system for stress detection and management requires specific hardware components to function properly. The first and foremost component is an Arduino UNO board, it functions as the main control unit of the system. The board is accountable for processing the data acknowledged from the physiological sensors and facial expression recognition system, and for triggering the notification system when a stress threshold is breached.

The Arduino UNO board requires a power supply unit to function, which is another hardware component of the system. This power supply unit provides the necessary voltage and current required for the Arduino board and other components to function properly. The system also includes three types of biosensors, namely a heartbeat sensor, temperature sensor, and sweat sensor. These sensors are used to measure and record the physiological parameters of the body, including heart rate, body temperature, and sweat production. The data from these sensors are then processed by the Arduino board to determine the stress levels of the individual.

To display the output and notifications of the system, an LCD display is also included as a hardware component. The LCD display shows the stress state and other relevant information.

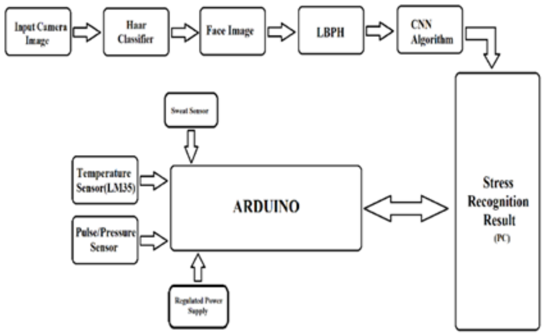


Fig.1: Implementation of the proposed system.

The proposed stress detection and management system requires several software components to function properly.

- Arduino IDE
- Embedded C
- Python
- OpenCV
- Interactive Computing Platform

The Arduino Software (IDE) is a development environment that provides a text editor for coding, a message area, a text console, a toolbar, and menus for common functions. It connects to the Arduino hardware to upload programs and communicate with them. Embedded C is an extension of the C language that is hardware-dependent and relies on the semantics of the hardware for which the code is written. Python is a programming language that is particularly suited for machine learning and AI paper work due to its simplicity, consistency, and access to a range of libraries and frameworks. OpenCV is a library of programming functions that is primarily used for real-time computer vision and is useful in implementing

Facial Landmark Detection.

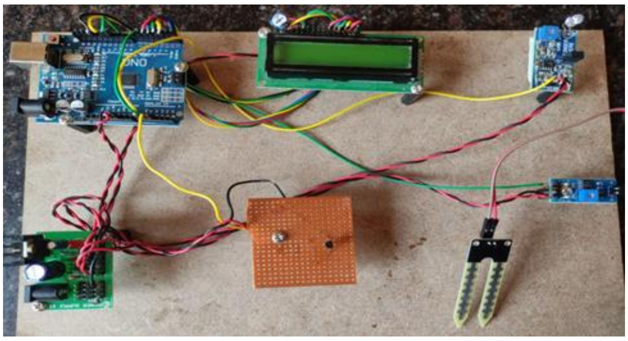


Fig.2: Hardware Implementation Component.

The proposed system includes both software and hardware components, which are illustrated in Fig. 1. Biosensors such as the Pulse/Pressure sensor, Temperature sensor, and Sweat sensor are connected to the Arduino, which is also connected to a power supply and a serial port for communication with a computer. The facial expression recognition system uses Haar Cascade and OpenCV for face detection, followed by image pre-processing and feature extraction using facial landmark detection. A convolutional neural network technique is then used to the feature vector to identify stress. The overall process generates a result indicating whether the person is stressed or not.

The system's hardware implementation model, as illustrated in Fig. 2, utilizes the Arduino UNO microcontroller board as its foundation. To power all of the system's components, a power supply unit is utilized to produce a 5V output. The three physiological sensors used to detect stress levels are the heart rate sensor, sweat sensor, and temperature sensor. These analog sensors produce an analog voltage output that is proportional to the physiological parameter being measured. The heart rate sensor is connected to the A0 port, and the sweat sensor is connected to the A1 port, while the temperature sensor is connected to the A2 port on the Arduino UNO board, which has six analog input pins.

To supply power to the sensors, all three are connected to the 5V pin and ground of the power supply unit. The LCD display, which is used to display any output messages, such as physiological measurements from the sensors, is connected to the Arduino UNO board through various pins, commonly using the I2C protocol. In summary, the stress detection system uses widely available and easy-to-find components to measure physiological parameters related to stress and display the real-time results on an LCD screen. It might be used for straightforward stress monitoring in different settings, such as at home or in a workplace.

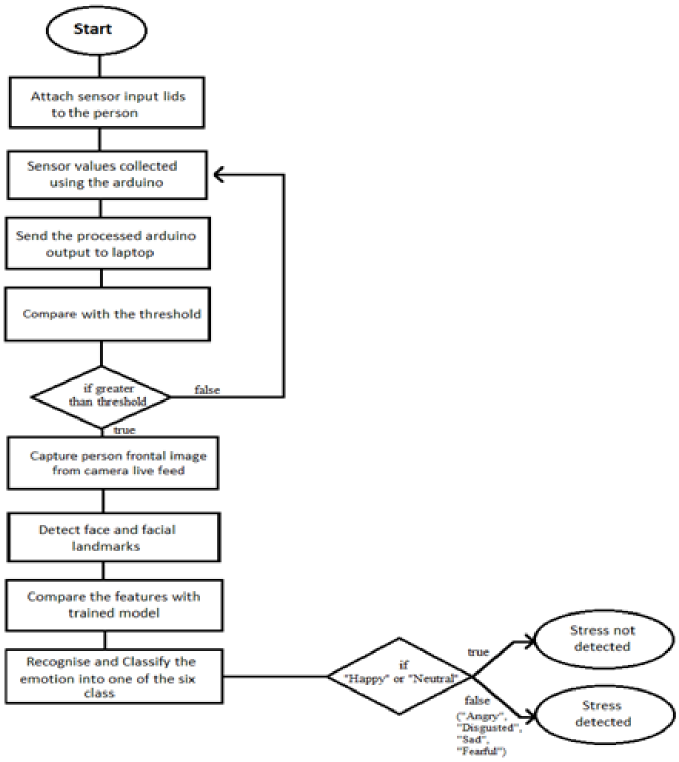


Fig. 3: Flow chart Process of Proposed System.

The flowchart in Fig. 3 outlines the different steps or methodologies that are used in the stress detection system. Here are the steps explained in more detail:

Step 1: Initially, the system takes input from the sensors - this refers to the heart rate, sweat, and temperature sensors that are connected to the Arduino UNO board. These sensors are used to collect physiological data that can indicate the presence of stress.

Step 2: The inputs collected from the Arduino board are then processed, and if the threshold values are breached, facial expression recognition is used to detect the emotion and classify the stress state. This means that the physiological data collected from the sensors is analyzed to see if it exceeds certain threshold values that are indicative of stress. If the thresholds are exceeded, facial emotion recognition is used to further confirm the presence of stress.

Step 3: Facial landmark using facial feature tracker is then used to detect facial expressions. This step involves analyzing the facial features and expressions of the user to determine their emotional state.

Step 4: Next, the system starts preprocessing the facial data. Based on the most frequent emotion detected, the system classifies the state of stress. This means that the system analyzes the facial data to determine the most common emotion displayed by the user, and uses this information to classify whether the user is experiencing stress.

Step 5: If stress is detected, the system updates and intimates the user and stops the process. This implies that the system will provide the user feedback and halt any more analysis or processing if it deems that the user is under stress.

Step 6: If stress is not detected, the system goes through the above steps again in order to get the desired result.

This indicates that if the system does not identify stress, it will restart the procedure in order to gather additional data and conduct the same type of analysis on it.

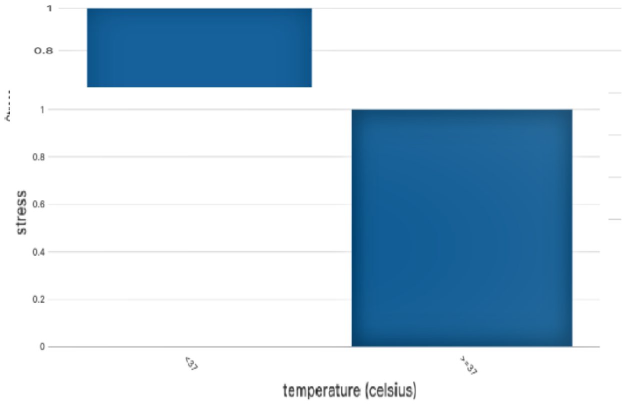
4. Results and Discussion

The images represent the result of the stress detection system's LCD display. It displays the instructions to the user to place their finger on the sensors to measure the parameters. The heartbeat, temperature, and perspiration levels are displayed on the screen, which are measured using the heartrate sensor, temperature sensor, and sweat sensor respectively. If all the measured parameters are below the threshold limit, then no stress is detected, and it is displayed on the LCD screen. However, if the heartbeat is above the normal limit and perspiration level is below the default value, it suggests the user is in a state of stress, which is further supported by examining additional circumstances. If any two of the measured parameters exceed the threshold limit, then the user is considered to be under stress. The value is then passed to the PC to detect facial emotion to confirm the state of stress.

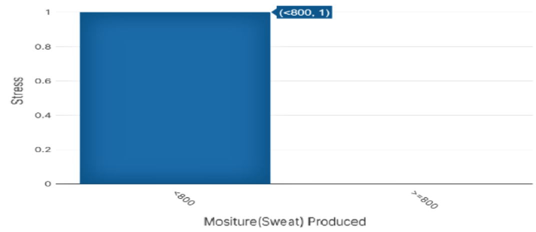
The graphs shown in Fig. 4 depicts relationship between stress and the physiological parameters which are measured using the biosensors. The graph (i.) in the Fig. 4 depicts the change in stress with the change in the temperature (Celsius) of an individual, if the temperature crosses the threshold value of 37oc, it can be a condition for stress. The graph (ii.) in the Fig. 4 depicts the change in stress with the change in the sweat(ppm) of an individual, if the sensor detects moisture and the value goes below the threshold value 800 from its default value of 1023, it can also be a condition for stress. The graph (iii.) in the Fig. 4 depicts the change in stress with the change in the heartrate(bpm) of an individual, if the sensor detects heartrate above threshold value 120 (varies from person to person), it can also be a condition for stress. When one of these two characteristics is met, it may be presumed that someone is under stress. Facial emotion recognition is used to support this assertion.

Fig. 5 displays the output of a face expression detection system that uses a laptop camera to identify a user's moods. The proposed structure is only activated when a threshold value is crossed by the sensor input. Once the threshold is crossed, the system prompts the facial emotion recognition test to classify the user's state of stress. The system detects the user's emotion and categorizes it as either happy, neutral, sad, angry, afraid, or disgusted using a trained emotion detection model. The system classifies the user's stress level based on the emotions that occur most frequently. If the emotions detected have more occurrences of "happy" or "neutral," the output is "no stress." However, if the emotions detected have more occurrences of "sad," "angry," "fearful," or "disgusted," the output is "stressful state." The system uses an Arduino UNO to obtain the sensor input and control the facial emotion. recognition process.

(i)



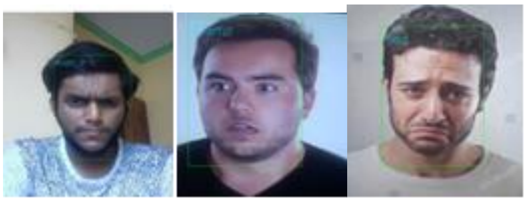
(ii)



(iii)

Fig. 4(i), (ii),(iii): Graphical Representation of physiological parameters

(i) (ii) (iii)



(iv) (v) (vi)

Fig.5 (i),(ii),(iii),(iv), (v),(vi): Facial Emotion Recognition.

Fig. 6 shows the data expected from the Arduino UNO, 'B' indicates that the threshold value has not been breached hence the process continues and does not prompt the Facial Emotion Recognition to start. When the received data is 'A' it indicates that the threshold value has been crossed and now the Facial Emotion Recognition process starts by turning on the camera for live input. The emotions detected are classified as a state of stress or not based on the maximum occurrence of an emotion. Fig. 7 shows if the list of emotions detected has more occurrences of "Happy" or "Neutral," the output is "No Stress," while Fig. 8 shows that the emotions such as "Sad," "Angry," "Fearful," and "Disgusted" are considered to be indicative of a stressful state.

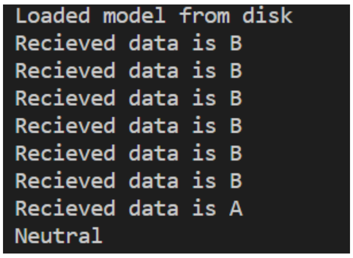


Fig.6: Terminal Output of Data received from Arduino

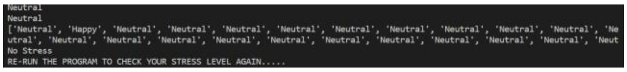


Fig.7: Terminal Output of Facial Expression Recognition and Stress detection

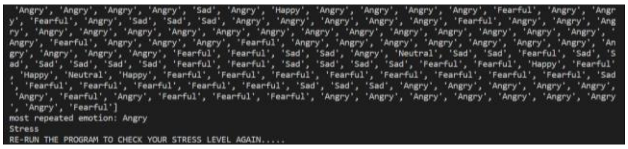


Fig. 8: Terminal Output of Facial Expression Recognition and Stress detection.

5. Conclusion

A Smart Biomedical Healthcare System to Detect Stress using IoT, Machine Learning and Artificial Intelligence aims at building a reliable stress detection system to monitor real-time the stress state of an individual. The system utilizes biosensors and facial emotion detection to detect the state of stress. A threshold value is set to detect anomalies in physiological parameters measured from the sensors. On measuring the physiological parameters such as heartrate, body temperature and sweat production, we compare these with the threshold value and on breaching it, we further use facial emotion detection to classify stress which is achieved with the help of Haar Cascade algorithm and Convolution Neural Network. On application of facial emotion detection, we compare the most frequent emotion detected and classify the state as stress or not-stress. Organizations, Institutes, IT sectors can implement this system in order to monitor the stress state of their employee and help produce a better outcome. This system provides a real-time stress detection mechanism.

Author Contributions

Dr. Manjunath R: Methodology, implementation and project administration, **Dr. Shivashankar:** Problem definition and idea, writing—original draft preparation, **Dr. Shivakumar** Swamy **N:** Data curation, corrections, **Dr. Erappa G:** Literature Survey and background work, **Dr. Manohar Koli:** resources, **Dr. Nandeeswar S B**: Software, Validation, **Dr. Niranjan R Chougala:** corrections, template.

Conflicts of Interest

Declare conflicts of interest or state "The authors declare no conflict of interest." Authors must identify and declare any personal circumstances or interest that may be perceived as inappropriately influencing the representation or interpretation of reported research results.

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