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Department of Computer Science and Engineering
Program: Bachelor of Science in Computer Science & Engineering
Course No: 4264

Course Title: Internet of Things (IOT) Lab

Project Progress - III

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Submitted by,

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Project Name:

"IoT-Based Integrated Stress and Mental Health Monitoring Chair."

Overview of Progress: Our project focuses on designing an IoT-based integrated chair for stress and mental health monitoring. Progress includes hardware setup with sensors for data acquisition, implementation of data processing on Raspberry Pi, and development of a mobile app for real-time feedback and visualization. Key achievements involve sensor calibration, initial machine learning model training, and seamless communication between hardware components for effective functionality.

Architecture:

Part 1: Hardware Components:

1. **Central Processing Unit:**

   Raspberry Pi 4: Serves as the primary processing unit, running Python scripts for data cleaning, analysis, and machine learning tasks.

2. **Sensors for Data Collection:**

- **DHT22 Sensor:** Measures environmental temperature and humidity for assessing thermal comfort.
- **MAX30102 Sensor:** Tracks heart rate and oxygen saturation as physiological indicators of stress.
- **BH1750FVI Sensor:** Measures ambient light levels to evaluate lighting conditions.
- **MAX4466 Microphone Module:** Records environmental sound levels to determine noise levels.

- **Camera Module:** Captures visual data (images/videos) for facial expression analysis.

3. Communication Modules:

- **ESP32 IoT Board:** Acts as a data aggregator and transmits sensor data, also performing some preprocessing.
- **GSM Module:** Supports data transmission in areas without Wi-Fi, ensuring connectivity.

Part 2: Software Components:

1. Communication Libraries:

- **Purpose:** Manage communication between hardware components and higher processing layers such as cloud systems and mobile applications.

- **Embedded Device Communication:**
  - **Wi-Fi Protocols:** Libraries integrated within the ESP32 facilitate seamless wireless data transmission to the Raspberry Pi or the cloud.
  - **Bluetooth Protocols:** Used for low-latency, local device communication between the chair system and the mobile app.

- **Python Libraries for Networking:**
  - **Socket Programming:** Manages data flow between sensors and central systems.
  - **MQTT Protocols:** Used for IoT-specific lightweight messaging between devices and cloud storage.

- **GSM Integration:** Libraries on the Arduino or ESP32 control the GSM module for data communication in areas with no Wi-Fi connectivity.

2. Control Logic:

○ Key Features:

- **Arduino Code:** Handles initial sensor data collection, calibration, and communication with ESP32.
- **ESP32 Firmware:** Aggregates data from sensors and applies preprocessing logic (e.g., filtering out noise).
- **Python Scripts on Raspberry Pi:** Applies threshold logic and coordinates communication between all hardware components.
- **Feedback Loops:** Monitors data continuously and triggers alerts based on predefined or user-defined thresholds (e.g., if posture deviates or heart rate rises).

3. Data Processing:

○ Preprocessing:

- **Noise Filtering:** Raw data from sensors like MAX4466 and DHT22 is cleaned using filtering techniques implemented in the ESP32.
- **Normalization:** All sensor data is scaled and aligned to consistent formats for further processing.

○ Core Analysis:

- **Machine Learning Models:** Posture classification (e.g., force sensor data mapped to posture states). Stress detection using heart rate variability and facial expression analysis etc.
- **Threshold-Based Analysis:** Immediate responses generated for metrics exceeding safe limits.

- **Cloud and Local Processing:**

  - **Local Processing on Raspberry Pi:** Python scripts perform low-latency analysis and generate user-specific feedback in near real-time.
  - **Cloud Integration:** Analyzes long-term data trends and enables advanced computation that may be resource-intensive locally.

Data Flow:

- **Input:** Sensors collect raw physiological, environmental, and posture data.
- **Processing:** Local filtering, threshold checks, machine learning classifications, and data storage.
- **Output:** Real-time feedback via app/LED/audio, actionable suggestions, and long-term insights through analytics**.**

Tasks Completed:

Hardware Setup:

- **Integrated:**

  - **DHT22 Sensor:** Measures environmental temperature and humidity to monitor the thermal comfort of the user.

  - **MAX30102:** Tracks heart rate and oxygen saturation, which are vital indicators of physiological stress.

- **BH1750FVI Ambient Light Sensor:** The BH1750FVI is a digital ambient light sensor that communicates via I2C. It reads light intensity from BH1750. Process and display the data.

- **MAX4466 Microphone Module:** Records environmental sound levels to determine the noise level, which may influence stress.

Software Implementation:

Developed Arduino code to:

- Read data from the DHT22 sensor (temperature and humidity).
- Read heart rate and SpO2 levels from MAX30102.
- Read reads light intensity from BH1750.
- Read sound intensity from MAX4466.
- Process and display the sensor.

The data from these four sensors is collected together and sent to the ESP32. Then, the ESP32 forwards the data to the Raspberry Pi using MQTT. On the Raspberry Pi, we have implemented two trained machine learning models. The sensor data is fed into these models, which generate predictions. Finally, the stress level is determined using a weighted average of the model outputs.

Developed Raspberry pi and Cloud integration:

- **Local Processing on Raspberry Pi:** The Raspberry Pi processes sensor data in real-time, performing initial filtering and analysis before transmitting relevant information.
- **Cloud Integration:** The processed data is sent to ThingsBoard via MQTT for remote monitoring, visualization, and further analytics.

- ## Dataset training using Machine learning models:

  We've trained various machine learning models on datasets, including SVM, SVC, Random Forest, and Gradient Boosting Classifier. The data was split using 80% for training and 20% for testing. The models were evaluated using performance metrics such as accuracy, with results showing that Random Forest gave the best performance. Some challenges faced including imbalanced dataset and correlation issues between columns.

Challenges Faced:

1. DHT22 (Temperature & Humidity) Challenges:

- Inaccurate readings due to unstable power or long wiring.
- Slow response time.
- Signal transmission issues over long cables.

2. MAX30102 (Heart Rate & SpO2) Challenges:

- Finger not detected due to weak IR signal or poor placement.
- Inaccurate readings caused by motion or external light.
- I2C communication issues due to wrong address or wiring.

3. BH1750FVI Sensor Challenges:

- Inaccurate Readings – Affected by sensor placement, reflections or obstacles.

4. MAX4466 Microphone Module Sensor Challenges:

- Sensitivity to Placement – Sensor placement can affect sound detection, making it difficult to capture accurate readings in all environments.

- Limited Frequency Response – The module might not capture the full range of frequencies accurately, especially in higher-pitched sounds.

Future Steps:

- **Camera Module:** The Camera Module will capture images to analyze facial expressions and detect emotional states like stress, fatigue, or discomfort. Using techniques like computer vision, it identifies visual cues such as frowning, squinting, or signs of fatigue. This data complements physiological inputs (e.g., heart rate) and enhances stress detection accuracy. It may also assist in posture observation and contextual monitoring for a comprehensive well-being assessment.

- **Feedback:** The feedback mechanism provides real-time alerts via mobile app notifications, RGB LEDs, or audio prompts to address issues like poor posture or high stress. It offers guided suggestions, such as breathing exercises and ergonomic tips, while visualizing long-term data trends to help users improve their habits and overall well-being.

- **Application Development:** The application provides real-time monitoring of metrics like heart rate, posture, stress levels, and environmental conditions, while sending alerts for corrective actions. It offers personalized suggestions, such as breathing exercises and ergonomic tips, and visualizes historical trends.

- **Prototype Design:** The prototype design for this project integrates sensors (e.g., heart rate, posture, light, and sound), a camera module, and an IoT-enabled processing unit (Raspberry Pi) to collect and process data. A mobile application provides real-time monitoring, alerts for corrective actions, guided suggestions (e.g., stretching or relaxation tips), and visualizations of historical trends. Feedback is delivered via app notifications, RGB LEDs, or audio prompts, ensuring users can track and improve their posture and stress levels effectively. This is how our project will work through prototype and application:

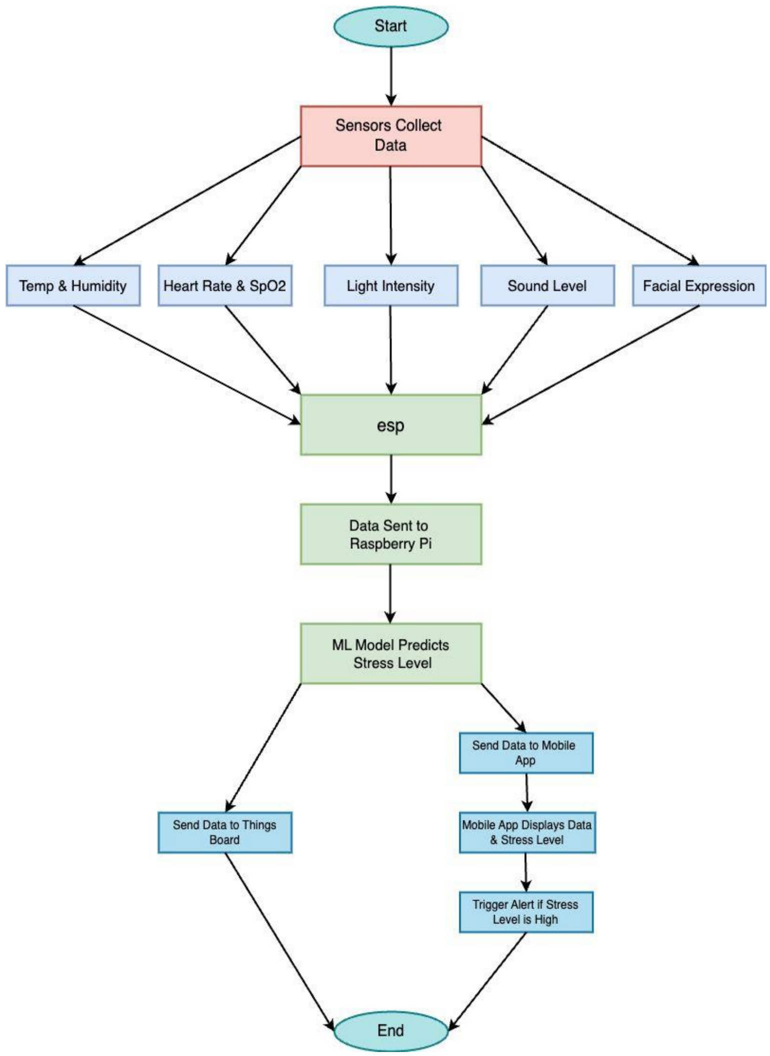

Figure: Working procedure flowchart

Conclusion:

The project integrates multiple advanced IoT, sensor, and machine learning technologies to address the growing need for stress and mental health monitoring in various environments, such as workplaces and study spaces. By leveraging data from sensors to monitor physiological and environmental factors, the system provides real-time insights into posture, stress levels, and overall well-being.

- ## Project Work Contribution (Till First & second Checkpoint Progress Report)

1. Shaikh Ramisha Maliyat (20200204054):

- Project proposal writing.
- First checkpoint progress report writing.
- Assistance in sensors collection.
- Dataset validation.

2. Rafiul Awal (20200204062):

- Dataset validation and assistance with collection.
- Project proposal writing.
- First checkpoint progress report writing.
- Dataset modification.
- Assistance in collecting codes for sensors.
- Wrote the second project progress report.

3. Nabila Rahman (20200204065):

- Dataset collection and research.
- Equipment research.
- First checkpoint progress report writing.
- Project proposal writing.

- Coding for the sensors used in the project.
- Connecting the Raspberry Pi.

4. Sabrin Sultana Chadni (20200204068):

- Project proposal writing.
- First checkpoint progress report writing.
- Assistance with dataset collection.
- Dataset validation.
- Assistance in second project progress report.

5. Syeda Tanjuma Tasnim Mayisha (20200204093):

- Dataset collection and research.
- First checkpoint progress report writing.
- Equipment research.
- Project proposal writing.
- Assistance in IoT board setup.
- Machine learning coding using the selected datasets.