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Department of Computer Science and Engineering
Program: Bachelor of Science in Computer Science & Engineering

Project Workflow and Architecture

Course No: CSE 4264
Course Title: Internet of Things (IoT) Lab

Date of Submission: 09/01/2025
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- ## Workflow of the IoT-Based Integrated Stress and Mental Health Monitoring Chair:

1. Data Acquisition

The system begins with the collection of raw data from various integrated sensors. These include:

- **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 Sensor:** Measures ambient light levels to assess the lighting conditions and their impact on mental well-being.
- **MAX4466 Microphone Module:** Records environmental sound levels to determine the noise level, which may influence stress.
- **Camera Module:** Captures images or videos to analyze facial expressions for detecting stress or discomfort.
- **Pressure and Force Sensors**: Monitor the user's sitting posture by detecting weight distribution and subtle movements.

These sensors work collectively to gather comprehensive data about the user's physical and mental state.

2. Data Transmission

- The ESP32 IoT Board and GSM Module act as communication hubs to transmit data from the sensors to the Raspberry Pi.
- The wireless transmission ensures a seamless connection, allowing data to be processed in real time without physical constraints.

3. Data Processing

- The Raspberry Pi 4 serves as the primary processing unit. It runs Python scripts to clean, preprocess, and analyze the incoming sensor data.
- Using machine learning algorithms, the system interprets the raw data to classify posture, evaluate stress levels, and identify environmental impacts on mental health.

4. Analysis and Interpretation

- **Threshold-based Analysis:** Predefined thresholds are used for parameters like heart rate, temperature, and humidity to assess stress levels.
- **Machine Learning Models:** Trained models classify the user's posture and stress state, providing insights like "Good Posture," "Slouched Posture," or "High Stress."
- **Comprehensive Feedback:** Combines multiple metrics (e.g., poor lighting, high noise, and elevated heart rate) to provide a holistic understanding of the user's well-being.

5. Feedback Generation

Feedback will be delivered through this process:

- **Mobile App Notifications:** A connected mobile app that provides real-time alerts, stretching suggestions, and relaxation techniques.

6. User Interaction

A mobile application is the primary interface for the user. It displays:

- Real-time sensor data, including heart rate, posture status, and environmental conditions.
- Alerts and notifications to guide users in improving their sitting habits.

- Suggestions for relaxation, including breathing exercises, stretching routines, and ergonomic adjustments.

7. Long-term Data Storage

- All collected data is logged into cloud storage or a local database.
- Historical trends are analyzed to offer personalized recommendations, such as adjustments to work or study environments for better health outcomes.

8. User Application Integration

The system integrates seamlessly with a mobile application that serves as the primary interface for users. Features of the application include:

- **Real-time Monitoring:** Displays live updates of vital parameters such as heart rate, posture, and environmental conditions.
- **Alerts and Notifications:** Sends alerts for corrective actions, like improving posture or reducing stress through relaxation exercises.
- **Personalized Recommendations:** Offers tailored suggestions, including stretching exercises, ergonomic adjustments, and relaxation techniques, to improve physical and mental health.
- **Data Visualization:** Displays historical trends using graphs and charts, helping users monitor their progress over time.
- **Dashboard Development**: The app will be developed using frameworks of ThingsBoard.io to ensure cross-platform compatibility and ease of use.

9. Periodic Updates and Maintenance

To ensure optimal performance and accuracy, the system is designed for regular updates and maintenance, including:

- **Software Updates:** Enhancing the mobile app and processing scripts with improved algorithms and features.
- **Machine Learning Model Retraining:** Updating models with new data to refine posture and stress detection accuracy.

- **Hardware Maintenance:** Periodically checking and calibrating sensors to prevent data inaccuracies due to wear and tear.

Maintenance schedules and guidelines are documented to ensure consistent performance.

10. Evaluation and Improvement

The system undergoes continuous evaluation to ensure it meets user needs and performs effectively:

- **Performance Testing:** Conduct tests under real-world conditions to validate system reliability and accuracy in detecting posture and stress levels.
- **User Feedback:** Regularly collect feedback to identify areas for improvement, such as interface usability, algorithm precision or feature set.
- **Data Analysis:** Review logged data for trends and anomalies to refine the machine learning models and feedback mechanisms.
- **Research and Development:** Explore new sensor technologies, advanced algorithms, and emerging ergonomic research to enhance system capabilities.

Iterative improvements are implemented based on findings, ensuring the system remains effective and user-friendly over time.

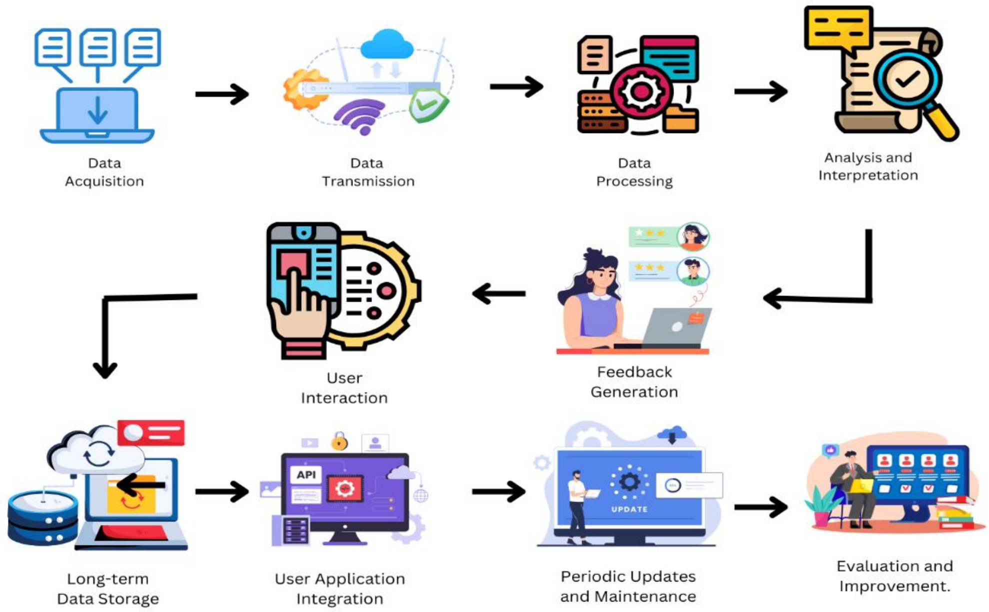

Figure 1: Workflow Diagram

- ## Basic Architecture of the IoT-Based Monitoring Chair:

1. Sensing Layer

This foundational layer collects raw data about the user's physical state and environmental conditions, serving as the input for the entire system.

Sensors:

MAX30102:

- Tracks heart rate and blood oxygen saturation (SpO2).
- Detects physiological indicators of stress, such as elevated heart rate or reduced oxygen levels during prolonged sitting.

DHT22:

- Measures environmental temperature and humidity, which significantly affect thermal comfort and stress levels.
- Detects deviations from optimal environmental conditions that may cause discomfort.

BH1750FVI:

- Measures ambient light intensity in lux.
- Identifies inadequate lighting conditions, which can lead to eye strain and mental fatigue.

MAX4466:

- Captures ambient noise levels (in decibels) to assess environmental noise, a key stressor in workplaces and study environments.

Camera Module:

- Captures images or video to analyze facial expressions using computer vision techniques.
- Detects emotional states such as stress, fatigue, or discomfort based on visual cues like frowning or squinting.

Force and Movement Sensors:

- Detect improper seating posture by analyzing weight distribution and subtle movements.
- Provide immediate feedback to users for posture correction.
- Embedded Systems

ESP32 IoT Board:

- Serves as the initial data processing unit for sensors, ensuring efficient data aggregation and transmission.
- Performs minor preprocessing tasks, such as noise filtering, to improve data quality before further processing.

2. Network Layer

- This layer ensures seamless and secure communication between sensors, processing units, and the application interface, enabling real-time feedback and data storage.

Communication Protocols

Wi-Fi:

- Provides fast and reliable data transmission to the Raspberry Pi for processing.
- Enables connectivity to cloud platforms for remote data storage and analytics.

Bluetooth:

- Facilitates local communication between the chair and the mobile app for real-time feedback without internet dependency.

GSM Module:

- Supports data transmission in areas with limited or no Wi-Fi connectivity, ensuring uninterrupted system functionality.

3. Data-Processing Layer

This critical layer transforms raw sensor data into actionable insights using advanced computation and analytics.

Processing Units

Raspberry Pi 4:

- Functions as the central processing unit, orchestrating data handling, analysis, and machine learning execution.
- Runs Python-based scripts for processing sensor inputs.

Edge Computing:

- Local processing on the Raspberry Pi reduces latency and ensures real-time feedback, even in offline conditions.

Cloud Computing:

- Platforms like AWS, Google Cloud, or Microsoft Azure can be integrated for:
- Advanced analytics requiring high computational power.
- Long-term data storage to support historical trend analysis and system improvements.

Machine Learning:

- Posture Detection Models: Analyze force sensor data to classify user posture as "correct" or "incorrect."
- Stress Analysis Algorithms: Use heart rate variability, facial expressions, and environmental factors to assess stress levels.
- Environment Analysis: Correlates noise, lighting, and temperature with user stress for a comprehensive view of external influences.

Databases:

- **Local Storage:** Temporary storage on the Raspberry Pi for immediate data access and system responsiveness.
- **Cloud Databases:** Securely store raw and processed data for extended periods to enable trend analysis and informed decision-making.

4. Application Layer

This user-facing layer provides an intuitive interface for accessing system insights, receiving feedback, and improving user habits.

Mobile App

Real-Time Monitoring:

- Displays live data on metrics like heart rate, posture, and environmental conditions.
- Alerts users to take corrective actions based on current conditions (e.g., adjust posture or reduce stress).

Guided Assistance:

Offers personalized suggestions, including:

- Stretching Exercises: Relieves muscle tension from prolonged sitting.
- Relaxation Techniques: Includes breathing exercises to lower stress levels.
- Ergonomic Adjustments: Recommends optimal seating adjustments for improved posture.

Customization Options:

- Allows users to set personalized thresholds for stress levels or posture alerts.

Dashboard

Data Visualization:

- Provides graphical representations of historical data, including:
- Posture patterns over time.
- Stress level trends correlated with environmental conditions.
- Helps users identify long-term behavioral patterns and environmental triggers affecting their well-being.

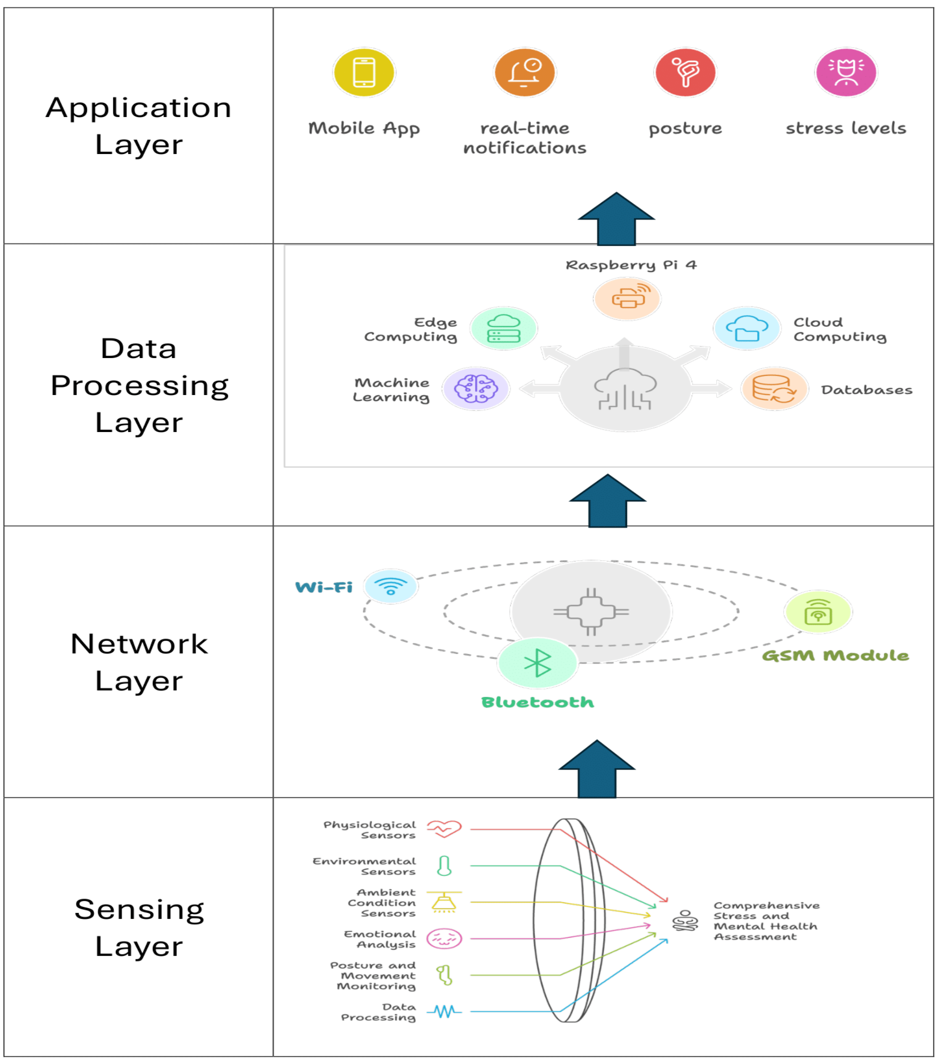

Figure 2: Building Blocks of IoT Architecture

- ## Implementation Steps:

1. Hardware Setup

- Assemble the chair frame and embed the sensors (DHT22, MAX30102, etc.) in designated locations to ensure accurate data collection.
- Connect all components, including the Arduino Uno, ESP32 IoT board, Raspberry Pi, and GSM module, using jumper wires for communication.
- Install the RGB LED on the chair for visual feedback.

2. Sensor Calibration and Testing

- Calibrate each sensor to ensure accurate readings. For example:
- Adjust the DHT22 for precise temperature and humidity measurements.
- Test the MAX30102 for heart rate and oxygen saturation accuracy.
- Verify the output of individual sensors under controlled conditions.

3. Software Development

- Write Arduino code to read sensor data and send it to the Raspberry Pi via ESP32 or GSM.
- Develop Python scripts to analyze sensor data using libraries like OpenCV (for facial expressions) and NumPy (for numerical analysis).
- Train machine learning models using labeled datasets to classify stress levels and posture states.

4. App and User Interface Development

- Build a cross-platform mobile app using frameworks like Flutter or React Native.
- Integrate features like real-time alerts, data visualization, and guided relaxation techniques.

5. Network Integration

- Configure the ESP32 and GSM modules to establish seamless connectivity for transmitting data between the chair and the mobile app.

6. System Integration

- Integrate all hardware and software components to create a fully functional system.
- Perform end-to-end testing to verify data flow, system responses, and feedback accuracy.

7. Feedback Mechanisms

- Enable app notifications to provide actionable advice, such as adjusting posture or taking breaks.

8. Data Logging and Trend Analysis

- Set up cloud or local storage for storing long-term data.
- Enable trend visualization in the mobile app to identify patterns and suggest improvements.

9. Deployment and Testing

- Deploy the system in real-world scenarios, such as offices or study environments, to evaluate its effectiveness.
- Collect user feedback and refine algorithms or app features based on performance.

10. Documentation and Maintenance

- Create detailed documentation for hardware setup, software installation, and usage instructions.
- Schedule regular updates for the app and machine learning models to enhance accuracy and user experience.

• Project Work Contribution (Till First Checkpoint Progress Report)

1. **Shaikh Ramisha Maliyat (20200204054):**

- Project proposal writing.
- First checkpoint progress report writing.

2. **Rafiul Awal (20200204062):**

- Dataset validation, assistance with collection & dataset modification.
- Assistance in equipment research.
- Project proposal writing.
- First checkpoint progress report writing.
- Assistance in coding implementation for heart rate & oxygen saturation calculation.

3. **Nabila Rahman (20200204065):**

- Dataset collection and research.
- Equipment research.
- Project proposal writing.
- First checkpoint progress report writing.
- Coding implementation for heart rate & oxygen saturation calculation.

4. **Sabrin Sultana Chadni (20200204068):**

- Project proposal writing.
- First checkpoint progress report writing.
- Assistance with dataset collection & modification.

5. **Syeda Tanjuma Tasnim Mayisha (20200204093):**

- Dataset collection and research.
- Equipment research.
- Project proposal writing.
- Assistance in IoT board setup & hardware implementation.