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Smart Band Enabled AI-System for Mental Health Tracking

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ABSTRACT

The paper presents the development of an AI- enabled smart band designed to continuously monitor mental wellness through the real-time analysis of three key physiological indicators: heart rate, body temperature, and movement patterns. These signals are captured by onboard sensors and transmitted wirelessly to a cloud-based platform using the ESP32/Node MCU module. The system applies AI algorithms to detect variations and correlations in the data that may indicate mental stress, fatigue, or anxiety. Elevated heart rate, abnormal temperature fluctuations, and irregular movement patterns—detected through the accelerometer—serve as critical markers for early- stage mental health concerns. The processed data is visualized on a user-friendly web and mobile dashboard, where users can monitor their mental state trends and receive real-time alerts. When stress thresholds are exceeded, the system delivers instant notifications via app alerts, SMS, or email, encouraging timely interventions. Personalized suggestions, such as light physical activities, deep breathing exercises, or short breaks, are generated based on individual user behavior. The smart band not only provides continuous, non-invasive mental health monitoring but also learns from user data over time using machine learning to improve prediction accuracy. This approach transforms traditional mental health assessment methods by introducing a proactive, AI-driven, and data- centric system for managing everyday stress and emotional well-being.

Keywords: AI-Enabled smart band, Real time mental health monitoring system, IoT Integration, Predictive Insights, Personalized Wellness recommendations.

INTRODUCTION

Mental health concerns, such as stress, anxiety, and sleep disorders, often go unnoticed until they reach a critical stage. Traditional methods of monitoring mental well-being are often reactive, requiring clinical visits and subjective self-assessments. To address this gap, this project introduces an IoT- Based Mental Health Monitoring System with a Smart Band, designed to provide continuousreal-time tracking of an individual's mental health status through physiological and behavioral indicators. The smart band is equipped with a MAX30100/MAX30102 sensor for heart rate and heart rate variability (HRV),a DS18B20/LM35 sensor for body temperature monitoring, and an MPU6050 accelerometer to track movement and sleep patterns. These sensors work together to collect crucial biometric data, offering a holistic view of an individual's mental wellbeing. To ensure seamless data transmission, the system employs an ESP32/Node MCU microcontroller, which continuously sends sensor data to a cloud server, enabling real-time accessibility from anywhere. Users can interact with a web dashboard, developed using HTML, parameters through intuitive graphs, charts, and trend analysis tools. Beyond real-time monitoring, AI-driven algorithms developed in Python analyze historical data, detect stress patterns, and predict potential mental health fluctuations. The system proactively sends alerts via email, SMS, or web notifications when abnormal stress levels or irregular health trends are detected. Additionally, it offers personalized well- being recommendations, including guided meditation, breathing exercises, and activity reminders, to help users manage stress effectively. To improve user engagement, the web interface was created with utility and simplicity in mind. The platform has a simple design with input areas for data collected by the sensors, including skin surface temperature, heart rate, sleep patterns. Following data submission, the system processes the input using AI algorithms to produce real- time results. Personalized advice for preventative Treatment or additional medical consultation. CSS, and JavaScript, to visualize their health.

Condition	Herat Rate (bpm)	H&T (°C)
Relax	60-70	36-37
Calm	70-90	35-36
Anxious	90-100	33-35
Stress	>100	< 33

LITERATURE REVIEW

[1]. The study states that ,Smart IoT technology dramatically improves mental health monitoring by combining data from wearable devices, mobile applications, and ambient sensors. These technologies gather physiological, behavioral, and emotional data, allowing machine learning to detect illnesses such as depression and anxiety early on. IoT- enabled applications analyses user communications, such as text messages and social media interactions, to monitor emotional states and deliver real-time feedback. Personalized interventions, such as mindfulness exercises and therapy recommendations, are a major emphasis. Concerns about data privacy, over medicalization, and ethical use of sensitive information are often debated. Remote monitoring provides mental health practitioners with real-time data to make prompt interventions. However, there are still issues in integrating various data sources and guaranteeing security. The literature emphasizes the importance of balancing technical innovation and ethical responsibility in order to make mental health care more accessible, proactive, and successful using IoT-driven solutions. This method transforms mental health monitoring and intervention.

[2]. The study employed a mixed-methods approach to investigate the use of smartphone sensors for unobtrusive behavioral monitoring of mental health. A total of 47 participants, primarily undergraduate and graduate students, were

enrolled over a ten-week period. Participants used customized smartphone software designed to collect multi-modal sensor data continuously, which included inputs from the microphone, GPS, accelerometers, Wi-Fi receiver, and light sensor. Daily self-reported stress ratings were prompted through the smartphone, in addition to pre- and post-study questionnaires assessing measures of stress, depression, and loneliness. This methodology allowed for the passive collection of behavioral data correlated with participants' daily mental health fluctuations, hypothesizing a relationship between sensor data and self-reported mental health indicators over time. The study aimed to explore the feasibility and effectiveness of smartphone- sensed data as actionable markers for mental health management beyond clinical environments.

[3]. The study established a set of relevant search terms (STs) to guide the literature review, including terms related to wearable sensors (e.g., "wearable sensors," "sensor devices"), mental health disorders (e.g., "anxiety disorder," "panic disorder," "panic attack"), and prediction methods (e.g., "machine learning, "prediction"). The search strategy employed logical operators (AND, OR) to combine these STs, ensuring a comprehensive.

[4]. The literature survey findings indicate that mental health tracker web applications significantly improve user outcomes by incorporating effective features such as mood tracking, goal-setting, and social support. Goal setting involves users defining specific, measurable objectives related to their mental well- being, such as improving mood, reducing anxiety symptoms, or increasing self-care activities. This process motivates users, enhances self-efficacy, and provides a structured framework for monitoring progress in managing mental health. These platforms enhance accessibility to mental health resources, empowering users to manage their conditions better. However, the need for evidence-based approaches remains critical, as not all applications provide effective support.

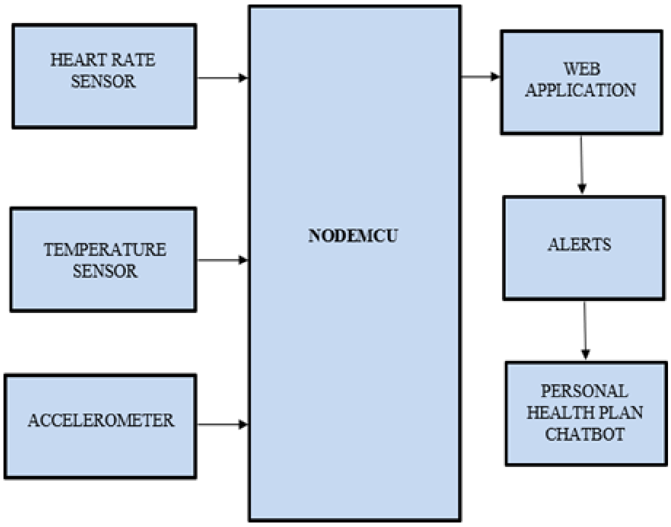
METHODOLOGY

The IoT-Based Mental Health Monitoring System with a Smart Band is designed to collect, process, and analyze physiological and behavioral data to monitor mental well-being in real-time. The system integrates multiple biometric sensors into a wearable device to track essential parameters like heart rate, stress levels, body temperature, movement, and sleep patterns. These physiological indicators provide critical insights into a person's mental health condition. The goal is to create an intelligent, data-driven, and user-friendly solution that allows individuals and healthcare providers to monitor and manage mental health effectively. The sensor data collection process is a crucial aspect of the system. The smart band is equipped with sensors including MAX30100/MAX30102 for heart rate and HRV,a DS18B20/LM35 sensor for body temperature monitoring, and an MPU6050 accelerometer and gyroscope for movement and sleep analysis. These sensors continuously collect real-time data, ensuring a comprehensive evaluation of the user's mental health state. The collected data is processed and sent to the system's microcontroller for further transmission. The combination of multiple sensors allows for a more accurate and holistic assessment of mental wellbeing. The ESP32/NodeMCU microcontroller plays a key role in the system's data transmission process. It collects the sensor readings, processes them, and transmits the data to a cloud server via Wi- Fi connectivity. This cloud-based approach ensures that the user's health data is securely stored and can be accessed from anywhere at any time. The system enables real- time data synchronization, allowing for continuous monitoring without manual intervention.

Cloud integration also facilitates remote access, enabling healthcare professionals or caregivers to monitor the mental well-being of individuals and provide necessary interventions. The web dashboard serves as the visualization and user interface component of the system. Built using HTML, CSS, and JavaScript, the dashboard provides real-time graphical representation of the collected data, allowing users to track their mental health trends. The dashboard includes interactive graphs and charts that display heart rate fluctuations, stress levels, temperature variations, movement patterns, and sleep quality. Users can log in securely to view their data, set encourage them to take immediate action. The personalized health goals, and receive notifications about significant changes in their mental health parameters. The user-friendly design ensures that both individuals and healthcare professionals can easily interpret and utilize the collected data. To enhance the system's intelligence, AI-based analysis is incorporated to process and interpret the collected data. Machine learning algorithms developed in Python analyze historical data to detect patterns and predict potential fluctuations in mental health conditions.

The AI system identifies stress trends, detects abnormal variations in physiological signals, and provides predictive insights to help users take proactive measures. By leveraging AI-driven data analysis and pattern recognition, the system improves its accuracy over time, making it a reliable tool for early detection and prevention of mental health disorders. One of the key functionalities of the system is its alerts and recommendations feature. When stress levels exceed a critical threshold or an irregular pattern is detected, the system sends automated alerts via email, SMS, or web notifications. These alerts notify users about potential mental health risks and system also provides personalized recommendations, such as guided meditation, breathing exercises, activity reminders, and sleep hygiene tips. These recommendations are tailored based on the user's historical data and AI-driven insights, promoting self-care and mental well- being management. To ensure continuous improvement and adaptability, several future enhancements are planned for the system. These include AI-based emotion detection using voice analysis and facial recognition, enabling a deeper understanding of emotional states. Additionally, Bluetooth-enabled offline tracking will allow users to collect data even when they are not connected to the internet. A mental health chatbot will also be integrated to provide real- time emotional support, self-help strategies, and stress management guidance. The ultimate objective of this project is to develop an accessible, data- driven, and AI-powered solution that empowers individuals to take control of their mental health, ensuring proactive intervention.

Fig 3.1 Block Diagram of Health Monitoring and Alert System



HARDWARE DESCRIPTION

4.1 ESP32/NodeMCU - ESP32 and NodeMCU are Wi-Fi- enabled The MAX30100/MAX30102 is an optical heart microcontroller widely used in IoT-based health monitoring systems for real-time data collection and transmission. They connect to sensors like heart rate monitors, temperature sensors, and motion detectors, sending data to cloud platforms (Firebase, AWS, or MQTT) for remote monitoring. The ESP32, with its dual-processor, higher RAM, and low power consumption, is ideal for advanced applications, while the NodeMCU (ESP8266) is a simpler, cost- effective alternative. Their built-in Wi-Fi and Bluetooth capabilities enable seamless communication core, making them suitable for wearable health devices, smart bands, and remote patient monitoring. These microcontrollers allow real-time tracking of vital signs, helping users and medical professionals detect abnormalities early and take timely action.

Fig 4.1 NODEMCU/ESP32

4.2 Heart Rate Sensor (MAX30100/MAX30102) - The MAX30100/MAX30102 is an optical heart rate sensor that uses infrared and red LEDs to measure heart rate (HR) and blood oxygen(SpO2)through photoplethysmography (PPG). It tracks heart rate variability (HRV), essential for stress and mental health analysis. With low power consumption, high accuracy, and a compact design, it is ideal for wearable health devices like smartwatches and fitness trackers. The MAX30102 improves on the MAX30100 with better noise resistance and higher sampling rates, making it more reliable for continuous health monitoring and IoT-based remote patient tracking. It seamlessly integrates with ESP32, Arduino, and NodeMCU, enabling real-time data transmission to it a key to cloud platforms for analysis. This makes component in IoT healthcare applications, fitness tracking, and personalized health monitoring.

Fig 4.2 HEART RATE SENSOR

4.3 Temperature Sensor (DS18B20/LM35) - Temperature sensors like the DS18B20 and LM35 are widely used for accurate temperature measurement in various applications. The DS18B20 is a digital temperature sensor that communicates using the 1- Wire protocol, allowing multiple sensors to be connected to a single d a t a l i n e . It provides high accuracy (±0.5°C from -10°C to+85°C) and supports a wide temperature range from -55°C to +125°C, making it ideal for industrial, environmental, and embedded systems. On the other hand, the LM35 is an analog temperature sensor that outputs a voltage proportional to the temperature in degrees Celsius. It has a linear output of 10mV per °C and operates efficiently within a range of -55°C to +150°C, with an accuracy of ±0.5°C at room temperature. Unlike thermistors, the LM35 does not require calibration and is commonly used in HVAC systems, weather stations, and medical devices. Both sensors offer reliable temperature monitoring but differ in interface and application suitability, with the DS18B20 preferred for digital systems and the LM35 for simple analog circuits.

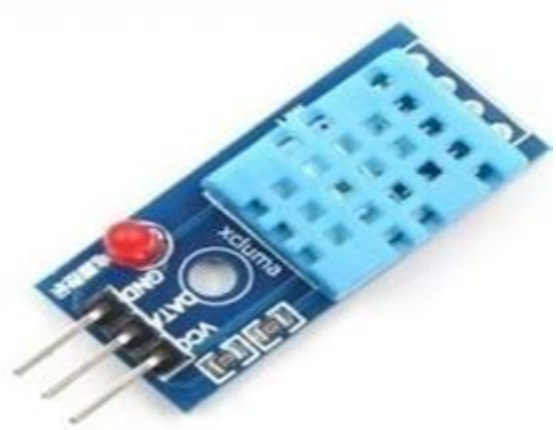


Fig 4.3 TEMPERATURE SENSOR

4.4 Accelerometer - An accelerometer is an electromechanical sensor used to measure acceleration forces, which may be static (like gravity) or dynamic (caused by motion or vibrations). It detects changes in velocity and orientation across three axes—X, Y, and Z—and converts mechanical movement into electrical signals for processing. Widely found in smartphones, fitness trackers, vehicles, and robotics, accelerometers play a key role in enabling features such as screen rotation, step counting, collision detection, and motion-based controls. Common types include capacitive, piezoelectric, and MEMS (Micro-Electro-Mechanical Systems), with MEMS being the most prevalent due to their compact size and low power requirements. In vehicles, accelerometers assist in airbag deployment and crash detection, while in medical devices, they monitor body posture and movement. Drones use them for flight stability, and various industrial systems employ them to measure vibration, tilt, and shock. The sensitivity and range of an accelerometer depend on its intended application, and calibration is essential for precise readings. Overall, accelerometers are fundamental in many modern technologies requiring motion sensing and analysis.

Fig 4.4 ACCELEROMETER

SOFTWARE DESCRIPTION

Arduino IDE - The Arduino IDE (Integrated Development Environment) is a free, open-source software platform designed to help users write, compile, and upload code to Arduino microcontroller boards. It provides a simple and user-friendly interface, making it easy for beginners and professionals alike to develop projects involving electronics and embedded systems. The code written in the Arduino IDE is called a "sketch," and it uses a simplified version of C/C++ language, tailored for Arduino development. One of the key strengths of the Arduino IDE is its compatibility with a wide range of Arduino boards, including the popular Arduino Uno, Nano, Mega, and others like ESP32 and ESP8266. Users can select the specific board and port from the "Tools" menu, making it easy to communicate with the connected device. The IDE includes essential tools such as the Verify button to check for code errors, the Upload button to transfer code to the board, and the Serial Monitor to display data from sensors or debug messages in real time. Additionally, the Arduino IDE includes a large collection of built-in libraries and examples that simplify working with sensors, motors, displays, and other hardware components. The Library Manager allows users to easily install and manage these libraries. There's also a Board Manager that helps download support for additional boards beyond the default Arduino ones. The IDE is available for Windows, macOS, and Linux, and it requires only basic system resources, making it accessible to a wide range of users and devices. Overall, the Arduino IDE is an essential tool for students, hobbyists, and engineers who want to explore electronics, robotics, and IoT projects. It encourages creativity and experimentation by providing a stable environment to prototype and test hardware-based applications. For more advanced features such as debugging, dark mode, and code auto-completion, users can also try the newer Arduino IDE 2.0, which enhances the development experience while maintaining the simplicity of the original version.

FIG 5.1 ARDUINO IDE

FLOWCHART

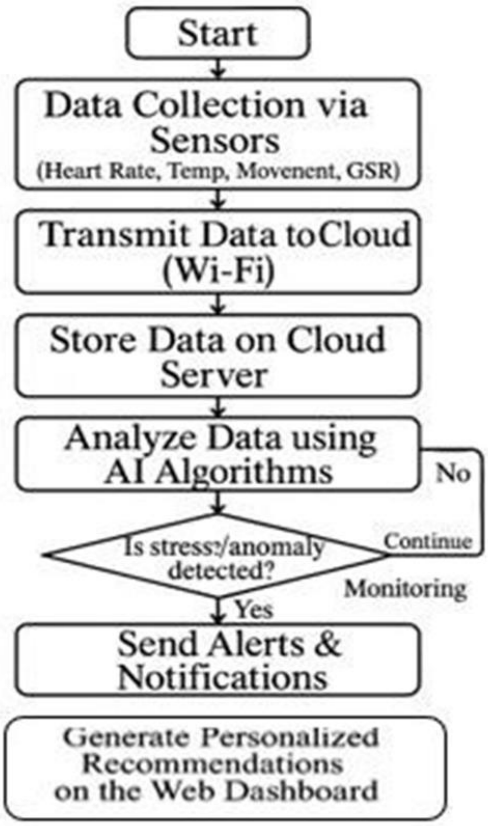


Fig 6.1 AI-Driven Stress Detection and Recommendation Flow

RESULT AND DISCUSSION

The developed AI-enabled smart band successfully monitored core physiological indicators—body temperature, heart rate, and movement patterns—in real time. Throughout the testing phase, the band consistently captured accurate sensor data and transmitted it to the cloud platform using the ESP32/NodeMCU module. AI algorithms analyzed the data to detect patterns associated with mental stress, such as elevated heart rate, abnormal temperature fluctuations, and irregular movement or inactivity. When stress indicators crossed predefined thresholds, the system promptly sent alerts to users via mobile notifications and email, enabling early and effective intervention. The web dashboard offered a user-friendly interface to visualize health data trends, making it easier for individuals to understand and track their mental wellness. The accelerometer played a key role in detecting physical activity levels and identifying signs of restlessness or sedentary behavior, both of which are important markers of stress. Combined with heart rate and temperature readings, the AI system generated personalized suggestions for stress relief, such as taking short walks or practicing relaxation techniques Over time, the machine learning model improved its ability to predict stress episodes by learning from individual user patterns. This adaptive capability allowed for more accurate and tailored health insights. Unlike traditional mental health monitoring methods, which are often reactive and periodic, this smart band offered continuous, real- time analysis, empowering users to manage their mental well- being proactively.

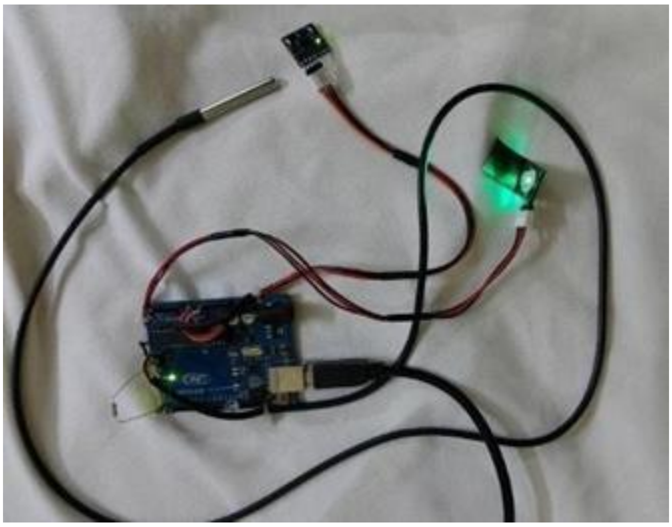


FIG 7.1 HARDWARE

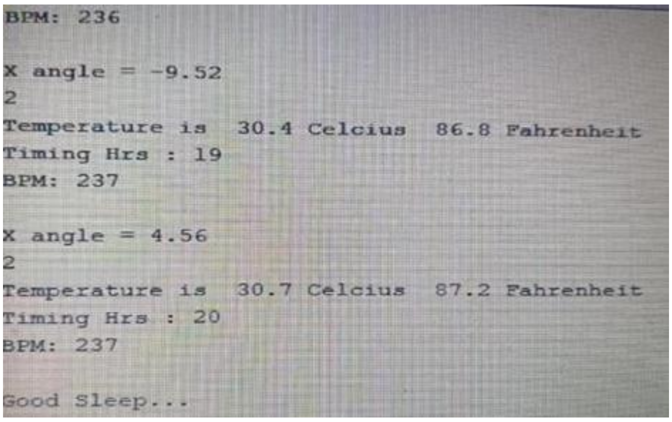


FIG 7.2 OUTPUT OF PHYSIOLOGICAL PARAMETERS AND SLEEP CONDITION

CONCLUSION

In conclusion, the proposed AI-enabled smart band offers a practical and innovative solution for real-time mental health monitoring using non-invasive physiological data. By focusing on key indicators such as heart rate, body temperature, and movement patterns, the system effectively identifies stress-related symptoms and provides users with timely alerts and personalized recommendations. The integration of IoT technology with AI-powered analysis ensures accurate detection of mental health variations, enabling proactive interventions and continuous well- being support. Unlike conventional mental health assessments, which rely on self-reporting or periodic evaluations, this smart band provides a seamless, continuous, and adaptive approach to mental wellness. The inclusion of cloud connectivity and a user-friendly dashboard enhances accessibility and engagement, empowering users to take charge of their mental health. As the system learns and evolves with user data, it holds significant potential to improve personalized care. Future advancements, such as offline Bluetooth connectivity and enhanced AI- based emotion detection, will further strengthen its impact, making it a valuable tool in the field of digital mental health care.

OUTPUT

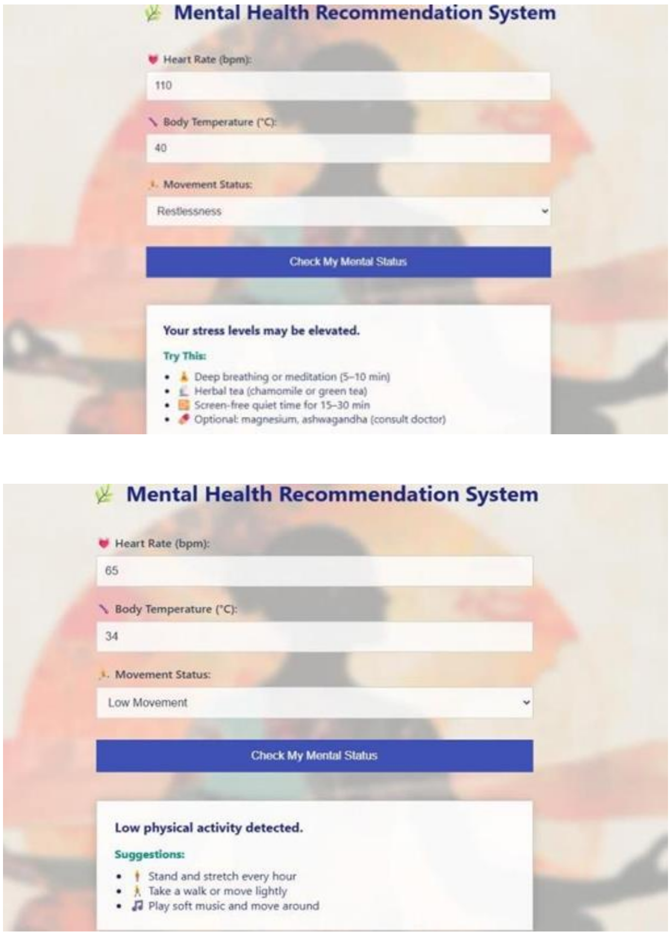


FIG 9.1 SYSTEM INTERFACE DISPLAYING MENTAL HEALTH RECOMMENDATIONS BASED ON SENSOR- ACQUIRED INPUTS

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