ವಿಶ್ವೇಶ್ವರಯ್ಯ ತಾಂತ್ರಿಕ ವಿಶ್ವವಿದ್ಯಾಲಯ, ಬೆಳಗಾವಿ

Visvesvaraya Technological University

"Jnana Sangama" Belagavi – 590018

Project Report

On

"Emotion Recognition System for Autistic Individuals using Hand and Head Movements"

Submitted in partial fulfilment for the award of degree of

Bachelor of Engineering

By

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ATRIA INSTITUTE OF TECHNOLOGY
(AN AUTONOMOUS INSTITUTION)
BENGALURU

CERTIFICATE

Certified that the project work entitled **"Emotion Recognition System for Autistic Individuals using Hand and Head Movements"** carried out by **Ms. H Yogitha – 1AT21EC044, Mr. Syed Masood Hussain – 1AT21EC162, Ms. Vaishnavi D P – 1AT21EC173,** a Bonafide students of VIII Semester Electronics & Communication Engineering, Atria Institute of Technology, Bengaluru in partial fulfilment for the award of Bachelor of Engineering in Visvesvaraya Technological University, Belagavi during the year **2024-25**. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said Degree.

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Dr. Rakhi S	**Dr. Jagadeesh H S**	**Dr. Rajesha S**
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Name of the Examiners Signature with date

1.
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DECLARATION

We **Ms. H Yogitha – 1AT21EC044, Mr. Syed Masood Hussain – 1AT21EC162, Ms. Vaishnavi D P – 1AT21EC173** students of final year Bachelor of Engineering , Department of Electronics and Communication Engineering, Atria Institute of Technology Bangalore, would hereby declare the project entitled **"Emotion Recognition System for Autistic Individuals using Hand and Head Movements"** has been carried out by us at Atria Institute of Technology Bengaluru and submitted in partial fulfilment of the course requirements for the award of degree of Bachelor of Engineering in Electronics and Communication Engineering of Visvesvaraya Technological University, Belagavi during the academic year 2024 – 2025.

Place: Bengaluru
Date: 15-05-2025

Signature of Students

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ABSTRACT

Autistic individuals often struggle with verbal communication and facial emotional expression, making it challenging for caregivers, therapists, and educators to interpret their emotional states. Traditional emotion recognition systems primarily focus on facial cues, which may not be effective for individuals on the autism spectrum. This project aims to bridge this gap by proposing a wearable AI-based emotion recognition system that leverages non-verbal cues specifically hand gestures and head movements to detect and classify emotional states such as happiness, sadness, anger, and excitement.

The proposed system comprises a smart glove and a smart headband integrated with various sensors including Inertial Measurement Units (IMUs), flex sensors, and pressure sensors. These devices capture real-time motion data which is processed locally using machine learning models implemented on edge devices like ESP32 or Raspberry Pi. By avoiding cloud-based processing, the system ensures user data privacy while providing instant feedback through visual, auditory, or tactile means such as LED indicators or mobile app interfaces.

Designed with affordability and usability in mind, the system offers a comfortable, non-intrusive experience suitable for use in homes, schools, and therapy centers. It enables timely and informed responses by caregivers and educators, facilitating better emotional support for autistic individuals. The project not only contributes to assistive technology but also highlights the potential of wearable AI solutions in improving the quality of life for people with special needs.

CONTENTS

List of Figures

Chapter – I

Introduction

CHAPTER 1

INTRODUCTION

1.1 Introduction

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by challenges in social interaction, communication, and behavioral flexibility. One of the most significant hurdles faced by individuals with ASD is the inability to effectively express or interpret emotions, especially through verbal communication and facial expressions. This limitation makes it difficult for caregivers, therapists, and educators to understand their emotional needs, often leading to misinterpretation or delayed responses. As a result, there is a growing need for alternative methods that can reliably decode emotional states through non-verbal cues.

Non-verbal communication, such as hand gestures, postures, and head movements, offers valuable insights into the emotional conditions of individuals with autism. However, most existing emotion recognition systems are heavily reliant on facial recognition techniques, which may not be suitable or accurate for this population. To address this gap, our project proposes a novel, wearable AI-powered emotion recognition system that utilizes hand and head movement data to classify emotions. This non-intrusive approach leverages advancements in sensor technology and machine learning to create a more inclusive and responsive system.

The system comprises a smart glove and a headband embedded with sensors including flex sensors to track finger bending, pressure sensors to detect grip force, and Inertial Measurement Units (IMUs) to monitor orientation and motion. These wearables capture real-time motion data that is processed by trained machine learning models running locally on hardware platforms such as ESP32 or Raspberry Pi. Local processing not only ensures real-time responsiveness but also addresses critical privacy concerns, as no data needs to be transmitted to cloud servers.

This solution is designed with accessibility, affordability, and ease of use in mind. By providing emotion feedback through visual indicators (LEDs), auditory cues, or even mobile app interfaces, the system allows caregivers and therapists to quickly understand and respond to the emotional state of the user. Whether in a classroom, home, or therapy centre, the proposed system can serve as an effective assistive technology tool, enhancing emotional awareness and improving the overall quality of interaction and care for autistic individuals.

Moreover, the system’s modular and scalable design ensures it can be adapted to various age groups and severity levels within the autism spectrum. Components like the glove, head-mounted IMU, and microcontroller can be customized or upgraded based on individual needs without significantly increasing cost or complexity. This adaptability makes the solution suitable for widespread implementation across educational institutions, therapy centers, and personal use. By lowering technological and financial barriers, the system has the potential to democratize access to emotional support tools, contributing to more inclusive care environments for neurodiverse communities.

In addition to its technical benefits, the system is built with the end user in mind both the autistic individual and the caregiver. The wearables are designed to be comfortable and unobtrusive, using stretchable materials like sports gloves and elastic headbands to ensure long-term wearability. The focus on affordability through off-the-shelf components like ESP32 microcontrollers and common sensors ensures that the system is not limited to clinical environments but can be adopted by families and schools with minimal financial burden. The user interface is kept intuitive and adaptable, with options for integration into a mobile app developed using platforms like React Native or Flutter.

Furthermore, the system supports multi-modal feedback and customization to cater to individual user needs. For example, the mode of feedback be it LED-based visual cues, sound alerts, or even haptic vibrations—can be tailored to the user's sensory preferences and the caregiver's requirements. In addition, a dedicated website has been developed as part of the system’s output interface, which displays the detected emotional states in text format. This web-based platform allows caregivers, therapists, or family members to remotely view and monitor emotional updates in a user-friendly and accessible manner.

1.2 Problem statement

i. Many autistic individuals have trouble recognizing and expressing emotions verbally or through facial expressions, making it hard for others to understand their emotional state.

ii. Existing emotion recognition systems primarily rely on facial recognition and speech analysis, which are not effective for individuals with autism who may not exhibit conventional emotional cues.

iii. Most current solutions ignore critical non-verbal indicators such as hand gestures and head movements, which are often more expressive and natural for autistic individuals.

iv. There is a lack of affordable, wearable, and non-intrusive systems that can detect emotions in real-time based on movement data, which limits timely intervention and support.

v. Many available emotion recognition technologies are cloud-dependent, raising privacy concerns and limiting accessibility, especially in home or low-resource environments.

1.3 Scope

The scope of the Sonic Sleep system encompasses the design, development, and deployment of a smart sleep optimization device capable of continuously monitoring critical physiological parameters such as heart rate, oxygen saturation, body posture, and movement during sleep. This involves selecting appropriate biomedical and motion sensors, developing efficient real-time data acquisition and processing techniques, designing a compact and reliable hardware architecture using the ESP8266 microcontroller, implementing adaptive audio feedback mechanisms for sleep enhancement, and establishing a user-friendly interface through an OLED display for real-time feedback. The project further emphasizes ensuring the system's scalability, accuracy, low power consumption, and ease of use for long-term personal health monitoring applications. Advanced signal processing algorithms will be applied to filter noise and extract meaningful sleep metrics from raw sensor data. Additionally, the system will feature customizable audio profiles that adapt to the user's sleep patterns and preferences, promoting deeper and more restorative sleep. Emphasis will also be placed on ergonomic design and user comfort, ensuring that the device remains non-intrusive and practical for everyday use.

Chapter – II

Literature Survey

CHAPTER 2

LITERATURE SURVEY

[1] "AffectNet: A Database for Facial Expression, Valence, and Arousal Computing in the Wild" – Mollahosseini, A., Hasani, B., & Mahoor, M. H. (2019)

This paper introduces AffectNet, a large-scale database of facial expressions collected from the internet and annotated for emotion, valence, and arousal. The dataset supports the development of deep learning-based models that classify emotions based on facial features under real-world conditions. AffectNet helps overcome limitations of controlled laboratory datasets by offering data with diverse backgrounds, lighting, and expressions. While this work significantly advances facial emotion recognition, its reliance on facial expressions may not effectively serve individuals with autism, who often exhibit atypical or subdued facial cues. This highlights the need for alternative modalities like hand and head movements for emotion detection.

[2] "Designing a Holistic At-Home Learning Aid for Autism" – Catalin Voss, Nick Haber, Peter Washington, et al.

This study focuses on the design and development of a wearable emotion recognition tool for children with autism, using smart glasses integrated with AI-based emotion detection. The system provides real-time social cues and feedback, enabling children to recognize and respond to emotions during interactions. The design prioritizes usability, comfort, and real-time assistance to support learning in natural environments. Although the system shows promise, the use of smart glasses may not be suitable for all individuals due to potential discomfort or sensory issues. Our project adopts a more accessible and non-intrusive approach by using gloves and headbands to detect emotional states based on physical movement, offering a viable alternative for those with sensory sensitivities.

[3] "Wearable Technology Design for Autism Spectrum Disorders" – M. Mazurek, L. C. Wagner, M. A. Vattikuti, and J. S. Keefer

This paper reviews the development of wearable technologies aimed at supporting individuals with Autism Spectrum Disorders (ASD), focusing on functionality, comfort, and social acceptability. The authors emphasize the importance of personalized and unobtrusive wearable solutions that collect behavioral and physiological data without causing distress. The research supports the integration of real-time feedback mechanisms and highlights challenges such as data privacy and user compliance. These insights are directly applicable to our system design, which leverages soft, comfortable materials and locally processed data to ensure user comfort and privacy while enabling effective emotion tracking through hand and head motion analysis.

[4] "OpenFace: An Open-Source Facial Behavior Analysis Toolkit" – T. Baltrusaitis, P. Robinson, and L.-P. Morency (2016)

This paper presents OpenFace, an open-source toolkit for facial behavior analysis, capable of real-time facial landmark detection, head pose estimation, and facial action unit recognition. It enables accessible research in affective computing and human-computer interaction. While powerful in facial analysis, its utility is limited for populations like autistic individuals who may not express emotions clearly through facial cues. This reinforces the importance of exploring alternative indicators such as body movement, which our system captures through hand and head gestures.

[5] "Affectiva-MIT Facial Expression Dataset (AM-FED)" – D. McDuff, R. El Kaliouby, T. Senechal, et al. (2013)

The AM-FED dataset provides naturalistic and spontaneous facial expressions recorded through webcams in uncontrolled environments. It is instrumental in training models for facial emotion recognition under real-world conditions. However, its dependence on facial expressiveness does not translate well to individuals with ASD, who may have limited or flat facial affect. This limitation supports our project's aim to recognize emotions through physical movement, bypassing the need for facial data entirely.

[6] "A Survey of Affect Recognition Methods: Audio, Visual, and Spontaneous Expressions" – Z. Zeng, M. Pantic, G. I. Roisman, and T. S. Huang (2009)

This survey categorizes affect recognition methods across audio, visual, and spontaneous expressions, identifying both strengths and limitations in each modality. It acknowledges the challenges of using facial expressions and speech in natural settings, especially with neurodiverse populations. The study advocates for multi-modal systems, echoing our approach of using physical gestures—particularly hand and head movements—as alternative, accessible inputs for affect detection in autistic users. It also provides insights into spontaneous expression datasets, which can guide the creation of training data for movement-based emotion models. The emphasis on real-world application contexts strengthens the justification for our wearable system's real-time functionality. Furthermore, the survey highlights the importance of context-aware affect recognition, suggesting that environmental and situational cues significantly influence emotional expression and interpretation. This aligns with the goals of our system, which aims to function effectively in varied real-life scenarios such as classrooms, therapy sessions, or home environments. By leveraging gesture-based inputs that are less affected by external distractions or communication barriers.

[7] "Deep Affect Prediction in-the-Wild: Aff-Wild Database and Challenge" – D. Kollias, G. Tzimiropoulos, S. Cheng, and S. Zafeiriou (2019)

This research introduces the Aff-Wild database and associated deep learning models for affect prediction using facial videos in dynamic environments. It showcases how robust, deep models can analyze human emotions under natural conditions. Although highly accurate in facial emotion recognition, the Aff-Wild database is again limited by its reliance on expressive facial data. Our system, by contrast, avoids this limitation by analyzing motion cues to serve individuals with reduced facial expressiveness. The Aff-Wild database sets a benchmark for deep learning-based emotion recognition but falls short in addressing the needs of neurodiverse users, particularly those with atypical or minimal facial expressions. Our motion-based approach complements this gap by focusing on more universally observable behaviors like gestures and head movements.

[8] "Facial Emotion Recognition: A Survey and Real-World User Experiences in Mixed Reality" – D. Mehta, M. F. H. Siddiqui, and A. Y. Javaid (2019)

This paper surveys facial emotion recognition technologies and evaluates their application in mixed reality systems. It discusses practical challenges like sensor integration, user comfort, and real-time feedback, offering insights into usability in diverse populations. The study indirectly supports our design principles, which prioritize user comfort, non-intrusiveness, and real-time feedback—achieved through our motion-based wearable system tailored for individuals with ASD. Their focus on user experience also highlights the importance of acceptance and adaptability, which are key to our system's success in real-world applications. Additionally, their observations on user fatigue and sensor load influenced our decision to use lightweight, wearable hardware. Furthermore, the paper's emphasis on seamless integration within daily life aligns with our objective to develop a system that blends naturally into the routines of autistic individuals. By minimizing the need for facial visibility or fixed positioning—often required in camera-based systems—our approach ensures greater freedom of movement and less dependency on environmental constraints. This reinforces the practicality and long-term usability of our solution, especially in dynamic settings like classrooms, therapy sessions, or at home.

[9] "Introducing the RECOLA Multimodal Corpus of Remote Collaborative and Affective Interactions" – F. Ringeval, A. Sonderegger, J. Sauer, and D. Lalanne (2013)

RECOLA is a multimodal dataset designed for emotion recognition during remote collaborative tasks. It combines physiological, visual, and audio data to track affective responses. This multimodal strategy underlines the effectiveness of combining various input sources for emotion detection. Our system adopts a similar philosophy by combining hand and head movement data as reliable, real-time indicators of emotional state in non-verbal individuals. Furthermore, RECOLA's focus on spontaneous interactions emphasizes the importance of capturing emotions in natural settings. The dataset's structure and evaluation techniques can guide future validation of movement-based emotion recognition systems. Additionally, RECOLA's annotated emotional dimensions—such as arousal and valence offer a valuable framework for interpreting the intensity and type of emotional responses, which can be adapted to our gesture-based system. By aligning our recognition outputs with such standardized metrics.

[10] "Rethinking the Inception Architecture for Computer Vision" – C. Szegedy, V. Vanhoucke, S. Ioffe, J. Shlens, and Z. Wojna (2016)

This paper introduces enhancements to the Inception deep learning architecture, boosting performance in computer vision tasks like classification and detection. Though not directly related to emotion recognition, its influence on deep learning model design is significant. It lays the foundation for future work in this project if visual input (e.g., posture or full-body tracking) is incorporated using convolutional networks. The architectural principles introduced in this model can be adapted to optimize gesture-based emotion classification. It also supports scalability, allowing complex models to run efficiently on resource-limited hardware such as the Raspberry Pi. Moreover, the modular structure of the Inception architecture enables flexible experimentation with various input streams—such as depth, thermal, or skeletal motion data—making it a strong candidate for future iterations of emotion recognition systems. By leveraging its parallel convolutional layers and dimensionality reduction techniques, we can enhance model accuracy while maintaining real-time performance. This is particularly valuable in wearable or embedded systems where computational resources are constrained, and efficient processing is crucial for seamless user experience.

[11] "Developing Multimodal Interactive Systems with EyesWeb" – A. Camurri, P. Coletta, G. Volpe, et al. (2000)

The EyesWeb platform enables interactive systems that analyze human gestures, posture, and sound for emotion detection and performance feedback. This early work validates the use of body movement for emotional analysis, aligning closely with our approach to interpret hand and head gestures as expressive cues, particularly for individuals who may not rely on speech or facial expressions. The modular nature of EyesWeb inspired systems that can adapt to different sensory inputs, which aligns with the flexibility of our wearable design. Additionally, it promotes real-time interaction, a core goal in emotion-responsive assistive systems. Furthermore, EyesWeb's integration capabilities with external devices and software frameworks open possibilities for creating comprehensive, multi-sensory environments—something our system aspires to achieve in future versions. Its emphasis on real-time feedback and adaptability to diverse user needs reinforces our design focus on immediate emotional interpretation and broad usability, especially for neurodiverse users.

[12] "Adaptive Neuro-Fuzzy Inference System for Classification of Human Emotions Using Physiological Signals" – S. Tripathi and S. K. Behera (2016)

This paper explores the use of an Adaptive Neuro-Fuzzy Inference System (ANFIS) to classify emotions using physiological signals such as electrocardiogram (ECG) and skin conductance. It combines the learning capability of neural networks with the reasoning style of fuzzy logic, resulting in more adaptive and flexible emotion classification. Though our project focuses on motion cues rather than biosignals, the integration of intelligent decision-making models like ANFIS provides a useful reference for enhancing classification accuracy in future versions. The paper also outlines the importance of feature extraction, which can be similarly applied to movement data. Moreover, ANFIS's ability to handle uncertainty and imprecision aligns well with the inherent variability in emotional expression among autistic individuals. Its layered architecture could be adapted to process gesture patterns that are subtle or inconsistent, improving the robustness of emotion detection. Incorporating such hybrid models into our system may facilitate better personalization by learning from individual behavioral patterns over time. As future work, combining motion-based features with adaptive inference models like ANFIS could lead to a more nuanced and responsive emotion recognition framework tailored to diverse user needs.

[13] "A Survey of Multimodal Sentiment Analysis" – M. Soleymani, D. Garcia, B. Jou, et al. (2017)

This comprehensive survey reviews how multimodal sentiment analysis integrates inputs such as text, audio, visual, and physiological data to understand emotional states. The study reveals that combining multiple data sources improves emotion detection accuracy, as each modality offers a unique perspective. Although our system currently focuses on physical movement, this paper supports the idea of future expansion into multimodal integration, possibly combining gesture data with physiological or contextual signals. It also addresses the challenge of data synchronization across modalities an issue that will be crucial when scaling our system. Proper alignment of gesture data with any additional inputs, like heart rate or ambient context, would be essential for achieving real-time, meaningful analysis. The survey further emphasizes the need for balanced datasets and robust fusion strategies, both of which inform our long-term vision for developing a highly adaptable and personalized emotion recognition system. By leveraging insights from multimodal sentiment analysis.

[14] "Wearable Sensors for Emotion Recognition and Self-Regulation" – R. R. Fletcher, M. Tamayo, J. Zavala-Ibarra, and R. Picard (2014)

This research explores wearable technologies that monitor emotions and provide real-time self-regulation feedback to users. It emphasizes the use of biosensors to capture subtle physiological changes and deliver interventions such as haptic alerts. The study's focus on low-power design and user comfort is especially relevant to our project, which uses lightweight gloves and headbands. The integration of real-time feedback mechanisms in wearable devices could provide an opportunity to further enhance emotional regulation for individuals with ASD, ensuring that interventions are timely and effective. It also highlights the importance of personalization—something we can incorporate by adapting emotion-movement mappings to suit individual users. The paper provides practical insights into real-world deployment, battery management, and user retention, which are critical considerations in designing assistive devices for long-term use. Additionally, it stresses ethical issues around privacy, aligning with our choice to process data locally on ESP32 boards.

[15] "Emotion Recognition in Autistic Children Using Machine Learning and Wearable Sensors: A Review" – A. Sani, M. Z. Ali, and M. A. A. Murad (2019)

This review examines current advancements in emotion recognition for autistic children using wearable sensors and machine learning algorithms. It identifies the need for systems that are non-intrusive, interpretable, and capable of real-time response. The review validates our approach of using movement-based inputs over facial or verbal cues, as it recognizes the limitations of traditional emotion detection for individuals with ASD. It also explores different types of sensors used in autism research, many of which influenced our selection of flex, pressure, and IMU sensors. Furthermore, the paper discusses how wearable tech must be designed to adapt to user-specific behavioural patterns. The review also highlights the importance of designing wearable systems that are both comfortable and unobtrusive, a consideration that directly informs our system's design. By focusing on movement-based signals, we align with the growing trend of developing assistive technologies that respect the unique needs of autistic individuals while ensuring ease of use. This comprehensive perspective strengthens the case for integrating wearable technology with real-time emotion detection for more effective interventions and support.

Chapter-III

Hardware and Software Used

CHAPTER 3

HARDWARE AND SOFTWARE USED

3.1 Hardware Requirements

3.1.1 Sensing module:

1. ESP32 Module

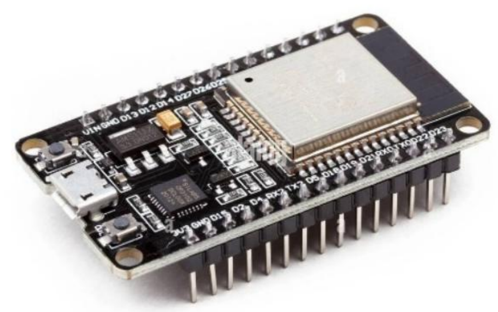

Fig 3.1 ESP32 Module

The above Fig 3.1 depicts an ESP32 module, it is a low-cost, powerful microcontroller developed by Espressif Systems, widely used in IoT and wearable technology applications. It features a dual-core 32-bit processor capable of running at up to 240 MHz, making it well-suited for real-time processing tasks. The module comes with built-in Wi-Fi and Bluetooth capabilities, allowing seamless wireless communication with other devices such as smartphones or external displays. It supports a variety of interfaces including GPIO, I2C, SPI, UART, and ADC, which makes it highly compatible with sensors like flex sensors, pressure sensors, and IMUs used in our project. In the context of the Emotion Recognition System, the ESP32 acts as the central unit that collects data from the hand and head movement sensors, processes this data locally, and provides real-time feedback without relying on cloud services—ensuring both low latency and user privacy.

2. IMU (Inertial Measurement Unit) Sensor:

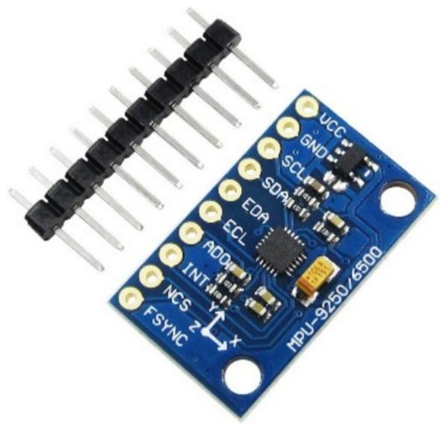

Fig 3.2 IMU Sensor

The Fig 3.2 depicts an IMU (Inertial Measurement Unit) sensor which is an electronic device that measures and reports an object's specific force, angular rate, and sometimes magnetic field, using a combination of accelerometers, gyroscopes, and sometimes magnetometers. In the context of this project, the IMU sensor is primarily used to capture head and hand movement data by detecting orientation, rotation, and motion. This information is crucial for identifying non-verbal emotional cues in autistic individuals. The IMU helps determine patterns such as nodding, shaking, or repetitive gestures, which are then analyzed by the system to classify emotional states. Its compact size, low power consumption, and ability to provide accurate motion data in real time make it ideal for wearable applications like smart gloves and headbands. By integrating the IMU with other components of the system, such as the fingerprint sensor or haptic feedback mechanisms, a more holistic and interactive experience can be created, improving the effectiveness of the device in recognizing and responding to emotional cues. This makes the IMU a key component in building assistive technologies that can support communication for individuals with autism.

3. OLED Display Module (0.96” I2C)

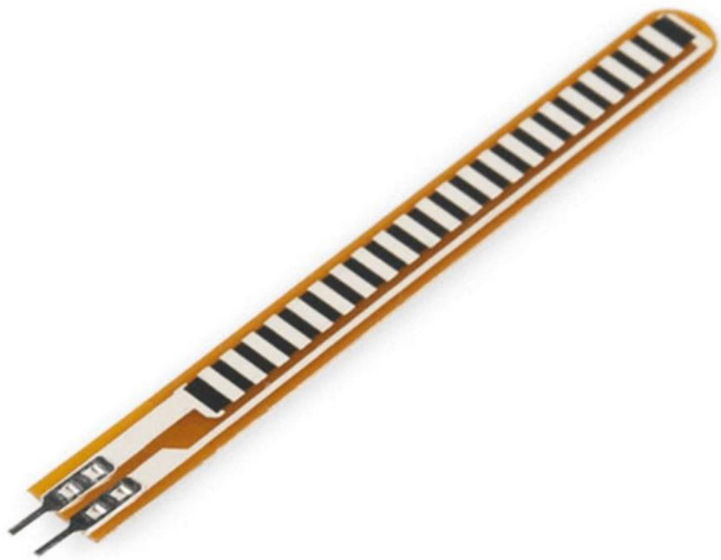

Fig 3.3 Flex Sensor

The fig 3.3 depicts a flex sensor, it is a type of sensor that changes its resistance based on the amount of bending or flexing it undergoes. When the sensor is straight, it has low resistance, and as it bends, the resistance increases. In this project, flex sensors are embedded in a wearable glove to detect the movement and bending of fingers, which are key indicators of hand gestures. These gestures can convey emotional cues such as excitement, frustration, or anxiety, especially in individuals with autism who may rely more on body language than facial expressions. The data from the flex sensors is processed by the microcontroller to help recognize emotional states, making them an essential component of the emotion recognition system. The flex sensors' ability to provide real-time data on finger movements enables precise tracking of hand gestures, enhancing the system's accuracy. Additionally, their lightweight and flexible design make them comfortable for long-term wear, ensuring that the user can engage naturally with the device.

4. Accelerometer Sensor

Fig 3.4 Accelerometer Sensor

The above Fig 3.4 depicts an accelerometer which is a sensor that measures acceleration forces acting on an object, which can be either static, like gravity, or dynamic, caused by movement or vibration. It detects changes in velocity and orientation by measuring acceleration along one or more axes, typically X, Y, and Z. In this project, the accelerometer is used as part of the IMU sensor to track head and hand movements. These movements are essential for interpreting non-verbal emotional cues in autistic individuals. By analyzing the speed and direction of motion, the system can identify specific gestures or patterns associated with different emotional states, aiding in real-time emotion recognition. The accelerometer's ability to measure both dynamic and static forces provides valuable insights into the intensity and context of movements. This feature helps distinguish between different types of gestures, such as calm movements versus rapid, agitated ones. The data gathered by the accelerometer is processed in real time, allowing for immediate feedback and interaction with user.

3.2 Software Used

3.2.1 Arduino IDE

Fig 3.5 Arduino IDE

The above Fig 3.5 depicts an Arduino Integrated Development Environment (IDE), it is an open-source software platform used for writing, compiling, and uploading code to Arduino microcontroller boards. It provides a user-friendly interface for programming Arduino-based projects using the Arduino programming language, which is based on Wiring. The IDE supports various Arduino boards and libraries, making it easy for both beginners and advanced users to develop projects ranging from simple blinking LED tasks to more complex robotics and IoT applications. Additionally, the IDE offers features such as syntax highlighting, automatic code formatting, and a serial monitor for debugging purposes. The Arduino IDE also allows users to easily manage and install external libraries, which extend the functionality of Arduino boards for specific sensors, modules, and communication protocols. This flexibility makes it an ideal tool for rapidly prototyping and testing new ideas. With its built-in support for various programming languages, including C and C++, the IDE offers both simplicity for novices and depth for experienced developers.

Chapter – IV

Methodology

CHAPTER 4

METHODOLOGY

4.1 Methodology

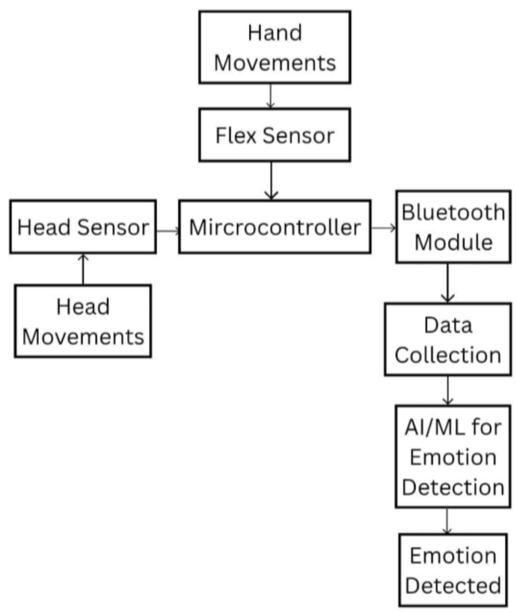

Fig.4.1 Block Diagram of Emotion Recognition System for Autistic Individuals using Hand and Head movement

The fig.4.1 depicts a step-by-step process to recognize emotions in autistic individuals based on their hand and head movements. The results are displayed in real-time, providing immediate feedback to caregivers, educators, or the individuals themselves, helping them understand and respond to emotional cues effectively. The system is designed to be adaptable to various users, ensuring its versatility and wide applicability in different environments. The methodology is designed to be non-intrusive, real-time, and wearable, ensuring comfort and practicality in everyday use.

1. Measurement of Hand and Head Movements:

The system begins by continuously monitoring physical gestures, focusing on finger bending and head movements like tilting or rotation. These movements are essential non-verbal indicators of emotional states, often providing more subtle and immediate insights than facial expressions. Detailed tracking of the hand and head enables the system to capture a wide range of emotional cues, from subtle shifts to more pronounced gestures. The accuracy of movement detection is crucial for distinguishing between different emotions, ensuring that the system can identify even minor emotional fluctuations.

2. Sensor Integration:

Flex sensors are embedded in a smart glove to capture the bending of fingers. An IMU sensor is attached to a headband to track head motion and orientation, allowing for comprehensive monitoring of both upper body and head movements. The sensors are strategically placed to ensure ease of wearability and minimal interference with the user's normal activities. This integration provides a seamless experience, where the system can detect a broad spectrum of hand and head motions, enabling detailed emotional analysis.

3. Data Processing with Microcontroller:

The sensor data is fed into an ESP32 microcontroller, which acts as the central processing unit. It reads, processes, and organizes the data from both the hand and head sensors, ensuring that no critical movement is missed. The microcontroller is capable of handling real-time data streams, allowing for swift processing of large amounts of sensor information. By employing efficient algorithms, the system ensures low latency and reliable performance, even in dynamic, real-world conditions. The integration of both hand and head motion analysis enables the system to capture a broad spectrum of emotional responses. Subtle cues, like repetitive behaviors often linked to stress (e.g., stimming), are also detected, providing early warnings of emotional distress. By considering both the context and frequency of these gestures, the system offers a nuanced understanding of the user's emotional state.

4. Wireless Communication:

The processed data is transmitted wirelessly via Bluetooth to an external device such as a smartphone, tablet, or local server for further processing or visualization. This wireless setup allows for flexible deployment, as the system can be easily connected to a variety of devices depending on the user's needs. The Bluetooth connection ensures a stable and efficient transfer of data, minimizing delays or interruptions in communication. Additionally, the external device can perform additional computations and storage, enabling advanced features like long-term tracking or cloud integration. In parallel, the IMU sensor, typically an MPU6050 or similar, is placed on the head to measure motion, acceleration, and orientation. This sensor detects subtle movements like head tilts, nodding, or shaking, which are also key indicators of emotional responses. By combining the data from both the flex sensors and the IMU, the system gains a multidimensional understanding of the user's non-verbal behavior. These sensors work in tandem to identify both static postures and dynamic gestures, offering a comprehensive way to interpret emotional cues, especially for individuals with autism who may have difficulty expressing emotions verbally.

5. Data Collection and Preprocessing:

The movement data is collected and formatted for input into a machine learning model. Basic filtering and preprocessing techniques are applied to improve accuracy. Basic filtering and preprocessing techniques, such as noise reduction and signal smoothing, are applied to improve accuracy and minimize false readings. These preprocessing steps ensure that the data is clean and ready for analysis, eliminating any distortions that may affect emotional state detection. Data normalization is also applied to ensure consistency across different sensor readings and users. In addition to handling sensor data, the ESP32 is responsible for system timing, ensuring that data is captured and transmitted at the appropriate intervals. The microcontroller also enables wireless communication with external devices, such as smartphones or tablets, via Bluetooth. If needed, the ESP32 can perform real-time emotion recognition through lightweight machine learning models (such as TinyML), enabling the system to classify emotional states directly on the device. This edge processing capability reduces latency and ensures that the system can provide immediate feedback, empowering users and caregivers with real-time emotional insights.

6. Machine Learning Integration:

AI/ML algorithms analyze the movement patterns and classify them into specific emotions such as happiness, sadness, anger, or excitement. The model is trained using labeled datasets of motion-based emotional expressions, ensuring that it can learn to recognize a wide range of emotional states. The system continuously improves over time by retraining the model with new data, adapting to individual users' unique gestures. These algorithms are designed to process the data quickly and accurately, allowing for real-time emotional state detection without sacrificing performance. The Bluetooth module allows the system to communicate with a mobile or desktop application, which can process and display the detected emotional states. The data is typically sent in structured formats like JSON or CSV, which are easy to parse and interpret by the connected application. This wireless interface not only simplifies data transfer but also enables the system to provide immediate feedback, such as visual or auditory cues, to the user. Additionally, it allows for historical data logging, where caregivers and therapists can review emotional patterns over time to track progress and adjust care strategies.

7. Emotion Detection and Feedback:

The recognized emotional state is displayed through visual indicators (LEDs, emojis), audio cues, or a mobile app. This feedback helps caregivers, therapists, and educators respond appropriately and provide emotional support, enhancing the overall user experience. Customizable feedback options ensure that the system can cater to different user preferences and needs. Additionally, the system's feedback mechanisms are designed to be non-intrusive, ensuring that the user's emotional privacy is respected while still offering valuable support.

This methodology ensures the system is accurate, responsive, and adaptable to real-world use, particularly in environments such as homes, schools, or therapy centers. It enables seamless human-computer interaction by interpreting emotional cues through natural gestures. The modular design also allows easy integration with other assistive technologies for enhanced accessibility.

4.2 Implementation

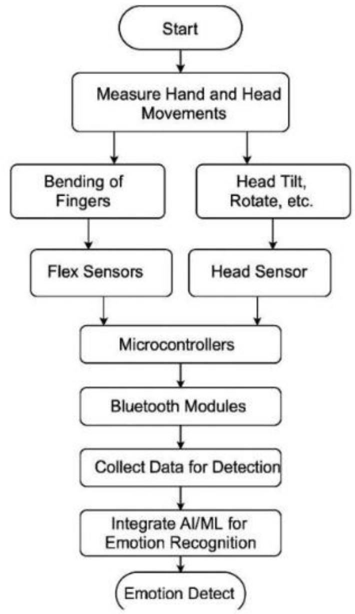

Fig.4.2 Flow Diagram of Emotion Recognition System

The Fig.4.2 depicts implementation of the Emotion Recognition System for Autistic Individuals using Hand and Head Movements integrates various advanced technologies to provide real-time emotional feedback. It leverages wearable sensing devices, embedded processing, wireless communication, and machine learning to interpret subtle physical cues and translate them into emotional states. This comprehensive system aims to bridge communication gaps, particularly for individuals with autism, who may have difficulty expressing or understanding emotions. Below is a more detailed and extended explanation of each step in the system's operation:

1. Start:

The system initialization is the first crucial step, where all components undergo a self-diagnostic routine to ensure proper functionality. This includes verifying the operation of key components like flex sensors, the IMU (Inertial Measurement Unit), the microcontroller, and the Bluetooth module. The system performs a calibration procedure to ensure the sensors are aligned and functioning optimally. The calibration phase involves checking the flex sensors for zeroing and adjusting any offsets caused by hardware placement, body posture, or sensor drift. This step is essential to ensure that motion tracking begins with high accuracy, providing a solid foundation for later stages of emotion detection.

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2. Measure Hand and Head Movements:

Once initialization is complete, the system enters its continuous monitoring phase. In this mode, it captures real-time data from both the hands and the head, tracking both static postures and dynamic gestures. This dual-tracking approach is particularly important for individuals with autism, as it allows the system to recognize non-verbal emotional cues that may be more prominent or frequent than facial expressions. Hand movements, such as flapping or clenching fists, and head movements like tilting or turning, are common indicators of emotional states. By monitoring these gestures, the system can continuously assess the user's emotional state in various environments and situations. This method of dual tracking provides a more robust understanding of emotional expressions, especially when verbal communication may not be available or reliable.

3. Bending of Fingers / Head Tilt, Rotate, etc.:

The system interprets specific hand and head movements as key emotional indicators. For instance, finger bending detected by the flex sensors may indicate stress, anxiety, or frustration, while hand flapping could signal excitement or nervousness. Similarly, head tilting or nodding might reflect curiosity, engagement, or even discomfort. These gestures are analyzed to determine the intensity of the emotional state. Repetitive behaviors, such as stimming, are particularly relevant in autism, as they may signify heightened emotional states or sensory overload. By tracking these patterns, the system is able to detect not just the emotion, but its intensity, offering more nuanced feedback for caregivers and educators.

4. Sensor Technology: Flex and IMU Sensors:

The system utilizes two primary types of sensors for motion capture: flex sensors and IMU sensors. Flex sensors embedded in a glove track finger movements by detecting the degree of bending in each finger. The flex sensors work by changing resistance as the fingers bend, with the resistance values converted into digital data by the microcontroller’s ADC (Analog-to-Digital Converter). This allows for precise tracking of finger movement angles. The IMU sensor (e.g., MPU6050) mounted on the user's head is crucial for capturing multi-axis motion data, such as acceleration, rotation, and orientation. This sensor provides data on how the head moves in space — whether the head is tilted, nodded, or turned, offering important insight into emotional expression.

5. Microcontrollers:

At the heart of the system is the ESP32 microcontroller, which serves as the central processing unit. This powerful, dual-core processor is capable of handling real-time data processing, managing sensor inputs, and ensuring efficient communication with connected devices. The ESP32 is selected for its integrated Bluetooth module, low power consumption, and high performance, making it ideal for wearable devices. The microcontroller processes the sensor data, applies basic filtering algorithms like moving average filters to smooth the signal, and manages the timing and flow of information between components.

6. Bluetooth Modules:

The ESP32's built-in Bluetooth functionality facilitates wireless communication between the system and external devices, such as smartphones, tablets, or PCs. This allows for seamless and low-latency data transmission, which is crucial for real-time emotional feedback. The Bluetooth module typically follows UART or BLE (Bluetooth Low Energy) communication protocols to ensure efficient power use and quick data transfer. The wireless connection ensures user comfort by eliminating physical cables, making the system more convenient and user-friendly for everyday use. Additionally, the data transmitted over Bluetooth is formatted in an easy-to-read structure, such as JSON or CSV, which allows for simple parsing and further analysis by external applications or caregivers.

7. Collect Data for Detection:

As the system continuously tracks and collects movement data, the data is stored in time-stamped sequences. These time-series sequences capture the user's motion over time, with additional metadata, such as user ID, session time, and activity context, providing valuable context for interpretation. Before feeding the data into the machine learning model, preprocessing steps are applied to clean and standardize the data. These steps include signal normalization (to ensure consistency across users), outlier removal (to eliminate noise), and windowing (to create meaningful data segments). These preprocessing techniques ensure that the machine learning model receives high-quality, consistent data, which is critical for achieving accurate emotion recognition.

8. Integrate AI/ML for Emotion Recognition:

The heart of the system's functionality lies in the AI/ML model, which interprets the motion data to recognize emotions. The model is trained using large annotated datasets containing labeled examples of hand and head gestures corresponding to various emotional states, such as happiness, sadness, anger, or anxiety. Machine learning techniques, such as Support Vector Machines (SVM), Random Forests, or lightweight neural networks like Long Short-Term Memory (LSTM) networks, are employed to identify temporal patterns in the data and classify the emotional state. The model also uses feature extraction methods, such as Fast Fourier Transform (FFT) for frequency analysis and statistical metrics like mean, variance, and root mean square (RMS) to capture key features of the motion data.

9. Emotion Detect:

Once the machine learning model classifies the emotional state, the system provides real-time feedback in a variety of ways. Visual feedback through colored LEDs (e.g., green for calm, red for stress) offers an immediate and easily understandable cue about the user's emotional state. Auditory feedback can also be provided through a buzzer or smartphone notifications, ensuring that caregivers are immediately alerted to any significant emotional changes. A mobile app can display the detected emotion and log the data for caregivers or educators to review. This app can provide insights into emotional trends over time, helping to identify patterns in the user's emotional behavior. Additionally, the system can store historical emotional data, which can be useful for monitoring progress in therapy or tracking emotional responses in different environments or contexts.

In conclusion, the proposed system effectively utilizes hand and head movement data to recognize emotional states in autistic individuals through a combination of wearable sensors and machine learning. Its non-intrusive, real-time approach ensures comfort and practicality. The integration of smart technology aids caregivers in understanding and responding to emotional cues. This system holds significant potential for enhancing emotional communication and support in autism care. The proposed Emotion Recognition System for Autistic Individuals using Hand and Head Movements is a powerful tool for understanding emotional states through wearable sensors and machine learning. It offers a non-intrusive, real-time method for detecting and responding to emotional cues, making it an invaluable resource for caregivers, therapists, and educators.

Chapter V

Result

CHAPTER 5

RESULT

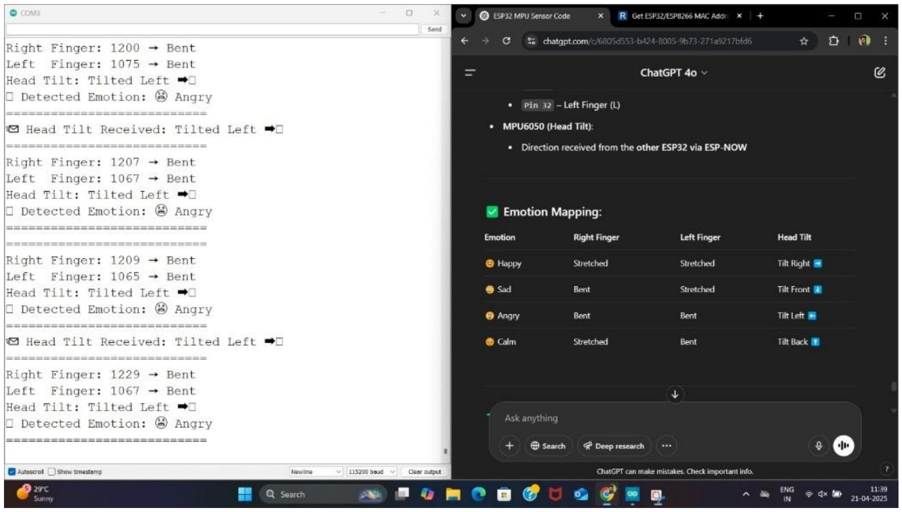

Fig. 5.1. Real-Time Emotion Detection Output using Sensor Data

The above Fig 5.1 displays the real-time execution of an emotion recognition system using ESP32 and various sensors. On the left, the serial monitor output shows continuous readings from flex sensors attached to the right and left fingers, along with head tilt data obtained from an MPU6050 sensor. In this instance, both the right and left fingers consistently show high values, indicating a bent position, while the head tilt is recognized as tilted left. These physical inputs are processed and matched against a predefined emotion mapping table, as seen on the right side of the image. According to this table, the combination of bent fingers and a leftward head tilt corresponds to the "Angry" emotion. The system accurately detects this emotion and displays it in each cycle of the loop, confirming the correct functioning of both the sensor integration and the logic implemented in the microcontroller. This successful detection illustrates how body posture and gestures can be used to interpret emotional states, especially useful in assistive technology for individuals with communication challenges.

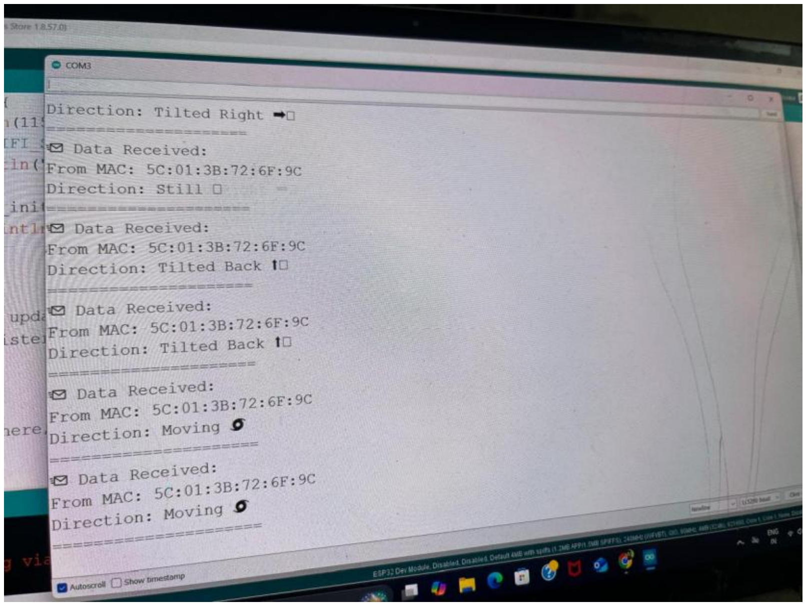

Fig 5.2 IMU Sensor Serial Monitor Output for Gesture-Based Emotion Recognition

The Fig 5.2 depicts IMU (Inertial Measurement Unit) sensor output which serves as the foundation for interpreting body movements as emotional indicators. The sensor continuously monitors orientation and motion using built-in accelerometers and gyroscopes. The data is transmitted wirelessly from the sensor module (identified by its MAC address) to a receiver, which processes the movement information. Movements such as tilting in different directions or general motion are captured and displayed in a human-readable format through the serial monitor.

This information is critical for training and validating the emotion recognition system, as each gesture corresponds to a predefined emotional state based on the movement patterns of autistic individuals. The real-time feedback helps in fine-tuning gesture detection accuracy and improves the responsiveness of the overall system. Moreover, by linking these movements to emotional expressions, the system enables a non-intrusive and accessible way for individuals to communicate their emotional states without relying on facial cues or verbal interaction.

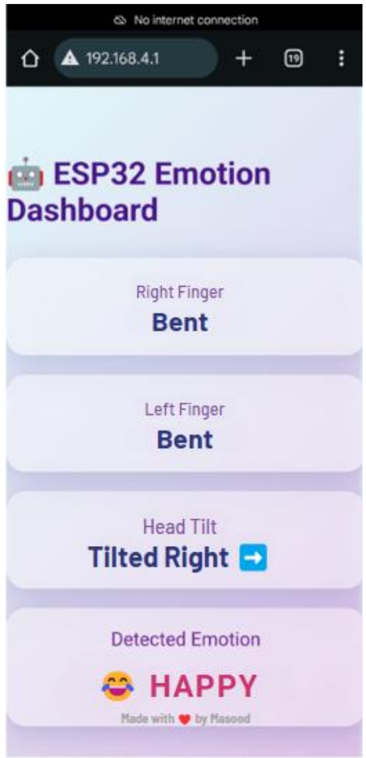

Fig. 5.3 ESP32 Emotion Detection Web Dashboard Output is happy

The Fig 5.3 illustrates the user interface of a web-based dashboard designed and hosted using the ESP32 microcontroller, serving as the visual output layer of the Emotion Recognition System. The dashboard displays real-time data acquired from the flex sensors and IMU sensor. In this scenario, the system reads both the Right Finger and Left Finger as "Bent," while the Head Tilt is detected as "Tilted Right." These combined gesture patterns—hand movements and head orientation—are processed by the onboard machine learning model or rule-based mapping logic, which classifies the emotion as "😊 HAPPY". The dashboard is developed to ensure clarity and accessibility, making it highly suitable for assistive applications where immediate emotional feedback is essential. The output is not only represented textually but also with a corresponding emoji, which enhances interpretability, especially for children or individuals with cognitive challenges.

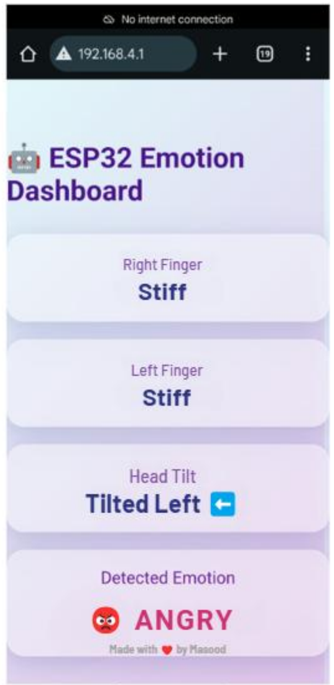

Fig. 5.4 ESP32 Emotion Detection Web Dashboard Output is angry

The Fig 5.4 displays the ESP32-hosted web-based Emotion Dashboard, which provides real-time emotional state monitoring based on hand and head movements. In this instance, both the Right Finger and Left Finger are detected as “Stiff,” while the Head Tilt is recognized as “Tilted Left.” This specific combination of sensor inputs maps to the emotion “😡 ANGRY,” as interpreted by the system’s predefined classification logic or integrated machine learning model. The interface maintains a clean, intuitive design that simplifies observation for caregivers or researchers. The detected emotion is presented with a visual emoji and bold text for enhanced clarity and quick interpretation. The structured layout of sensor inputs and emotion output helps in effective emotion tracking, debugging, and further system training.

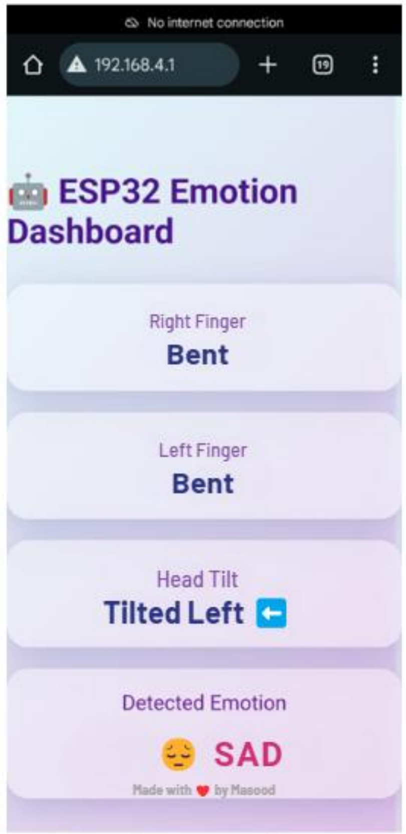

Fig. 5.5 ESP32 Emotion Detection Web Dashboard Output is sad

The Fig 5.5 showcases the real-time web-based ESP32 Emotion Dashboard interface, where the system has detected the emotional state as "😔 SAD." The dashboard indicates that both the Right Finger and Left Finger are in a "Bent" position, and the Head Tilt is towards the left. This specific combination of hand gestures and head movement corresponds to the emotion *Sad*, as per the predefined logic or trained model embedded within the system. The interface provides a clear, structured, and user-friendly layout, enabling easy emotional state monitoring for caregivers and therapists working with autistic individuals. The clean and user-friendly interface allows for easy monitoring and debugging, particularly useful in wearable and assistive emotion recognition applications.

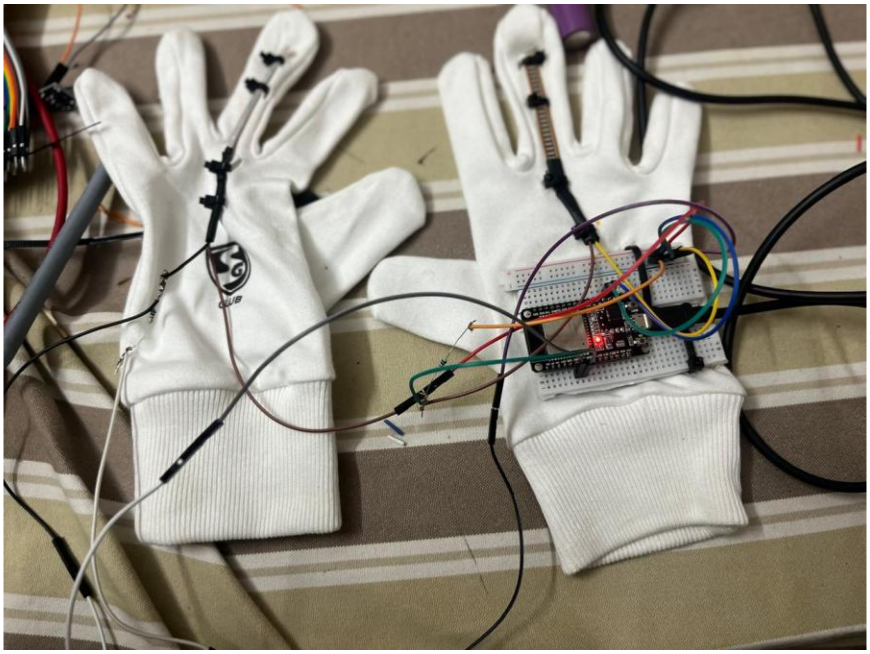

Fig. 5.6 Emotion Detection Smart Glove Hardware Setup

The above Fig 5.6 displays the hardware implementation of a wearable smart glove system used for emotion detection. The setup includes a pair of gloves embedded with flex sensors, visible along the fingers, which are used to detect finger bending. The glove on the right also shows a breadboard setup with an ESP32 microcontroller and various jumper wires connecting the sensors to the board. The microcontroller collects data from the flex sensors and transmits it for processing via Bluetooth or Wi-Fi. This configuration enables the system to interpret hand gestures as part of emotion recognition logic, especially when combined with head movement data from another sensor like an MPU6050. The design is compact, wearable, and tailored for real-time gesture-based emotion detection, making it suitable for assistive technologies, particularly for individuals with communication challenges.

Chapter VI

Applications, Advantages & Disadvantages

CHAPTER 6

APPLICATIONS

The system offers versatile applications across various domains, including:

- **Special Education Centres:**
  The system assists teachers in understanding the emotional states of autistic students through non-verbal cues, allowing them to adjust their teaching strategies and interactions accordingly.
- **Home Use:**
  Parents and family members can use the device to monitor emotional changes in real-time, helping them respond with appropriate care and support during daily activities.
- **Therapy and Counselling:**
  Therapists can use the emotion recognition system during sessions to better understand a patient's emotional responses, improving the effectiveness of behavioural therapies and interventions.
- **Caregiver Assistance:**
  Caregivers can interpret emotional cues that may not be verbally expressed, enabling more empathetic and timely support for individuals with autism.
- **Healthcare Monitoring**:
  The system can be used as a tool for early detection of stress or anxiety in patients with communication difficulties, contributing to mental health monitoring and intervention.
- **Assistive Technology Development**:
  It serves as a foundation for developing more advanced assistive technologies that combine emotion recognition with other supportive tools like speech generation or behaviour prediction.

ADVANTAGES

- **Non-Intrusive Design:**
  The system uses lightweight wearable components like gloves and headbands that do not interfere with the user's natural movements, making it comfortable for prolonged use.
- **Real-Time Emotion Detection:**
  It allows immediate detection of emotional states using embedded sensors and microcontrollers, enabling timely responses by caregivers, teachers, or family members.
- **Focus on Non-Verbal Cues:**
  By analysing hand gestures and head movements, the system captures emotional signals that are often more accurate and expressive in autistic individuals than facial expressions or speech.
- **Privacy-Preserving Operation:**
  The entire process is performed locally without cloud dependency, ensuring user data remains secure and accessible only to authorized users.

DISADVANTAGES

- **Sensor Dependency:**

  The accuracy of emotion detection heavily depends on proper placement and calibration of sensors; incorrect readings may result in misclassification.

- **Limited Emotion Range:**

  The system may not accurately capture complex or subtle emotional states like confusion, excitement, or boredom, which do not have distinct physical gestures.

- **User Variability:**

  Different users may express the same emotion through different movements, making it difficult to generalize models across individuals without personalization.

- **Discomfort for Sensitive Users:**

  Individuals with sensory sensitivities may find it uncomfortable to wear the device for extended periods, limiting its use in continuous monitoring applications.

Chapter VII

Conclusion and future scope

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

7.1 Conclusion

This project presents a novel approach to emotion recognition tailored specifically for autistic individuals by focusing on non-verbal cues such as hand gestures and head movements. Unlike traditional systems that rely heavily on facial expressions and speech—which may not be reliable indicators for those on the autism spectrum, this method ensures a more inclusive and effective emotional analysis. The integration of real-time recognition with a user-friendly web interface enhances accessibility for parents, teachers, therapists, and caregivers.

By emphasizing movement-based emotional cues, the system helps bridge a significant communication gap, empowering stakeholders to respond more empathetically and effectively. The website developed as part of the output visually displays the interpreted emotional states, contributing to awareness and actionable insights. This not only supports daily interactions but also lays the groundwork for future innovations in assistive technologies and mental health monitoring.

This project also highlights the potential for wearable technology to improve the quality of life for individuals with autism by offering a non-intrusive and real-time method for emotion detection. Through the combination of sensors and machine learning, the system offers a personalized approach to understanding emotional states, allowing for tailored interventions. The real-time feedback and data logging feature not only provide immediate support but also offer long-term insights for better managing emotional health.

In summary, the project successfully demonstrates how emotion recognition can be reimagined to serve neurodiverse populations more meaningfully. It provides a foundation for ongoing research and development in the field of affective computing, particularly for socially assistive systems.

7.2 Future Scope

The proposed emotion recognition system lays the groundwork for numerous future enhancements and applications. One promising direction is the integration of machine learning algorithms that adapt to individual users over time, making emotion detection more personalized and accurate for each autistic individual. Expanding the dataset to include a wider range of gestures and emotional variations will also improve the system's robustness and generalizability.

In future iterations, the system can be extended to include multimodal emotion recognition, combining hand gestures, head movements, physiological signals (like heart rate), and facial micro-expressions to achieve a more comprehensive emotional understanding. Additionally, incorporating voice-independent speech cues and contextual data could further increase reliability in varied environments.

Another potential development is the integration of advanced artificial intelligence techniques, such as deep learning models, to recognize more complex emotional patterns and subtle changes in behaviour. By continuously training the system on more diverse datasets and including feedback from real-world applications, the system's predictive capabilities can be refined, making it not just reactive but proactive in identifying early signs of emotional distress. This could open up opportunities for the system to be used in preventive care, offering early interventions before emotions escalate into more significant behavioural challenges. Furthermore, collaboration with autism specialists and therapists could help fine-tune the system to address specific behavioural markers unique to each individual.

Additionally, future versions of the system could explore the use of augmented reality (AR) to create interactive learning environments. By overlaying emotional cues and feedback in real-time, AR could serve as an engaging tool for teaching emotion recognition skills to individuals on the autism spectrum. This immersive approach could help bridge the gap between abstract emotional concepts and tangible learning experiences. With these enhancements, the system has the potential to become an indispensable tool in the daily lives of those on the autism spectrum, offering not only emotional insight but also practical support for improving social interactions and overall well-being.

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