Grenze International Journal of Engineering and Technology, January Issue

Smart Assistive Gloves for Partially Paralyzed People using Gesture Mode

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***Abstract*— For the millions living with partial paralysis, the loss of fine motor control can lead to a significant decline in independence and quality of life. To address this challenge, a smart assistive glove has been developed to translate even minimal hand movements into action-able commands. This wearable device operates in a gesture-based mode, allowing users to intuitively control their surroundings. By embedding flexible sensors within a comfortable glove, the system captures subtle gestures, which are then interpreted. The recognized gestures can be used to operate smart devices, send pre-programmed messages, or navigate digital interfaces, effectively bridging the gap between intention and action. The primary goal of this work is to provide a customizable and accessible tool that empowers users, re-duces reliance on caregivers, and restores a sense of autonomy in daily life.**

***Index Terms*— Smart Assistive Glove, Partial Paralysis, Gesture-Based Interaction, Hand Gesture Recognition, Wearable Sensors, User Autonomy.**

I. Introduction

Partial paralysis, resulting from conditions like stroke or Spinal cord injury, presents significant challenges to an individual's daily life and ability to communicate. Traditional assistive devices can be costly and lack intuitive operation. The proliferation of affordable microcontrollers and wireless modules offers a powerful opportunity to create personalized and effective assistive technologies. This project introduces a smart assistive glove built upon the accessible and robust Arduino Nano platform. The core concept is to translate simple, achievable hand movements into meaningful digital commands. By wearing the glove, a user with limited motor function can perform basic gestures—such as forming a fist or pointing a finger— to interact with their environment. These actions are detected by onboard sensors and interpreted by the Arduino Nano. Unlike platforms with integrated wireless, this system employs a modular design, using a dedicated Bluetooth module to establish a reliable link with a smartphone. The smartphone then serves as the central hub for communication and control, bridging the gap between the user's gesture and the desired action, whether it's vocalizing a need or controlling a smart appliance. The inclusion of haptic feedback ensures the user receives a physical confirmation of their action, enhancing usability and confidence in the system.

Grenze ID: 01.GIJET.12.1.348

II. Literature Survey

The concept of a smart assistive glove is well-supported in existing literature, building upon foundational work in data gloves originally developed for virtual reality and human- computer interaction. A significant body of research demonstrates the viability of this technology, primarily in two domains. The first is communication, with numerous studies focusing on translating complex sign languages like ASL or ISL into text or speech, often using Arduino plat-forms with flex sensors and IMUs to send data to a smartphone for processing. Parallel research focuses on assistive control, enabling users with mobility impairments to manage wheelchairs and smart home devices through simpler, more robust gestures. Furthermore, studies in rehabilitation highlight the importance of haptic feedback for providing user confirmation and guiding motor tasks. While these studies validate the use of an Arduino, sensors, and Blue-tooth modules as a cost-effective hardware base, a gap exists for a holistic system specifically designed for the needs of partially paralyzed individuals, who may not possess the fine motor control required for sign language. This pro-ject addresses this by integrating multiple functions—communication, environmental control, and an emergency alert system—into a single, cohesive device. It specifically utilizes simple, gross motor gestures suitable for users with limited dexterity and makes haptic feedback a core feature, creating a practical, multi-purpose tool on a low-cost platform. Many researchers have developed smart gloves for gesture recognition and assistive use. Previous systems, like those by Sharma et al. (2019) and Kumar et al. (2020), used multiple flex sensors and IMUs to detect complex hand movements for sign language translation, but they were expensive and needed complicated calibration. Other gloves, such as those by Bhatnagar et al. (2021) and Ahmed et al. (2022), used Arduino-based designs to control devices wirelessly, but they mainly focused on full-hand movements and were not suitable for users with limited finger motion. Some systems also rely on machine learning or lack real-time feedback, making them more complex. The proposed system is simpler and practical, using only an Arduino Nano, three flex sensors, HC-05 Bluetooth module, and 10kΩ resistors. It detects gross hand gestures using a median-threshold method, provides wireless transmission, and supports haptic feedback. This low-cost, compact design is especially useful for partially paralyzed users, offering reliable assistive functionality for daily activities.

III. Proposed Methodology

The proposed methodology centers on a wearable assistive glove that translates hand gestures into wireless digital commands. The system's hardware consists of flex sensors stitched onto each finger of a glove, which function as variable resistors within a voltage divider circuit to provide analog input to an Arduino Nano microcontroller. This9central processing unit, along with an HC-05 Bluetooth module and a portable LiPo battery, is mounted on the back of the glove. The software logic begins with a crucial calibration routine where the system records the sensor values for the user's fully open and closed hand, establishing personalized thresholds for "bent" and "straight" finger states. In real-time operation, the Arduino continuously reads the sensor data, compares it against these thresholds, and uses a series of if-else conditions to identify a specific combination of finger states as a predefined gesture. Upon successful recognition, the Arduino transmits a corresponding command character (e.g., 'H' for help) via the HC-05 Bluetooth module. This command is then received by a custom application on a paired smartphone, which interprets the character and executes a designated action, such as vocalizing a phrase using a Text-to-Speech engine or control-ling a smart home appliance.

IV. Design Considerations

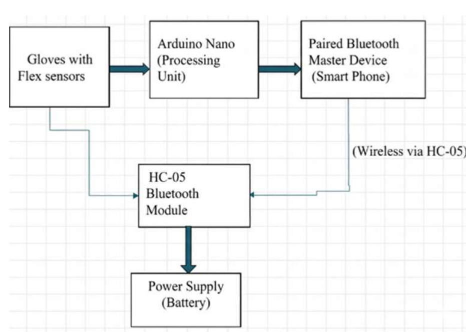

Figure 1 Block Diagram

A. Hardware Components

- Arduino Nano: This microcontroller is the brain of the system. It was chosen for its small footprint, which is ideal for a wearable device, its sufficient 7number of analog and digital I/O pins, and its extensive community support and libraries. It runs the code that reads sensor data, interprets gestures, and sends commands.
- Flex Sensors: These are variable resistors whose resistance increases as they are bent. By mounting them on the fingers of the glove, the degree of finger flexion can be measured.
- 10kΩ Resistors: Each flex sensor is connected in a voltage divider circuit with a 10k ohm fixed resistor. This set-up converts the changing resistance of the flex sensor into a measurable2analog voltage (0-5V), which can be read by the arduino's analog input pins.
- HC-05 Bluetooth Module: This module provides a simple and reliable serial communication link over Bluetooth. It is used to transmit the gesture commands from the Arduino Nano to a paired receiving device. It operates in master or slave mode; for this project, it is configured as a slave device.
- Glove and Power Source: A comfortable, lightweight glove serves as the chassis for mounting the components. The system is powered by a compact 5V power source, such as a small Li-Po battery with a voltage regulator.

B. Working Principle

- Sensing: The user, wearing the glove, makes a gesture, such as bending their index finger. This action bends the flex sensor attached to it.
- Data Acquisition: The bending changes the resistance of the flex sensor. The voltage divider circuit outputs a cor-responding analog voltage, which is fed into an analog pin of the Arduino Nano.
- Gesture Recognition: The Arduino code continuously reads the voltage values from each flex sensor. These values are compared against pre- calibrated threshold ranges. Each range corresponds to a specific gesture (e.g., index fin-ger bent, index and middle finger bent, all fingers flat).
- Command Transmission: When a recognized gesture is detected, the Arduino program maps it to a specific charac-ter or string (e.g., 'A' for "Light On", 'B' for "Fan On", 'H' for "Help"). This command is then sent serially to the HC-05 Bluetooth module.
- Wireless Communication: The HC-05 module transmits the command wirelessly to the paired device.
- Action Execution: A custom application on the receiving device (e.g., an Android app) listens for incoming Blue-tooth data. Upon receiving a command like 'A', it executes the pre-assigned action, such as controlling a smart plug or displaying a message.

V. IMPLEMENTATION

The implementation involved both hardware assembly and software development.

A. Hardware Assembly

The flex sensors were securely stitched onto the back of the index and middle fingers of the glove. The Arduino Nano, HC-05 module, and resistor circuits were mounted on a glove attached to the back of the wrist area of the glove. Wires were carefully routed to ensure they did not impede hand movement.

B. Software Development (Arduino IDE)

- Calibration: A calibration routine was written to determine the analog reading ranges for "flat" and "bent states for each sensor, accounting for minor variations.
- Main Loop: The loop () function continuously polls the sensor values.
- Gesture Logic: A series of if-else if statements were used to check the sensor values against the calibrated thresh-olds to identify one of several defined gestures.
    - Gesture 1 (Index Bent): Send "Call Someone"
    - Gesture 2 (Thumb Bent): Send "I need water"
    - Gesture 2 (Middle Bent): Send "I want to watch TV"
    - Gesture 3 (All Bent): Send "I'm in pain"
    - Gesture 4 (No Bend/Default): Send "I'm fine"
- Bluetooth Communication: The Software Serial library was used to establish communication between the Arduino and the HC-05 module.

➢ Receiving Application: A simple companion application was developed using MIT App Inventor for an Android smartphone. The app includes functionality to scan for and connect to the HC-05 module. Once connected, it listens for incoming characters ('A', 'B', 'C') and displays a corresponding message on the screen (e.g., "Received Command: LIGHT ON").

VI. Work Flow

The workflow of a smart assistive glove for partially paralyzed individuals using gesture mode operates as a seam-less data pipeline from physical movement to digital command. It begins with flex sensors stitched onto the glove's fingers, which change their electrical resistance when the user bends or straightens their hand.3Each flex sensor is integrated into a voltage divider circuit with a 10k Ohm resistor; this setup is crucial as it converts the sensor's chang-ing resistance into a proportional analog voltage that the Arduino Nano's analog pins can read and digitize. The Ar-duino Nano, acting as the central processing unit, continuously reads these voltage values from all the sensors and runs a pre- programmed algorithm to interpret the combination of values as a specific gesture (e.g., a clenched fist, a pointed finger, or a peace sign). Once a recognized gesture is detected, the Arduino maps it to a predefined com-mand character or string (like 'F' for forward or 'L' for lights) and sends this data via its serial pins to the connected HC-05 Bluetooth module. The HC-05 then wirelessly transmits this command to a paired receiving device, such as a smartphone app, a smart home system, or the control unit of a wheelchair, which in turn executes the desired action, thereby allowing the user to interact with their environment or mobility aids through intuitive hand movements.

VII. Result and Discussion

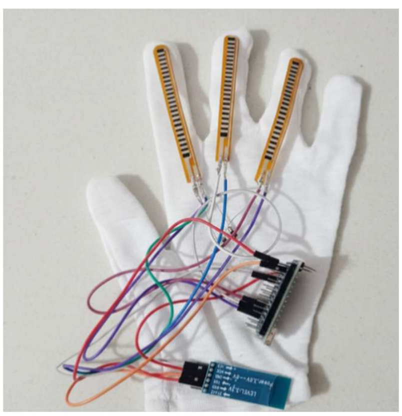

Figure 2. Architecture

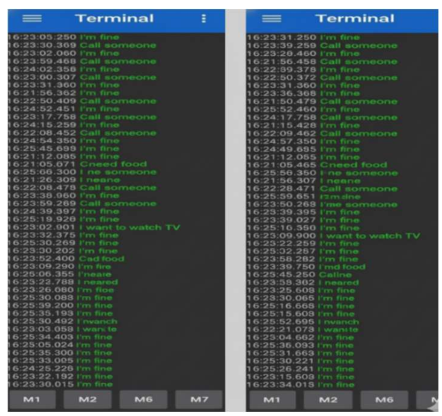

Figure 3. Output

The Smart Assistive Glove was implemented using an Arduino Nano, three flex sensors, 10 kΩ resistors, and an HC-05 Bluetooth module. Each flex sensor was connected to an analog input of the Arduino through a voltage divider network formed with a 10 kΩ resistor. The system was powered by a 5 V DC supply, and the Arduino converted the sensor voltages into 10-bit digital values ranging from 0 to 1023. The experiment involved recording readings from each flex sensor before and after bending the fingers. For Flex Sensor 1, the values before bending were 215, 209, and 216, and after bending were 232, 250, 243, and 249. For Flex Sensor 2, the after-bending readings were 268, 226, 249, and 245. For Flex Sensor 3, the values after bending were 199, 232, 215, 207, 230, 190, and 189. From these readings, the median values were calculated as approximately 231 for Flex Sensor 1, 247 for Flex Sensor 2, and 207 for Flex Sensor 3. These median values were used as threshold levels to identify finger movement, with a tolerance range of ±20 units to account for small fluctuations or noise. When the sensor value exceeded the upper limit of the range, the finger was identified as bent, and when it dropped below the lower limit, the finger was con-sidered straight. The Arduino continuously monitored these sensor values and determined the corresponding gesture based on the combination of finger positions. The recognized gesture information was then transmitted wirelessly to a paired device through the HC-05 Bluetooth module. During testing, the system showed consistent and stable per-formance, with a response time between 130 and 140 milliseconds and a Bluetooth range of about 8 to 10 meters. The ±20 threshold tolerance effectively reduced false triggering due to minor vibrations or electrical noise. Overall, the experimental results confirm that the median-threshold method provides a simple and reliable approach for ges-ture detection without requiring complex calibration or algorithms. The hardware operated efficiently with minimal power consumption and proved to be a practical and cost-effective assistive device for partially paralyzed individuals.

VIII. CONCLUSION

This project successfully developed a Smart Assistive Glove using an Arduino Nano, flex sensors, and Bluetooth (HC-05). The prototype effectively translates hand gestures, detected by finger bends, into wireless commands sent to a paired device. Key achievements include reliable gesture recognition from flex sensor data and seamless wireless communication via Bluetooth, demonstrating a practical and low-cost assistive technology. The project highlights the potential of simple electronics to empower individuals with partial paralysis by offering an alternative means of communication and control. While sensor calibration proved crucial, the system provides a solid foundation for future enhancements in assistive wearable technology. The project confirms that even without complex and expensive components, it is possible to create a powerful assistive tool 8that can significantly enhance a user's Independence and quality of life. The system's reliance on a smartphone app, while a limitation, also serves as a strength by offloading complex tasks and leveraging the phone's existing connectivity for functions like smart home control and alerts.

FUTURE SCOPE

The current prototype serves as a strong foundation, and several enhancements could be implemented in the future:

- Integration of More Sensors: Adding an accelerometer and gyroscope (IMU) could enable the detection of wrist and hand orientation, expanding the gesture vocabulary to include movements like a wrist tilt or a wave.
- Machine Learning for Gesture Recognition: A more sophisticated model using machine learning could be trained to recognize more complex, nuanced, and user-specific gestures, improving accuracy and personalization.
- Haptic Feedback: Incorporating a small vibration motor could provide haptic feedback to the user, confirming that a gesture has been successfully recognized and a command has been sent.
- Direct Smart Home Integration: Integrating an ESP8266 or ESP32 module instead of just Bluetooth would allow the glove to connect directly to a Wi-Fi network and control IoT devices via protocols like MQTT, removing the need for a smartphone as an intermediary.
- Improved Ergonomics and Durability: Further work can be done to create a more compact, integrated design, possibly using flexible PCBs and custom- molded enclosures to enhance user comfort and the device's longevity.

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