TUNABLE GRIP MEASUREMENT DEVICE FOR ARTHRITIS PATIENTS

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Introduction:

Individuals suffering from neurological and musculoskeletal conditions such as stroke and arthritis often experience a significant loss in hand functionality, particularly affecting their grip strength and dexterity. This impairs their ability to perform everyday tasks such as holding utensils, opening containers, or writing, leading to a decline in independence and quality of life. While rehabilitation exercises are essential for restoring motor function, many existing tools lack the ability to provide quantitative, real-time feedback, making it difficult for therapists to accurately monitor patient progress and adapt therapy accordingly. Moreover, conventional rehabilitation methods can be monotonous, unengaging, and inaccessible for home-based therapy, reducing patient compliance and recovery efficiency.

To address these challenges, this project proposes the development of a Tunable Grip Measurement Device integrated into a wearable glove that enables continuous and precise monitoring of grip force. The solution leverages custom-built Force Sensitive Resistors (FSRs) using Velostat, a cost-effective, pressure-sensitive material. These sensors are strategically embedded across key areas of the hand to capture real-time pressure data. The signals are processed using an ESP32 microcontroller and visualized through an OLED display and a Graphical User Interface (GUI), providing instant feedback and progress tracking. This system is adaptive, allowing calibration to different grip strengths and therapy stages, and is designed to be lightweight, portable, and suitable for both clinical and home use, making it a comprehensive, engaging, and user-friendly solution for effective hand rehabilitation.

Objective:

- To design a tunable grip measurement device tailored for arthritis and stroke rehabilitation.
- To develop and integrate custom Force Sensitive Resistors (FSRs) for accurate hand pressure sensing.
- To monitor grip strength and hand dexterity through a wearable glove system.
- To provide real-time feedback via an OLED display and graphical user interface for patient and therapist use.
- To support adaptive rehabilitation by tracking patient progress and enabling safe, repetitive motion exercises.
- To ensure the device is low-cost, portable, and suitable for both clinical and home environments.
- To explore the potential for patenting and future development into a scalable medical product.

Methodology:

The development of the Tunable Grip Measurement Device follows a structured approach involving sensor design, integration, calibration, data acquisition, and real-time feedback. The core sensing element is a custom Force Sensitive Resistor (FSR) made using Velostat, a pressure-sensitive conductive material. This material is sandwiched between copper electrodes and mounted onto foam plates for uniform pressure distribution.

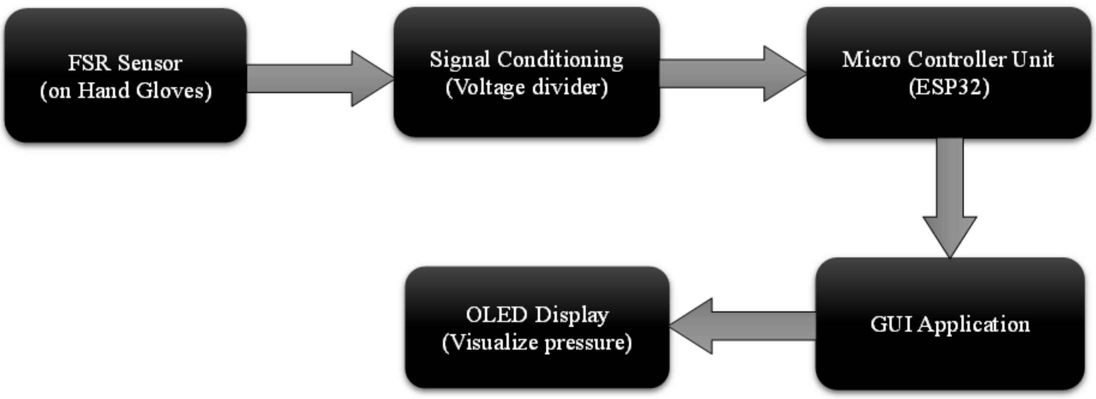

Figure 1: Block Diagram

Fifteen such FSRs are fabricated and strategically placed across a wearable glove: 4 on the palm, 2 on the thumb, and 2 or 3 on each finger. These positions are chosen to capture comprehensive grip and grasp pressure data during rehabilitation exercises.

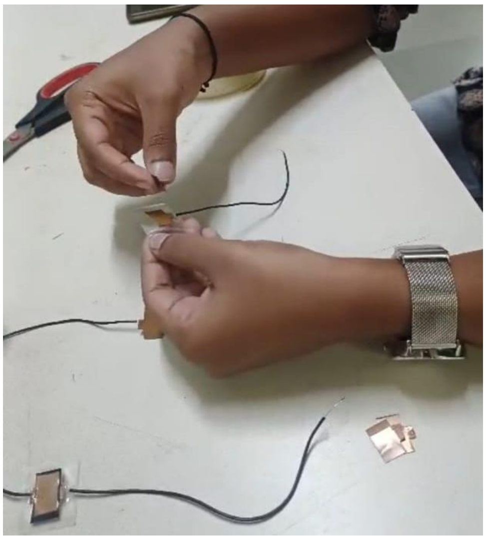

Figure 2: Fabrication of FSR Sensors

Each FSR is connected to a voltage divider circuit and interfaced with an ESP32 microcontroller, which reads analog voltage values. The Analog-to-Digital Converter (ADC) of the ESP32 converts these voltages into digital signals corresponding to applied pressure.

During the calibration phase, sensors are tested under known weights to record baseline resistance and create calibration curves. These curves are used to correlate resistance changes with actual pressure values.

Figure 3: FSR Sensors with Glove

The microcontroller processes the input in real time and sends data to an OLED display for instant visual feedback. Simultaneously, data is transmitted to a computer for visualization using a Graphical User Interface (GUI) developed in Arduino IDE and Python.

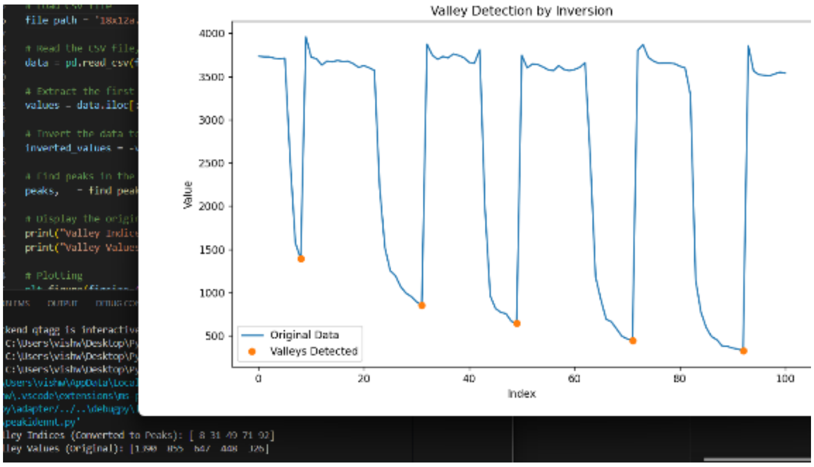

Figure 4: Calibration Curve Analysis

The glove enables users to perform controlled grip exercises, while therapists can assess grip strength, coordination, and progress over time. Minor modifications like sensor repositioning and code optimization are carried out to improve system stability and responsiveness.

This methodology ensures a robust, adaptive, and user-friendly device suitable for both clinical and home-based rehabilitation of arthritis and stroke patients.

Results and Conclusion:

The hand rehabilitation glove system demonstrates a significant advancement in assistive rehabilitation technology. During calibration, resistance values under varying weights were accurately recorded to generate a weight-resistance graph, forming a solid baseline for interpreting sensor data. The system effectively translates pressure into real-time readings, displaying them on both a GUI and an OLED screen for easy monitoring.

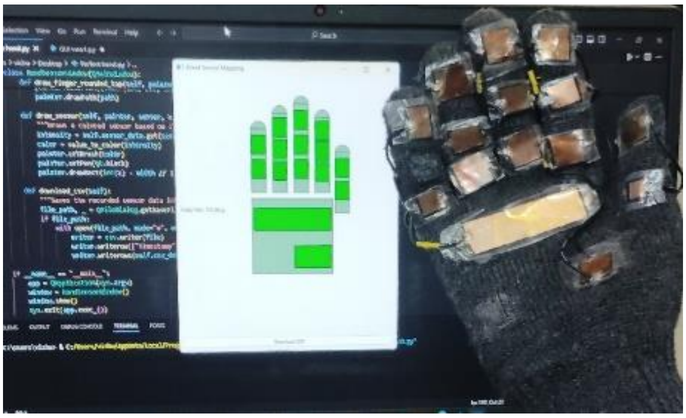

Figure 5: Initial functionality checks for each sensor

Initial functionality tests confirmed each sensor's responsiveness and the system's ability to process individual and combined sensor inputs accurately. A real-time color-coded feedback mechanism using green, red, blue, and white offers intuitive visual cues to patients and therapists regarding grip strength and muscle activity.

This mechanism is powered by FSR sensors, with pressure ranges mapped to meaningful feedback: 0–19g (no grip), 20–49g (weak grip), 50–80g (ideal grip), and 81–100g (excessive force). These indicators help patients adjust their grip strength during exercises, promoting consistent rehabilitation progress.

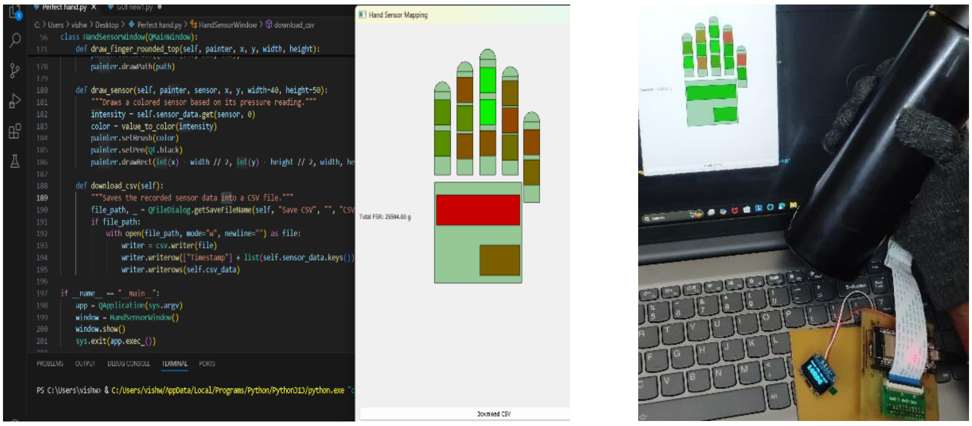

Figure 6:

Final output of the device showing Measurement's Mapping

The device demonstrated a total applied force of 15,471g under full pressure, and 720.5g in idle state. This confirms the sensor system's sensitivity and accuracy. By providing immediate, actionable feedback and visual indicators, the glove supports stroke patients in regaining hand function through guided, personalized rehabilitation.

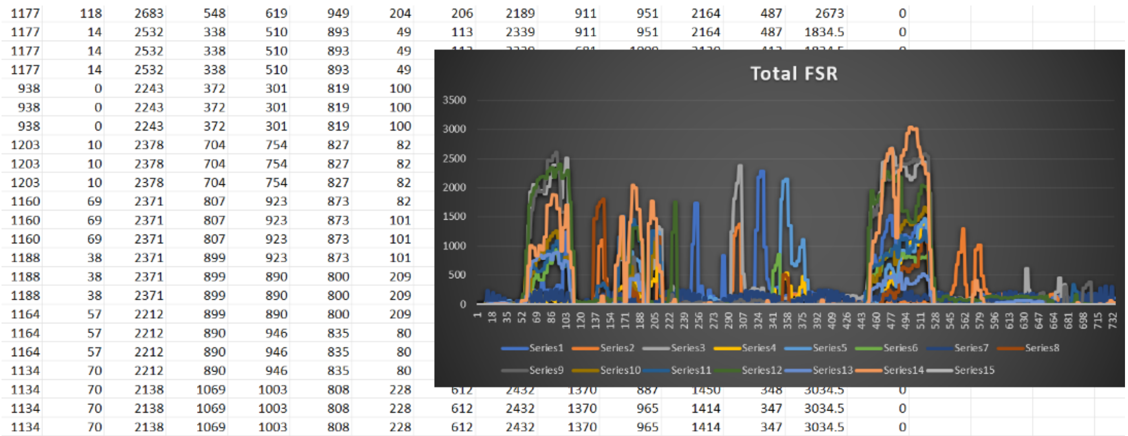

Figure 7: Pressure Measurements of Each Sensors

Future improvements could include enhanced sensor precision and broader motion tracking, further expanding its clinical applicability. The project stands as a promising solution in the field of wearable healthcare technology.

In conclusion, this rehabilitation glove is a significant innovation in stroke recovery, offering real-time feedback on grip strength and pressure through an intuitive, color-coded system. Its ability to support both clinical and home-based therapy makes it a versatile tool for continuous rehabilitation. By helping patients engage in targeted exercises and allowing therapists to monitor progress accurately, the device promotes faster and more effective recovery. Future enhancements in sensor precision and motion detection will further increase its impact, making it an even more powerful aid in restoring hand functionality and independence for stroke survivors.

Project Outcome and Industry Relevance:

The outcome of this project is a fully functional smart rehabilitation glove that uses pressure sensors (FSRs) to monitor and provide real-time feedback on hand grip strength, aiding stroke patients in their recovery journey. The system includes a responsive GUI and OLED display, offering visual feedback through colour changes based on grip pressure. With accurate pressure detection and user-friendly design, the glove supports both clinical evaluations and home-based rehabilitation exercises. It helps patients adjust their grip strength effectively, promoting muscle recovery and functional hand movement.

From an industry perspective, the project addresses a growing need in the healthcare and rehabilitation sector for wearable, intelligent assistive devices. Its integration of sensors, visual feedback, and real-time data processing aligns with current trends in tele-rehabilitation and personalized healthcare. The device can be commercialized for use in physiotherapy clinics, rehabilitation centres, and home care, reducing the burden on therapists and increasing patient engagement. With further development, including wireless connectivity and mobile app integration, the glove has strong potential for adoption in the medical technology industry, especially in neuro rehabilitation and post-stroke care.

Working Model vs. Simulation/Study:

This project qualifies as a working model because it involves actual hardware implementation using FSR sensors to measure real-time hand grip pressure. The system has been calibrated with physical weights, and sensor outputs are processed and displayed on an OLED screen and GUI. Real-time color-coded visual feedback responds dynamically to grip strength, demonstrating the integration of sensors, microcontroller, and display systems. The device has been tested with actual pressure application, showing outputs like 15,471g under load and 720.5g at rest. These features confirm that the glove functions in real-world conditions, beyond theoretical or simulated environments.

Project Outcomes and Learnings:

The key outcomes of this project include the successful development of a working rehabilitation glove that accurately measures grip strength using FSR sensors and provides real-time visual feedback through an OLED display and GUI. The system was calibrated using actual weights, ensuring reliable interpretation of sensor data, and implemented a color-coded feedback mechanism to guide patients in adjusting their grip strength during exercises. This makes the device effective for both clinical assessment and home-based rehabilitation. Through the process of designing, implementing, and analysing the project, valuable insights were gained into sensor integration, data processing, and user-interface design. It also highlighted the importance of precise calibration for consistent performance and reinforced the role of real-time feedback in improving patient engagement. The project deepened our understanding of how wearable technology can enhance rehabilitation outcomes, while also improving our practical skills in electronics, programming, and system troubleshooting.

Future Scope:

The future scope of this project includes:

1. **AI-Powered Analysis:** Integrating Artificial Intelligence (AI) with the app could enable predictive analytics, personalized exercise recommendations, and early detection of complications during rehabilitation. Machine learning models could analyse large datasets to refine therapy protocols and adapt in real-time to patient needs.
2. **Enhanced Sensor Technology:** Future iterations could incorporate advanced, multi-functional sensors to monitor additional metrics such as hand temperature, sweat levels, or muscle activity (EMG). This would provide a more holistic understanding of hand function and rehabilitation progress.
3. **Full-Hand and Arm Rehabilitation:** Expanding the system to include sensors for the wrist, forearm, and upper arm could support comprehensive motor rehabilitation for patients with more extensive impairments
4. **Integration with Wearable Ecosystems:** The glove could integrate with other wearable devices, such as smartwatches or fitness trackers, to provide a more

comprehensive health monitoring solution. Data could be combined with metrics like heart rate, sleep patterns, and physical activity levels for a holistic view of recovery.

5. **Clinical Trials and Standardization:** Large-scale clinical trials could establish the efficacy of the system and lead to its integration into standard rehabilitation protocols.