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DEVELOPMENT HAND REHABILITATION DEVICE USING IOT

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Abstract:

This project presents the development of a wearable IoT-based hand rehabilitation device aimed at assisting individuals suffering from nerve or tendon weakness. The system is designed to automate hand exercises by enabling controlled opening and closing of fingers at specific speeds, time and the selected the number of specific fingers. It is powered by an ESP32 microcontroller and controlled via the Blynk mobile application or manually using potentiometers to set speeds and time. The device utilizes an air pump, vacuum pump, and seven solenoid valves to manage pneumatic movement for each finger independently. An I2C LCD is used to display current settings, fingers, speed levels and time. All components are securely mounted inside a laser-cut acrylic box, offering portability and safety. This solution provides a cost-effective and customizable alternative to conventional rehabilitation methods, enhancing recovery through consistent and precise training routines.

Keywords: IoT-Based Rehabilitation, Wearable Hand Device, Pneumatic Control System, ESP32 Microcontroller, Physical Therapy Technology

1. Introduction

Hand function plays a pivotal role in performing everyday tasks, maintaining independence, and ensuring a high quality of life. For individuals affected by neurological disorders, chronic conditions, or traumatic injuries, the loss of hand mobility can lead to severe physical, emotional, and social challenges. Rehabilitation is essential for restoring hand function and promoting recovery, but traditional methods often lack the accessibility, affordability, and convenience needed for consistent use. This research focuses on the development of a comprehensive hand rehabilitation device designed for individuals with limited or no voluntary hand movement due to conditions such as stroke, spinal cord injuries, chronic illnesses, or neurological disorders. The device is portable, rechargeable, and integrates advanced features such as a dual-mode system (manual and Wi-Fi-enabled IoT control) and a built-in heating system and electric finger movement separation. These innovations aim to enhance the rehabilitation experience by providing tailored, effective therapy in both clinical and home settings.

Research background

Importance of Hand Rehabilitation

The human hand is a highly complex and essential organ responsible for a wide range of daily activities, from gripping objects to performing delicate tasks. When hand function is lost due to neurological disorders, strokes, or injuries, it leads to a significant decline in independence and overall quality of life. Traditional rehabilitation techniques rely heavily on manual physical therapy guided by professionals, which can be expensive, time-consuming, and difficult to access—especially for individuals in rural or low-resource areas. Studies have shown that early and consistent hand therapy significantly improves functional recovery outcomes in patients post-stroke or injury (Langhorne et al., 2009). The demand for more accessible, affordable, and continuous therapy has driven researchers and engineers toward developing assistive technologies that support motor recovery without constant clinical supervision.

Pneumatic Systems in Rehabilitation

Pneumatic actuation systems—based on air pressure—offer several advantages in rehabilitation technology. Unlike rigid motors, pneumatic systems can create smooth, soft, and adaptive movements that are more natural and safer for delicate joints and tendons. This makes them ideal for hand therapy applications, where flexibility and safety are crucial. Devices using air pumps, vacuum pumps, and solenoid valves can imitate the natural motion of muscles and tendons, creating a lifelike motion of finger flexion and extension. These systems also allow for selective activation of fingers, which is critical for personalized therapy.

The Role of IoT in Modern Healthcare

The integration of Internet of Things (IoT) technologies into healthcare systems has revolutionized how patients and doctors interact. IoT allows for the creation of connected medical devices that can monitor health conditions in real-time, adjust treatment plans remotely, and collect valuable data for analysis. In rehabilitation, IoT makes it possible to design smart devices that adapt to user needs, track progress, and provide feedback. Mobile apps such as Blynk are particularly valuable in this context. They allow users to control physical hardware (e.g., pumps, motors, valves) through their smartphones, enabling real-time control and customization of rehabilitation routines without needing medical personnel physically present.

Literature review

In recent years, the development of assistive technologies for hand rehabilitation has gained significant attention, especially in the field of wearable robotics and soft actuation systems. Many researchers have attempted to design gloves and exoskeletons capable of aiding patients suffering from limited hand movement due to conditions such as stroke, spinal cord injuries, or neurological disorders. Among these efforts, one of the most prominent is the soft robotic glove presented by Polygerinos et al. (2015), which employed pneumatic actuators to assist finger motion. The design emphasized comfort and natural hand movements, proving to be highly effective in therapeutic scenarios. However, despite its success, the glove's dependency on external bulky pneumatic equipment and lack of real-time customization posed limitations for independent home use.

Another relevant project was developed by Cempini et al. (2013), where a rigid-link exoskeleton was introduced to enable precise joint movements for each finger. While it showcased accuracy and structural control, the rigidity and complexity of the system made it less suitable for long-term wear or usage outside clinical environments. Similarly, Yap et al. (2017) proposed a cost-effective, fabric-based soft robotic glove for post-stroke rehabilitation, focusing on user comfort and affordability. Despite its lightweight and wearable design, the device lacked the capability for individualized finger control and was limited in terms of remote programmability or integration with smart systems.

Across these studies and others, a recurring challenge is evident: most rehabilitation gloves are either too expensive, too complex, or not sufficiently adaptable for at-home therapy. The majority of solutions require supervision by trained professionals or are confined to laboratory conditions, which drastically reduces their accessibility for daily, unsupervised use. Furthermore, many systems lack real-time feedback, user-friendly interfaces, or the ability to personalize rehabilitation sessions according to the specific needs of the user—whether in terms of speed, intensity, or targeted fingers. This is where the integration of Internet of Things (IoT) technology shows significant promise. With platforms such as Blynk, users can control physical hardware devices via smartphones, creating opportunities for smarter rehabilitation tools that can be customized and controlled remotely. Despite this potential, very few rehabilitation devices in existing literature utilize IoT technology effectively to allow dual-mode functionality—manual and smart control together.

Hence, the current project aims to address these gaps by proposing a comprehensive and portable hand rehabilitation system that combines the strengths of previous research while eliminating many of their limitations. The proposed glove incorporates pneumatic actuation using an air pump, vacuum pump, and seven solenoid valves to replicate smooth, controlled finger motion. It also offers both manual control (using potentiometers) and smart control (via the Blynk IoT platform), allowing the user or caregiver to select which fingers to activate and adjust the speed of flexion and extension in real-time. The entire system is housed in a compact acrylic box, making it both functional and user-friendly for clinical and home-based use alike. By integrating real-time wireless control, selective finger therapy, and portability in a single device, this project introduces a novel approach that fills the current research and practical gaps in hand rehabilitation systems. It sets the foundation for future improvements in tele-rehabilitation and personalized healthcare devices.

Problem statements

Many people with neurological disorders, spinal injuries, or muscle weakness suffer from impaired hand function, limiting their independence. Traditional rehabilitation methods are costly, time-consuming, and often inaccessible, especially in remote areas. Existing devices are usually bulky, rigid, and lack user comfort, making home use difficult. Most systems offer limited control options, with fixed routines and no customization. There is a need for affordable, user-friendly rehabilitation solutions that offer both manual and smart controls, remote access via smartphones, and real-time monitoring with adjustable therapy settings for personalized care.

Objectives

a. Design and develop a soft, wearable glove capable of opening and closing the hand using air pressure through an air pump, vacuum pump, and solenoid valves.

b. Implement dual-mode control, allowing the device to be operated manually (via potentiometers) and remotely (via the Blynk IoT platform), giving users flexibility based on their needs.

c. Enable finger-specific therapy, allowing users to select individual fingers for flexion and extension exercises based on their condition or rehabilitation plan.

d. Integrate adjustable speed control, enabling users or caregivers to set the rate of contraction and relaxation during therapy sessions.

e. Ensure portability and user comfort by housing all components in a compact acrylic box and using lightweight, ergonomic materials for wearable parts.

f. Promote independent home-based rehabilitation, reducing reliance on in-clinic visits and offering patients more control over their recovery process.

Project Organization

Introduction: Provides background on the importance of hand rehabilitation and introduces the motivation, scope, and objectives of the project.

Literature Review: Summarizes existing research and technologies related to hand rehabilitation and IoT-based healthcare devices, highlighting the gaps this project aims to address.

Methodology: Outlines the development process of the device, including component selection, circuit design, programming, and testing procedures.

System Design: Explains the architecture of the system, covering the interaction between the ESP32, valves, pumps, user interface, and mobile control via Blynk.

Implementation: Describes the practical steps taken to build the system, including hardware integration, software development, and the design of the acrylic enclosure.

Results and Evaluation: Presents the results of testing, evaluating the device's performance, responsiveness, and usability in rehabilitation scenarios.

Conclusion and Future Work: This section summarizes the key outcomes of the project and reflects on its effectiveness in addressing the rehabilitation needs of individuals with limited hand movement. It also proposes directions for future development, such as enhancing the comfort of the wearable glove, integrating additional sensors for feedback, and improving the intelligence and adaptability of the system.

2. Materials and Methods

The development of the wearable IoT-based hand rehabilitation device involved several key steps. Initially, the project began with identifying the needs of patients with nerve or tendon weakness, focusing on creating an affordable, customizable, and portable rehabilitation solution. Suitable hardware components were selected, including the ESP32 microcontroller for wireless connectivity, pneumatic elements such as an air pump, vacuum pump, and seven solenoid valves to control individual finger movements, and an I2C LCD for real-time display of settings. The software design included integration with the Blynk mobile application to allow remote control of finger selection, speed, and time, alongside manual control via potentiometers. The system architecture was then developed to ensure seamless interaction between hardware and software components. All parts were securely mounted in a laser-cut acrylic box to ensure safety and ease of use. Finally, the device was tested for performance, reliability, and usability, ensuring it met the therapeutic objectives for hand rehabilitation.

Hardware

- ESP32 microcontroller
- I2C_LCD 4*20.
- Air pumps.
- Air valves.
- Variable resistors.
- Buzzer.
- Relays.
- ULN2003 / Drive.

Software

- Arduino IDE. (https://www.arduino.cc).
- Blynk cloud platform. (https://blynk.com/).

ESP32 microcontroller

ESP32 is a microcontroller developed by Espressif Systems and is considered one of the most popular components in Internet of Things (IoT) applications. It is characterized by its support for wireless communication via Wi-Fi and Bluetooth in a single module, allowing for easy communication with networks and nearby devices. The ESP32 features a powerful dual-core Xtensa LX6 processor, running at a speed of up to 240MHz, providing high data processing capacity and efficient multitasking. The ESP32 consists of several integrated modules, including a wireless communication unit that supports Station and Access Point modes for connecting to internet networks, and Bluetooth 4.2 BLE + Classic for communicating with nearby devices. It has 520KB of SRAM for temporary data storage, with support for up to 16MB of external flash memory.

(a) (b)

Figure 1. Snapshot for a) ESP8266 Microcontroller, b) processor.

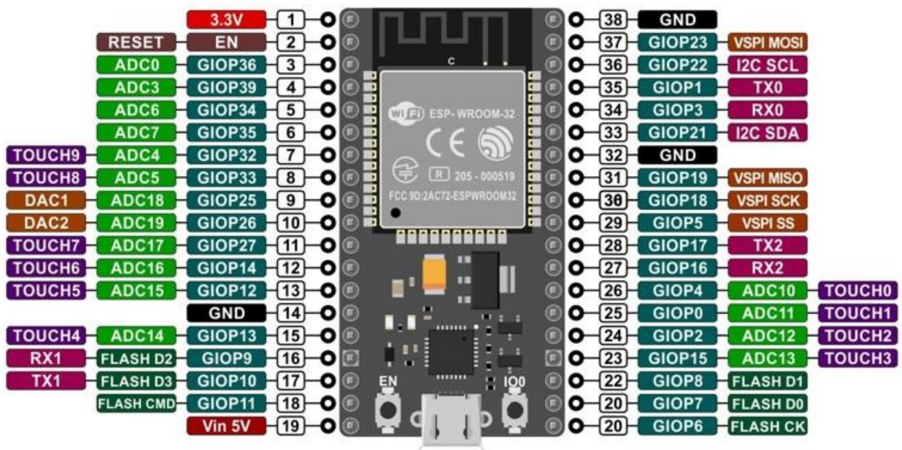


Figure 2. ESP32 Microcontroller pin out.

The ESP32 provides multiple GPIO (General Purpose Input/Output) pins that can be used to connect different sensors and devices. It also supports communication protocols such as UART, SPI, I2C, I2S for easy integration with external devices, in addition to analog and digital converters (ADC and DAC), enabling the reading and control of analog signals. With its high performance, ease of programming, and versatility, the ESP32 is an ideal choice for developing smart systems.

I2C LCD 20×4

The I2C LCD 20×4 is a Liquid Crystal Display (LCD) with an I2C module, designed to simplify communication with microcontrollers like ESP32 using only four wires (VCC, GND, SDA, SCL). It displays up to 80 characters across 20 columns and 4 rows, making it ideal for presenting long text or multiple pieces of information. The I2C adapter converts the interface from Parallel to I2C, reducing the number of required connections. The display features a contrast adjustment pin to control text brightness and a backlight for improved visibility in low light. It is easy to program using the LiquidCrystal_I2C library in Arduino IDE, with stable performance and low power consumption.

Figure 3. I2C_LCD Screen.

2H_Relay

A relay is an electrical device that controls circuits using low-power signals. It consists of an electromagnetic coil and a switch that opens or closes the circuit when the coil is activated. Relays can handle high currents with low voltage signals and are commonly used in industrial and electronic applications to control devices like motors and lights. Relays come in different types, including Single Pole Double Throw (SPDT) and Double Pole Double Throw (DPDT), depending on the number of circuits they control. The 2H-Relay has two independent switches, allowing control of two circuits simultaneously, useful for controlling multiple devices with one relay.

Relays are widely used in automation systems, home appliances, and security systems to switch devices remotely. The 2H-Relay is particularly beneficial in projects that require precise control of multiple circuits.

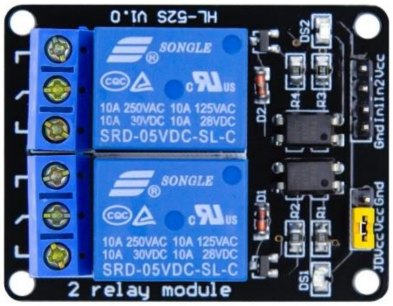


Figure 4. Snapshot for Relay.

Potentiometer

A potentiometer is a type of variable resistor used to adjust the level of resistance in an electrical circuit. It consists of a resistive track, a wiper that slides across the track, and three terminals: two connected to the ends of the resistive track and one connected to the wiper. By rotating the knob or adjusting the slider, the wiper moves, changing the resistance between the terminals and altering the output voltage. Potentiometers are commonly used to control volume, brightness, and speed in various electronic devices. They are also widely used in microcontroller projects to create analog inputs for controlling values such as light intensity or motor speed. Potentiometers are available in various sizes, with different resistance values and adjustments (e.g., rotary or linear).

Figure 5. Potentiometer.

Electric air Valve

powered by 6V DC, which opens or closes the valve to regulate the air flow. The valve typically has an inlet and outlet for air, and its actuator is controlled by a microcontroller or controller to provide precise flow control. Electric valves are commonly used in pneumatic systems, HVAC systems, and industrial applications. When the valve is open, air flows freely through the system; when it is closed, the air flow is completely stopped. This ability to precisely control air flow is essential for pressure regulation, preventing leaks, or directing air to specific areas in a system. Electric valves are fast, reliable, and highly precise, making them ideal for automation systems, air compressors, and pneumatic control systems. Their ease of control and 6V DC operation make them suitable for integration with microcontrollers like Arduino and ESP32.

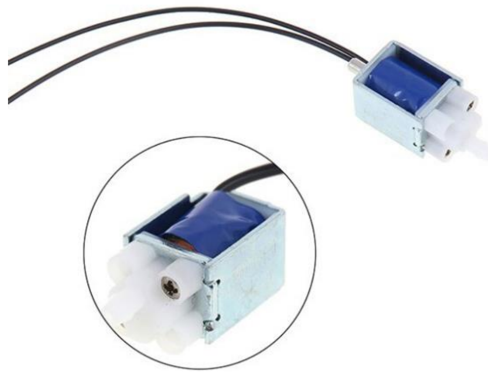


Figure 6. Snapshot for Electric air Valve

Buzzer

A buzzer is an electronic device that produces a sound (beeping, buzzing, or ringing) when activated. It is commonly used in alarms, timers, notifications, and electronic circuits. Buzzers can be active (built-in oscillator, just need power) or passive (require an external signal to generate sound).

Figure 7. Buzzer.

Air pump

A vacuum motor is an electric motor that generates suction power in devices like vacuum cleaners and air purifiers. It operates at 6-12V DC and uses a spinning fan to draw in air and particles through an intake for filtration or storage.

A vacuum motor uses a rotating fan to create suction by generating negative pressure. Commonly operating at 6V-12V DC, these motors are energy-efficient and ideal for handheld vacuums, robotic cleaners, and automotive tools. Their low voltage allows battery or DC power usage, making them suitable for compact applications.

Figure 8. Air pump.

ULN2003 / Driver

The ULN2003 is a Darlington transistor array used to control high-voltage, high-current devices like solenoids and electrical valves with low-voltage logic signals. It supports up to 50V and 500mA per channel and includes flyback diode protection for inductive loads, making it ideal for automation systems.

Figure 9. ULN2003 / Drive.

Battery

A rechargeable battery is a battery that can be reused by recharging after discharge. It stores energy for powering devices and is commonly used in electronics, vehicles, and backup systems, We use in this device 7.4V / 3600 mA.

Figure 10. Battery.

Software

Arduino IDE

To upload the code to our microcontroller, we use an integrated development environment (IDE) that deals with AVR-type microcontrollers, including Arduino and Esp32, which work in the same environment using the Arduino IDE, which is a software available for various operating systems, Windows, Linux, and Mac. It can be downloaded from the official Arduino website. The code can upload from the Arduino IDE to our microcontroller by connecting the microcontroller to the PC, selecting the port on which the microcontroller is connected, and then uploading the code quickly. Arduino software URL to download: https://www.arduino.cc/en/software.

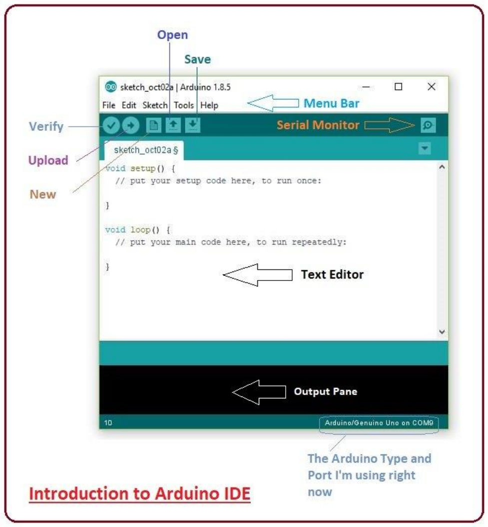


Figure 11. Arduino Software (IDE).

Blynk cloud platform

Blynk is an open-source platform that allows users to build applications for controlling smart devices via mobile phones using IoT (Internet of Things) technologies. It provides an easy-to-use graphical interface that enables fast app design through drag-and-drop. The platform supports various devices such as ESP8266, ESP32, and Arduino, and offers cloud connectivity for monitoring data and managing devices remotely. The user interface can be customized, and devices can be controlled online using a mobile phone. It also supports MQTT and HTTP protocols for easy integration with other systems. Blynk is used in applications like smart homes, industrial automation, and controlling entertainment devices.

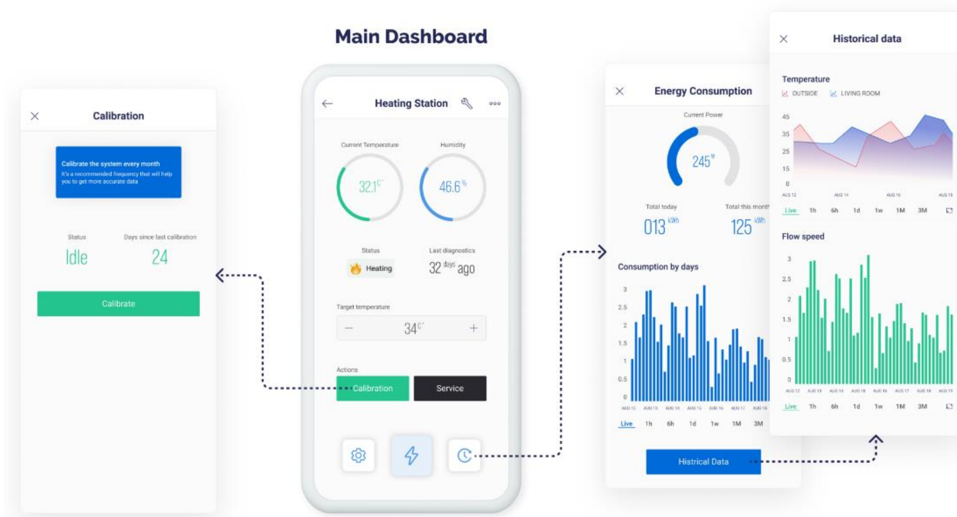


Figure 12. Blynk cloud platform.

Block diagram and system architecture

Block diagram

The block diagram of the proposed hand rehabilitation device illustrates the integration of several essential hardware components that work together to enable smart and flexible rehabilitation. At the core of the system is the ESP32 microcontroller, which acts as the brain of the device, handling both manual and wireless control operations. The system includes seven solenoid valves connected to an air pump and a vacuum pump, which are responsible for the inflation and deflation of finger actuators to perform controlled hand opening and closing movements. Each valve is mapped to a specific finger, allowing the user to select which fingers to activate through either manual input or a mobile interface. Potentiometers are used for manual mode to adjust the speed of contraction and relaxation, while an I2C LCD display provides real-time feedback on the device status and current settings. In wireless mode, the system is controlled via the Blynk application, which enables the user to choose active fingers and control speed through a user-friendly smartphone interface using Wi-Fi communication. The entire system is powered through a rechargeable battery and neatly housed in a custom-designed acrylic box, ensuring both portability and protection for the electronics. The block diagram provides a clear overview of the interaction between the control unit, actuators, sensors, and user interfaces that make up the device architecture.

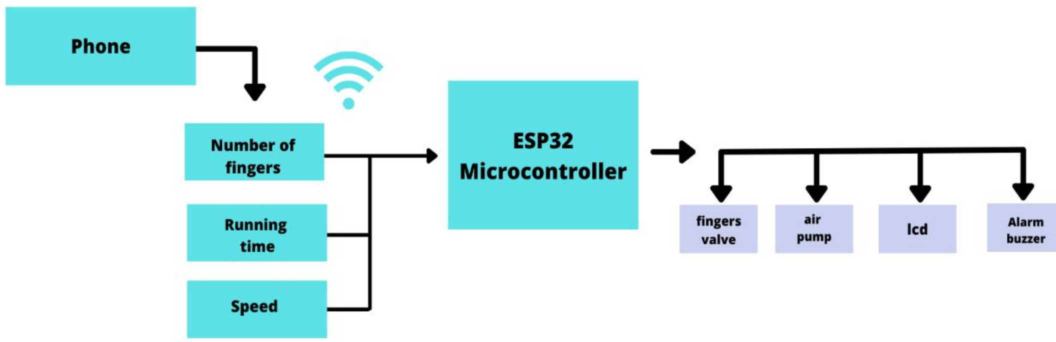


Figure 13. Block diagram for the proposed system.

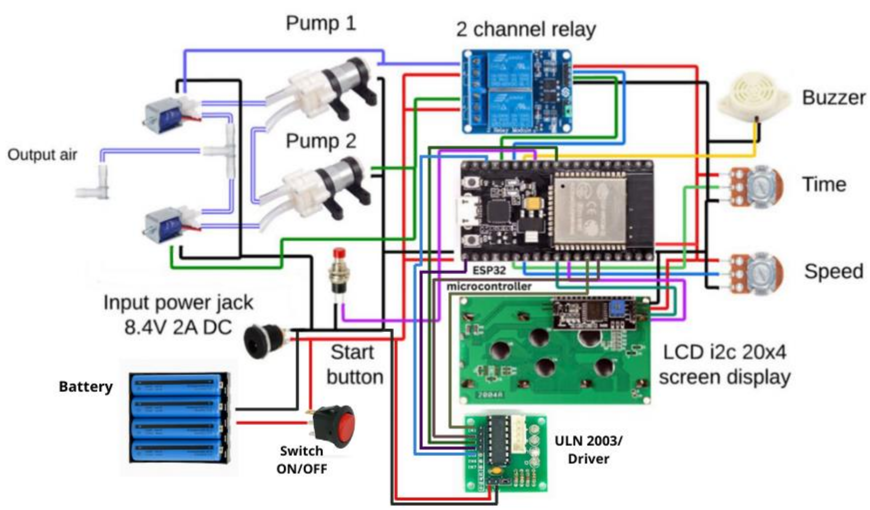


Figure 14. System schematic Diagram.

System architecture

The proposed system involves an ESP32 microcontroller, I2C_LCD 4*20, two Air pumps, two Air valves, two variable resistors, a Buzzer, ULN2003 / Drive, and an input DC power jack of about 8.4 V /2A as show in figure 14. All components are put in an acrylic materials box, according to Figure 15. Figure 16 shows the components for the proposed system, which involves a glove insert on five finger air valves to control the finger's movement. That can control movement-based mobile application via Wi-Fi module, as shown Figure 18.

Figure 15. Project design.

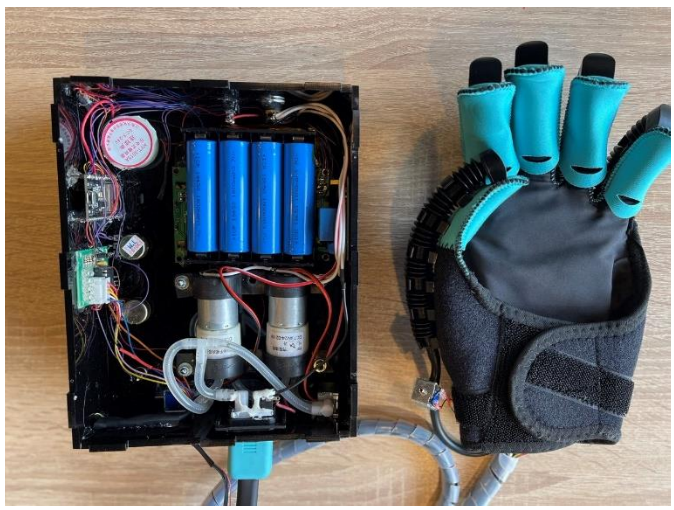
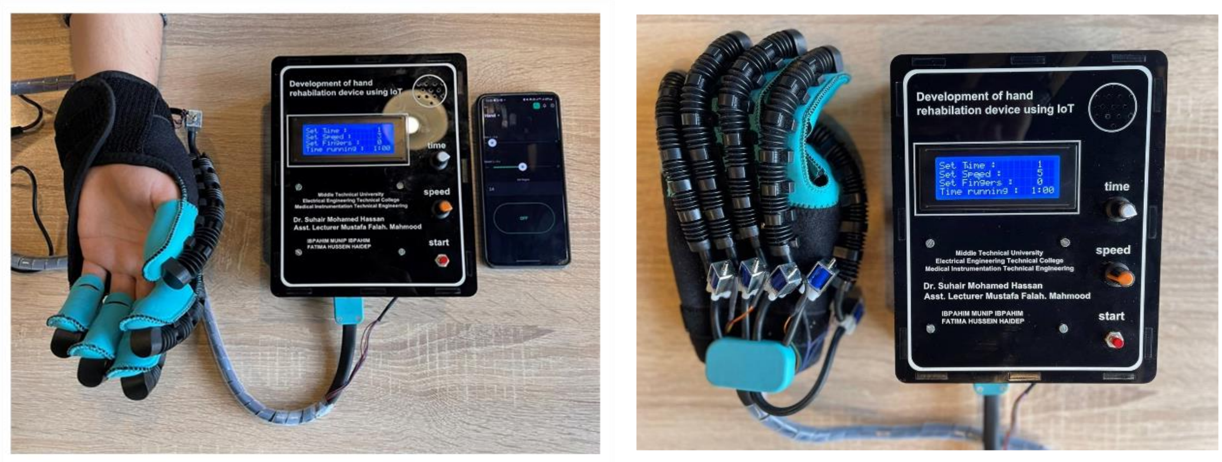


Figure 16. Connect all project components.

Figure 17. Hand and valves.



(a) (b)

Figure 18. Final design (a and b).

3. Results

Validate the new proposed system

The project has been successfully powered up and tested, and its dedicated interface on the application displays the components that make up the set section, as well as the parts used to control state of devices.

Figure. 19 show the control interface of the program used in the device: Time: Used to set the duration of the treatment, ranging from one to five minutes. Speed: control the speed of the fingers' flexion and extension movements, with options ranging from the fastest (1) to the slowest (5). Set Finger: Enables the user to input the number of the finger or group of fingers to be treated.

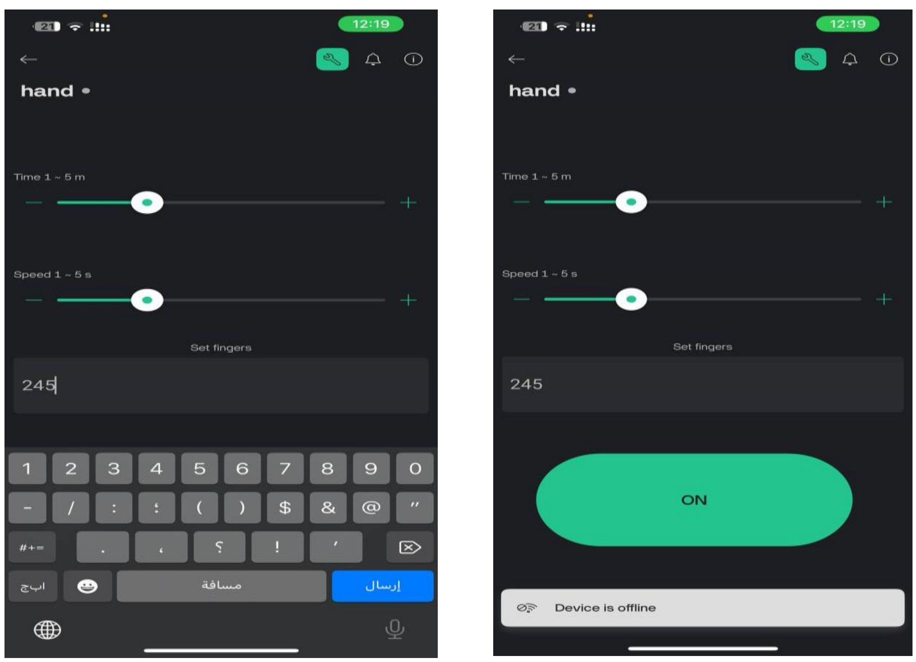
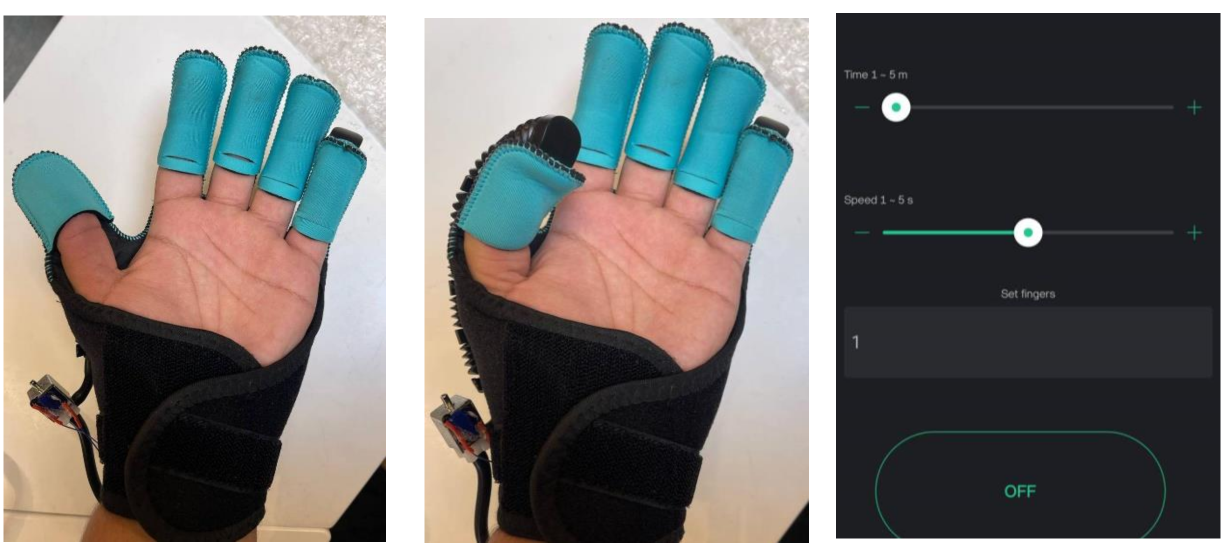


Figure 19. Enable device and validate.

Figure 20. Number of fingers.

Figure 20 illustrates the finger numbering mechanism in programming. Each finger is assigned a unique number for ease of use and programming. The system relies on entering the number of the finger or group of fingers to be treated, and this data is then sent to the device to begin operating according to the specified settings. This approach simplifies the control process and allows flexibility in selecting the appropriate therapeutic movements for each case.

The finger rehabilitation project was developed using fine motor control. The device allows individual or group movement of fingers (two, three, four, or all fingers together) based on the user's needs. The device is designed to support 15 programmed finger movements, contributing to improved motor function and enhanced personalized rehabilitation with flexibility and efficiency.

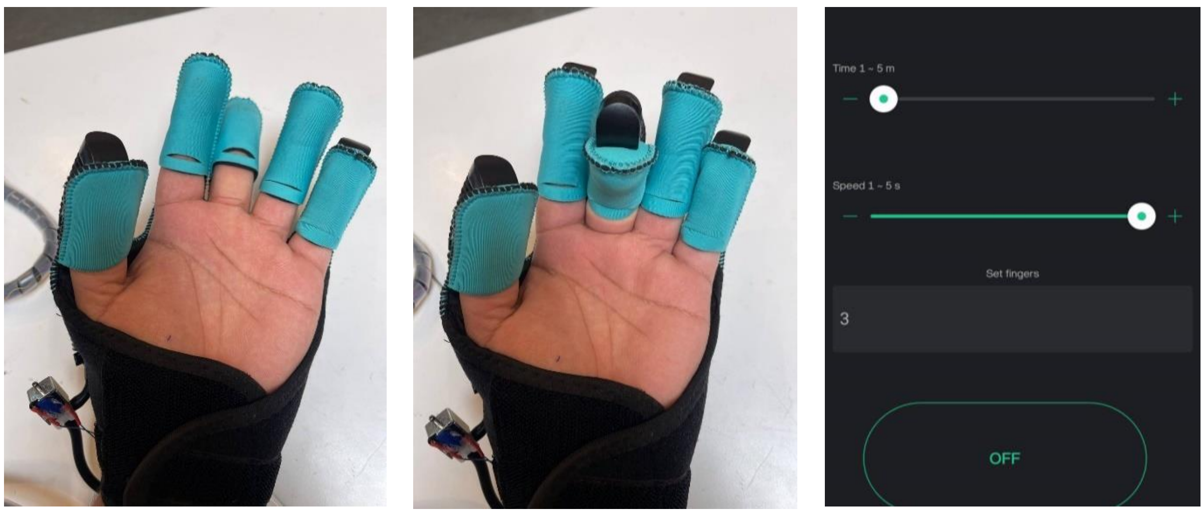


(a)

Figure 21. Move the finger no.1 with speed (3s) and time (1min).

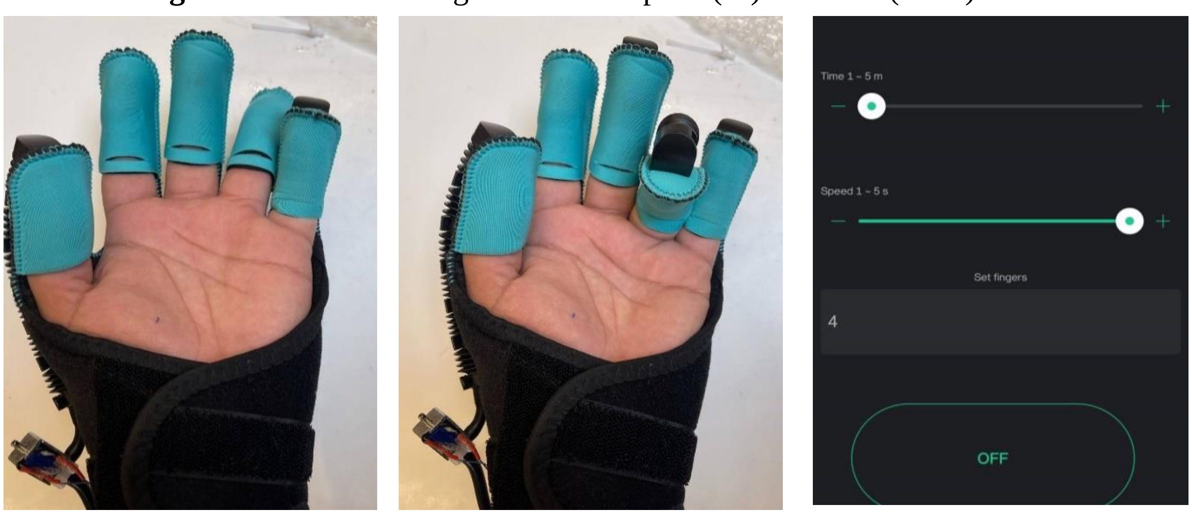
(b)

Figure 22. Move the finger no.2 with speed (5s) and time (1min).



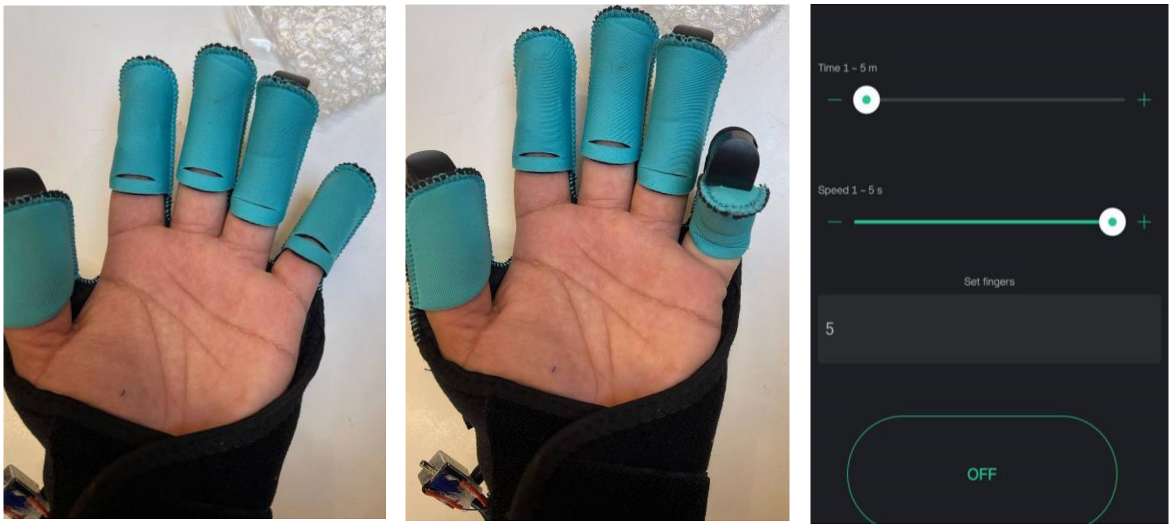
(c)

Figure 23. Move the finger no.3 with speed (5s) and time (1min).



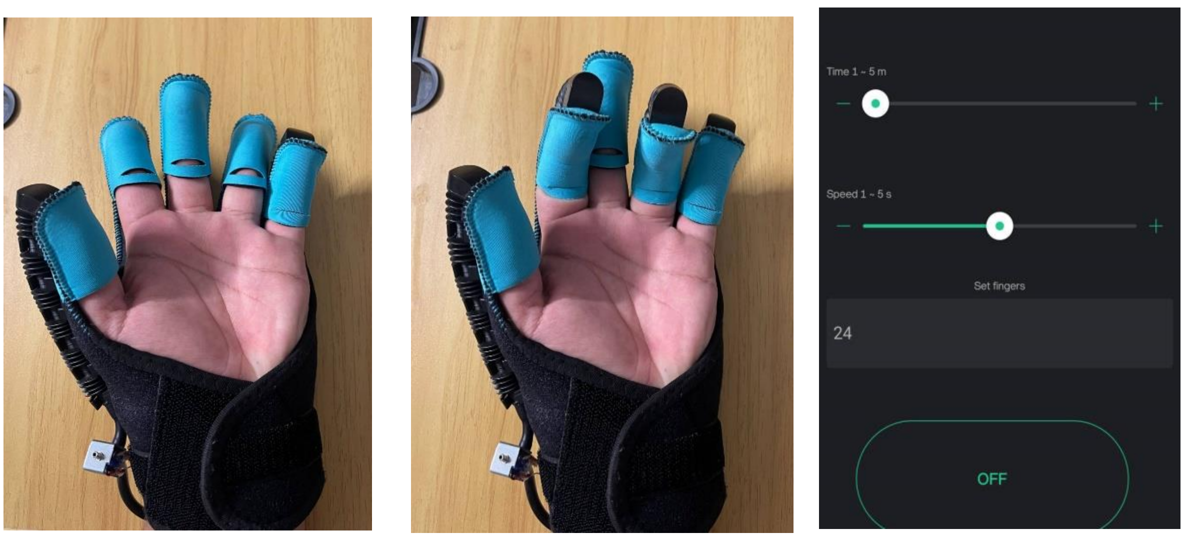
(d)

Figure 24. Move the finger no.4 with speed (5s) and time (1min).



(e)

Figure 25. Move the finger no.5 with speed (5s) and time (1min).

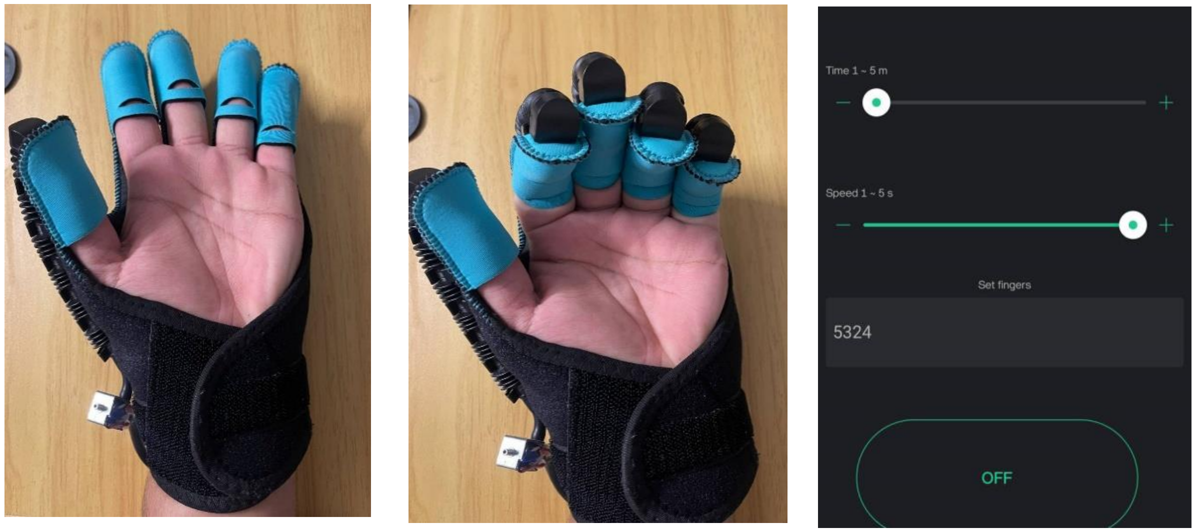


(f)

Figure 26. Move the finger no.2 and no.4 with speed (3s) and time (1min).

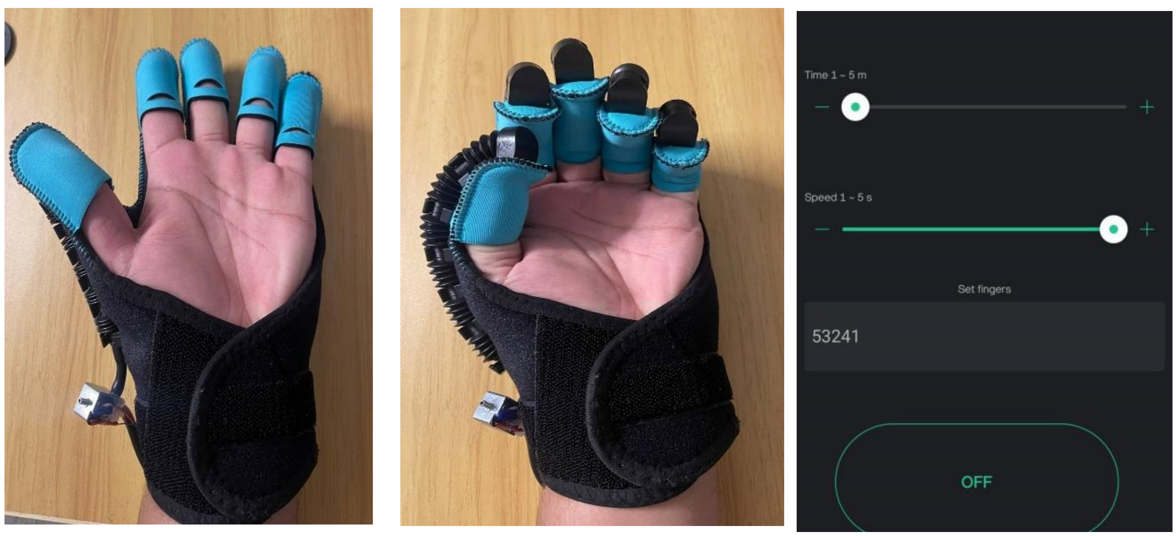
(g)

Figure 27. Move the finger no.2, no.3 and no.4 with speed (5s) and time (1min)



(h)

Figure 28. Move the finger no.2, no.3, no.4 and no.5 with speed (5s) and time (1min).



(i)

Figure 29. Move the finger no.1, no.2,no.3,no.4 and no.5 with speed (5s) and time (1min)

Figure Individual finger movements and some group finger movements (a – i).

4. Discussion

This device is a useful tool for patients suffering from strokes, nerve impairment, and paralysis, providing physical and functional therapy, facilitating and accelerating recovery.

1. It is portable and cost-effective.
2. Its light weight and durability allow the patient the freedom to carry it anywhere.
3. The device can be controlled from anywhere in the world via the internet.
4. The number of fingers to be treated, the treatment time, and the speed of finger movement can be controlled.
5. The device's application interface is easy, simple, and uncomplicated.

5. Conclusion

This project successfully presents the design and development of a smart, wearable hand rehabilitation device based on IoT technology. The system was specifically created to aid individuals suffering from limited hand mobility due to neurological disorders, injuries, or chronic conditions. By combining soft actuation, dual-mode control (manual and wireless via Blynk), and finger-specific operation, the device offers a customizable, accessible, and affordable rehabilitation solution. The integration of ESP32, air and vacuum pumps, solenoid valves, an I2C LCD display, and adjustable potentiometers resulted in a compact and user-friendly prototype housed within a lightweight acrylic box. The system's ability to allow users to select finger movements and control the speed of contraction and relaxation enhances its suitability for both clinical and home-based therapy sessions. This project demonstrates how IoT and automation technologies can be effectively utilized to improve healthcare accessibility and support personalized recovery plans. While the current prototype meets its core objectives, future versions could incorporate real-time data monitoring, mobile progress tracking, machine learning–based adjustment of therapy routines, and enhanced ergonomic design for improved comfort and durability. Ultimately, the developed system has the potential to bridge the gap between traditional rehabilitation and modern, smart healthcare solutions, empowering patients to actively participate in their recovery process.

Future work

a. Adding sensors to measure finger bending and grip strength during exercises, providing accurate data for immediate feedback and performance improvement.

b. Developing the app to include session tracking, user profiles, and cloud storage for easy remote data access.

c. Integrating artificial intelligence algorithms to automatically adjust treatment parameters based on usage patterns and recovery outcomes.

d. Improving comfort with lightweight materials and ergonomic designs, adding wireless charging, and implementing an automatic shutdown mechanism when abnormal resistance occurs.

e. Collaborating with medical centers to conduct patient trials and evaluate the device's effectiveness in real-world settings.

f. Adding multilingual interfaces and improving accessibility for people with additional disabilities.

References

Kosar, T., Lu, Z., Mernik, M., Horvat, M., & Črepinšek, M. (2021). A case study on the design and implementation of a platform for hand rehabilitation. Applied Sciences, 11(1), 389.

Bouteraa, Y., Ben Abdallah, I., Alnowaiser, K., Islam, M. R., Ibrahim, A., & Gebali, F. (2022). Design and development of a smart IoT-based robotic solution for wrist rehabilitation. Micromachines, 13(6), 973.

Yang, G., Deng, J., Pang, G., Zhang, H., Li, J., Deng, B., ... & Yang, H. (2018). An IoT-enabled stroke rehabilitation system based on smart wearable armband and machine learning. IEEE journal of translational engineering in health and medicine, 6, 1-10.

Kabir, R., Sunny, M. S. H., Ahmed, H. U., & Rahman, M. H. (2022). Hand rehabilitation devices: A comprehensive systematic review. Micromachines, 13(7), 1033.

Bouteraa, Y., Ben Abdallah, I., Ibrahim, A., & Ahanger, T. A. (2020). Development of an IoT-based solution incorporating biofeedback and fuzzy logic control for elbow rehabilitation. Applied Sciences, 10(21), 7793.

Postolache, O., Hemanth, D. J., Alexandre, R., Gupta, D., Geman, O., & Khanna, A. (2020). Remote monitoring of physical rehabilitation of stroke patients using IoT and virtual reality. IEEE Journal on Selected Areas in Communications, 39(2), 562-573.

Megalingam, R. K., Manoharan, S. K., Mohandas, S. M., Reddy, C. P. K., Vijay, E., Naveen, P. N. V. K., & Chandrika, D. (2023). Wearable hand orthotic device for rehabilitation: Hand therapy with multi-mode control and real-time feedback. Applied Sciences, 13(6), 3976.

Duy, C. V. (2024). Design and development of a wrist rehabilitation device with an interactive game. Results in Engineering, 22, 102336.

Izhar, M. A. M., Ahmad, N., Dziyauddin, R. A., Sarip, S., Mashudi, N. A., SZA, J., & Alam Khan, M. A. (2023). A smart IoT-based prototype system for rehabilitation monitoring. International Journal of Integrated Engineering, 15(3), 104-111.

Alexandre, R., & Postolache, O. (2018, September). Wearable and IoT technologies application for physical rehabilitation. In 2018 International symposium in sensing and instrumentation in IoT era (ISSI) (pp. 1-6). IEEE.

Nadian-Ghomsheh, A., Farahani, B., & Kavian, M. (2021). A hierarchical privacy-preserving IoT architecture for vision-based hand rehabilitation assessment. Multimedia Tools and Applications, 80(20), 31357-31380.

Tan, C. W. (2022). Development of wearable rehabilitation device for wristfinger mobility rehabilitation (Doctoral dissertation, UTAR).

Rahman, A., & Al-Jumaily, A. (2013). Design and development of a bilateral therapeutic hand device for stroke rehabilitation. International Journal of Advanced Robotic Systems, 10(12), 405.

Chen, X., Gong, L., Wei, L., Yeh, S. C., Da Xu, L., Zheng, L., & Zou, Z. (2020). A wearable hand rehabilitation system with soft gloves. IEEE Transactions on Industrial Informatics, 17(2), 943-952.

Arivarasi, A., Thiripurasundari, D., Selvakumar, A. A., Kumaar, B., Aghil, T., Rahul, S., & Kannan, R. (2023). An advanced cost-efficient IoT method for stroke rehabilitation using smart gloves. Nanotechnology and Precision Engineering, 6(4).