DEVELOPING A SUPPORTIVE DEVICE FOR WRIST INJURY REHABILITATION TRAINING

Dien Thi Hong Ha

University of Economics - Technology for Industries, Hanoi, Vietnam

ARTICLE INFORMATION

Journal: *Vinh University Journal of Sciences*
ISSN: *1859-2228*

Volume: 52
Issue: 4A
****Correspondence:***
dthha@uneti.edu.vn

Received: *18 September 2023*
Accepted: *12 October 2023*
Published: *20 December 2023*

Citation:
Dien Thi Hong Ha (2023). Developing a supportive device for wrist injury rehabilitation training. ***Vinh Uni. J. Sci.*** *Vol. 52 (4A), pp. 49-58*
doi: 10.56824/vujs.2023a110

ABSTRACT

In this paper, we develop a supportive device to monitor the rehabilitation exercise process for people with disabilities to use their hands. The prototype is designed to include a resistance cable system to support the rehabilitation of the patient's hand motor function. During training, the patient pulls the resistance cable to exercise, and the resistance cable system applies force to the product's sensor block. The sensor block is capable of measuring parameters when force is applied, allowing the calculation of hand force during the patient's training. The hand force data obtained from the sensor block is then sent to a separate IoT-based application. This mobile-platform app is particularly developed for hosting data and providing a view for user to track his/her process of training. Additionally, the product is designed with angle measurement capabilities to track motion coordinates during the patient's hand training. The product is tailored to the physique of Vietnamese individuals. The patient's training results are stored on the Internet and displayed on a mobile application, facilitating the monitoring of training progress, comparing patient training results with standard data, and allowing remote monitoring by the patient's family members or healthcare professionals.

Keywords: Medical assistance device; training; rehabilitation; robotic rehabilitation; Internet of Things

1. Introduction

Wrist injuries are among the most common types of injuries, especially during sports and daily activities. A wrist injury is a misalignment of the bones of the wrist or damage to the tendons and muscles that can cause instability in the wrist joint after a fall or a strong impact. Additionally, wrist injuries can also develop from poor habits in daily life. In these cases, the severity gradually increases over time, with persistent, chronic pain. The most common types of wrist injuries are sprains and fractures. Sprained wrists usually result in pain, swelling, and are relatively easy to treat. However, in the case of a wrist fracture requiring surgical intervention, it can be challenging to fully restore hand function to its original state. In addition to medical care, monitoring, and medication-based treatment plans prescribed by doctors, individuals with wrist injuries (patients) should combine various rehabilitation methods to aid in their recovery. Wrist injury rehabilitation includes medical, economic, social, vocational guidance, and rehabilitation techniques to minimize the impact of reduced abilities and disabilities, ensuring that individuals with disabilities can integrate into society, have equal opportunities, and fully participate in social activities.

In Vietnam, hospitals have begun using rehabilitation devices for hand injuries (such as the one shown in Figure 1) to serve patients in need. Scientific publications or devices, machines, or robots that assist patients in the process of hand injury rehabilitation are quite diverse, with each product having different characteristics and usage for different purposes [1]-[3]. However, the disadvantages of these products include their high cost (making them less suitable for financially disadvantaged patients who need to purchase them for training and treatment at home), complex technology, fuel consumption, and the use of intricate designs, requiring users to have a high level of expertise. Maintenance and upkeep at home can also be challenging [4]-[7]. In this study, the authors aimed to develop and design an intelligent supportive device for patients that inherits the advantages of previously published products. This research has novelty in its attempt to build an affordable, easy-to-install, and maintainable product while still meeting the required design functions [8]-[11].

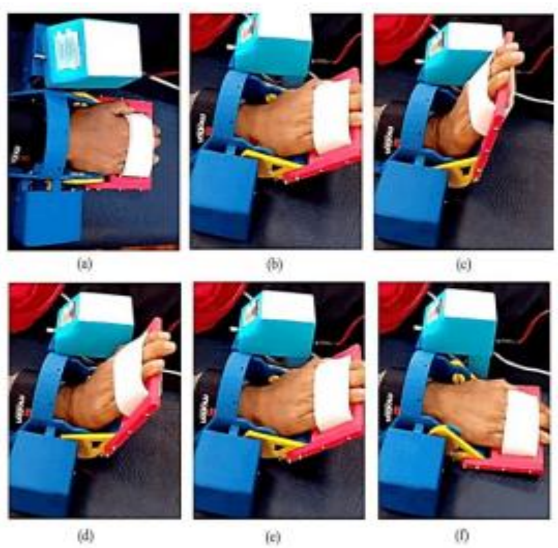

Figure 1: *Exercise support device [8]*

2. Harware and Sofware requirements:

In this study, modern devices and sensors commonly used today were employed [2], such as: *Node MCU ESP8266; Weight sensor Loadcell; Loadcell HX711; Module Battery Fast Charging IP5328P; LCD 1602.*

Blynk, an Internet of Things platform that allows users to remotely control and monitor devices through mobile applications, has been used to design the software interface. Blynk provides tools and libraries for developing remote control applications for embedded devices such as Arduino, Raspberry Pi, and ESP8266. Blynk supports various types of connections such as Wi-Fi, Ethernet, Bluetooth, and even 2G/3G/4G, enabling users to access devices from anywhere and at any time. Additionally, Blynk allows users to customize the mobile app interface and set up alerts and notifications for IoT device events. Blynk also provides other supporting features such as data storage, event-triggered notifications, device status monitoring, and data logging.

There are three main components in the Blynk platform:

- Blynk App: Allows users to create interfaces for their applications by simply dragging and dropping various pre-designed widgets.
- Blynk Server: Responsible for processing data as a central hub between the phone, tablet, and hardware.
- Blynk Library: Supports most popular hardware platforms, enabling communication with the server and handling all incoming and outgoing commands.

3. Analysis and design

3.1. The block diagram of the system

The product is designed to include a resistance cable system to support the rehabilitation training process for people with hand injuries. During the training, the patient pulls the resistance cable to exercise, and at this point, the resistance cable system applies force to the product's sensor block. The sensor block is capable of measuring parameters when force is applied, allowing the calculation of hand force during the patient's training. The hand force data obtained from the sensor block is then sent to a dedicated app for the product using IoT technology. In addition to the sensor system used to measure hand force, the product is also designed to measure angles to track the degree of movement during the patient's hand training. The product is tailored to the physique of Vietnamese individuals. The application of IoT technology in the product's design enables the storage of patient training data on the Server. Moreover, displaying the results on a mobile app makes it convenient to monitor training progress, compare patient training results with standard data. Additionally, it allows the patient's family members or healthcare professionals to easily monitor and supervise the patient's rehabilitation training process remotely.

The block diagram of the system is as follows [3-7]:

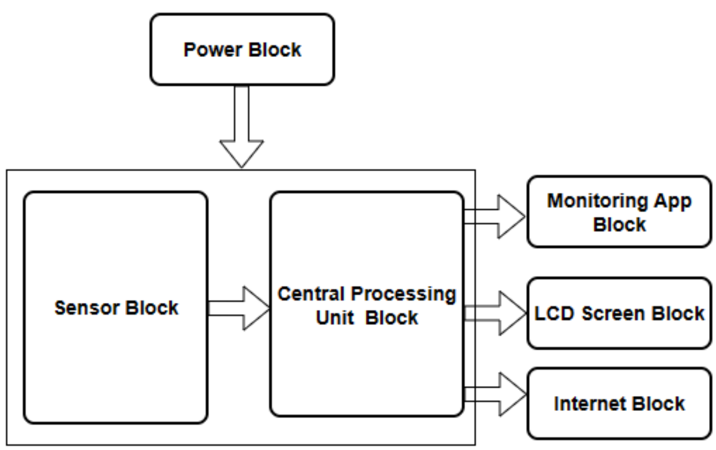

Figure 2: *System Block Diagram*

The block diagram (Figure 2) consists of 5 blocks with specific functions as follows:

- Power Block: Provides power to the entire system.

- ***Sensor Block:*** Detects changes in the user's hand force applied to the device, converts them into electrical signals, and sends them to the central processing unit block.

- ***Central Processing Unit Block:*** Receives signals from the sensor block, processes the signals, and transmits data to a compatible software application via the Internet.

- LED Display Block: Receives and displays data from the central processing unit block.

- Internet Block: Facilitates the transmission of signals from the central processing unit block, which are then displayed on the mobile phone screen.

- ***Monitoring Application Software Block:*** Displaying the software application interface with system parameter monitoring functions.

3.2. Circuit Connection Diagram and Operating Principle

The hardware connection diagram is illustrated as shown in Figure 3.

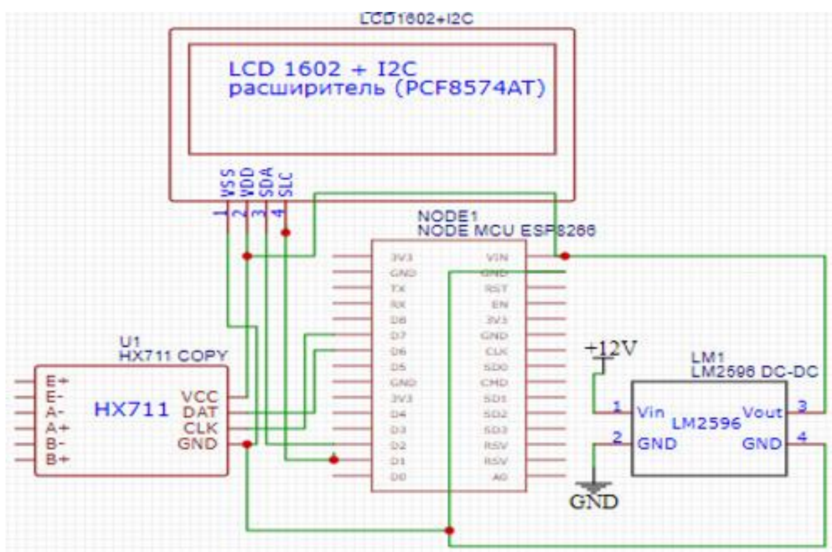

Figure 3: *System Circuit Connection Diagram*

After power is supplied, the system will proceed to measure hand force using the Load Cell sensor (the Load Cell force sensor is connected to the HX711 ADC Module). The HX711 ADC Module analyze and read the value of the Load Cell sensor with a 24-bit resolution and transmit it via 2-wire communication (Clock and Data) to the Arduino microcontroller.

The VCC pin of the HX711 ADC Module is connected to the Vin pin of the ESP8266; the SCK pin of the HX711 ADC Module is connected to the D7 pin of the ESP8266; the DT pin of the HX711 ADC Module is connected to the D6 pin of the ESP8266; the GND pin of the HX711 ADC Module is connected to the GND pin of the ESP8266.

Transmitting data to the Blynk App: The data from the hand force will be processed by the ESP8266 and transmitted via the wireless Wi-Fi network to the Blynk Server, where it will be displayed on the smartphone app.

3.3. Flowchart Diagram of System Algorithm

The algorithm flowchart of the system as shown in Figure 4, can be described as follows [8-15]:

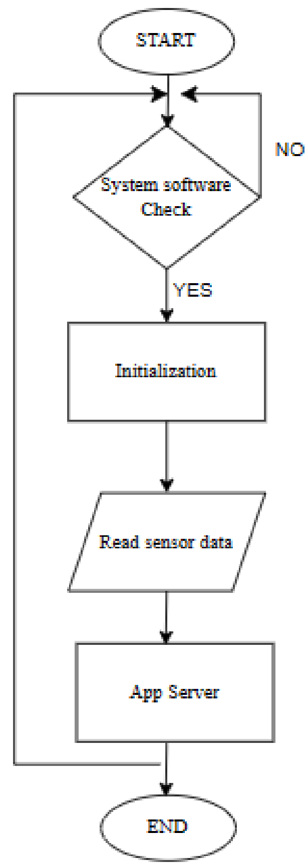

Figure 4: *Flowchart Diagram of System Algorithm*

Explanation of Control Algorithm: When the program starts, it needs to check the system's software. If the system's software does not meet the requirements, the system will recheck until it meets the conditions. Then, it will initialize the libraries and verify the connections between peripherals. Once the initialization is complete, the microcontroller will read data from the sensors, process it, and send it to the App Server. Here, the data parameters and the progress of the operation will be displayed on the App and connected to the user.

4. Design of the product

Based on the process of analysis, design, and component selection as described in the above section, the author's team proceeded to construct the initial product model (prototype as shown in Figure 5). The product utilizes simple, readily available materials that are easy to source and assemble, such as wooden boards, plastic handles, elastic cords for creating tension, and an angle measuring board for the arm's rotation. Note: In Figure 5, the numbered positions serve the following functions:

- Position (1): Angle measurement board.
- Position (2): Table for placing the arm.
- Position (3): Handle for pulling the assistive cord.
- Position (4): LED screen for displaying information.

Figure 5: *Rehabilitation Hand Injury Training Device*

To exercise, the patient places their arm (at position number 2) and uses their hand to grip the handle (position number 3), then lifts or pulls the assistive cord up and down. Depending on the exercise intensity, the height can be measured at the angle indicator on the board (position number 1). Exercise parameters will be displayed on the LED screen (position number 4) for the patient to monitor.

In this study, the Blynk platform is used to develop the smartphone application (App) software, with a user interface as shown in Figure 6

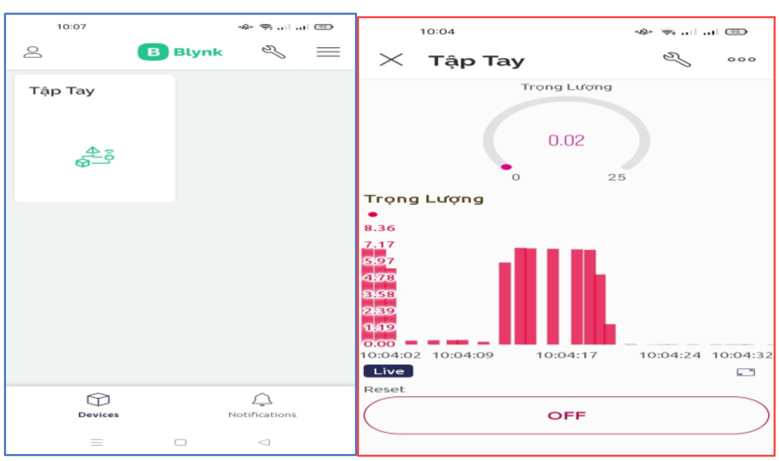

Figure 6: *App interface and performance data for hand exercises*

5. Results and discussion

The completed hardware product was tested with parameters as shown in Table 1.

Table 1: *The results when performing product tests*

Test times	Delay	Device/Product	Results
1	1 (s)	Activity meets the requirements	The difference information between the LED and the App is 0.5 kg
2	1 (s)	Activity meets the requirements	The difference information between the LED and the App is 0.3 kg
3	2-3 (s)	Activity meets the requirements after 5-6 seconds.	The information regarding the difference between the LED and the App is the same
4	2-3 (s)	Activity meets the requirements after 5 second.	The difference information between the LED and the App is 0.1 kg

The designed product includes a resistance cable system to support the patient's arm function recovery training process. During the training, the patient pulls the resistance cable, and the resistance cable system applies force to the product's sensor block. The sensor block can measure parameters when force is applied, and it can calculate the arm force during the patient's training. The parameters regarding the arm force obtained from the sensor block are then sent to the App using IoT technology. Additionally, the sensor system is used to measure arm force and angles to determine the motion angle during the patient's training. The product is designed to be suitable for the physique of Vietnamese people. The training results of the patient are stored and can be monitored through the smartphone App. This is convenient for tracking and comparing the patient's training results with standard data. Furthermore, family members of the patient or doctors can remotely monitor the patient's recovery training process. The hardware product is completed and functions as expected. Through several tests, when connecting the product to the App on a smartphone, the measurement results show insignificant differences between the App and the information displayed on the LED.

6. Conclusion

The device has operated in accordance with the specified requirements. The test results for various parameters and indices indicate alignment with the prior design and programming intent. The product operates reliably and is user-friendly. The product model can be assembled and put into practical use for patients to exercise at home.

REFERENCES

[1] Y. Bouteraa and F. Gebali, "Design and Development of a Smart IoT-Based Robotic," *Micromachines (Basel)*, 13(6): 973, pp. 1-20, 2022. DOI: 10.3390/mi13060973

[2] Q. Meng, H. Zhang, and H. Yu, "The Internet of Things based rehabilitation equipment monitoring system," *IOP Conf. Ser., Mater. Sci. Eng.*, vol. 435, pp. 1-6, Nov. 2018. DOI: 10.1088/1757-899X/435/1/012015

[3] R. Saini, P. Kumar, B. Kaur, P. P. Roy, D. P. Dogra, and K. C. Santosh, "Kinect sensor-based interaction monitoring system using the BLSTMneural network in healthcare," *Int. J. Mach. Learn. Cybern.*, vol. 10, no. 9, pp. 2529–2540, Sep. 2019. DOI: 10.1007/s13042-018-0887-5

[4] L. H. Hiep, "Design a robotics forearm product for bioinformatic laboratories", *TNU Journal of Science and Technology*, vol. 226, no. 11, pp. 226-233, 2021. DOI: 10.34238/tnu-jst.4659

[5] L. Xing and J. Zhong, "Upper Limb Rehabilitation Robot System Based on Internet of Things Remote Control," *IEEE Access*, vol. B, pp. 154461- 154470, 2020. DOI: 10.1109/ACCESS.2020.3014378

[6] H. Al-Fahaam, S. Davis, and S. Nefti-Meziani, "Wrist Rehabilitation exoskeleton robot based on pneumatic soft actuators," *International Conference for Students on Applied Engineering (ICSAE)*. pp. 491-496, 2016. DOI: 10.1109/ICSAE.2016.7810241

[7] D. Dauria, F. Persia, and B. Siciliano, "Human-Computer Interaction in Healthcare: How to Support Patients during their Wrist Rehabilitation," *IEEE Tenth International Conference on Semantic Computing (ICSC)*. Pp. 325-328, 2016. DOI: 10.1109/ICSC.2016.21

[8] M. A. H. M. Adib and N. Daud, "Development of the Wrist Rehabilitation Therapy (WRist-T) Device based on Automatic Control for Traumatic Brain Injury Patient," *International Medical Device and Technology Conference 2017*, pp. 152-155, 2017.

[9] A. Hacıoğlu, O. F. Özdemir, A. K. Şahin, and Y. S. Akgül, "Augmented reality-based wrist rehabilitation system," *Signal Processing and Communication Application Conference (SIU)*, pp. 1869-1872, 2016. DOI: 10.1109/SIU.2016.7496128

[10] W. M. Hsieh, Y. S. Hwang, and Y. L. Chen, "Application of the Blobo Bluetooth ball in wrist rehabilitation training," *Journal of Physical Therapy Science*, vol 28, pp. 27-32, 2016. DOI: 10.1589/jpts.28.27

[11] Z. J. Lu and L. C. B. Wang, "Development of a robot MKW-II for hand and Wrist Rehabilitation Training," *The Annual IEEE International Conference on Cyber Technology in Automation, Control and Intelligent Systems*, pp. 302-307, 2016.

[12] M. Takaiwa, "Wrist rehabilitation training simulator for P.T. using pneumatic parallel manipulator," *IEEE International Conference on Advanced Intelligent Mechatronics (AIM)*, pp. 276-281, 2016. DOI: 10.1109/AIM.2016.7576779

[13] S. Esmaeili and A. Al-AbdulRazag, "Design and Assembly of an Automated Juice," *International Journal of Computing and Digital Systems*, sys. 10, no.1, pp. 227-296, 2021. DOI: 10.12785/ijcds/100129

[14] T. Proietti, V. Crocher, A. Roby-Brami, and N. Jarrassé, "Upper-limb robotic exoskeletons for neurorehabilitation: a review on control strategies," *IEEE reviews in biomedical engineering*, Vol. 9, pp. 4-14, 2016. DOI: 10.1109/RBME.2016.2552201

[15] S. Vukićević, Z. Stamenković, S. Murugesan, Z. Bogdanović, and B. Radenković, "A new telerehabilitation system based on Internet of Things," *Facta Universitatis*, vol. 29, no. 3, pp. 395-405, 2016. DOI: 10.2298/FUEE1603395V

[16] Y. P. Zhang and X. P. Xu, "Design of a wear able human computer interaction system based on bioelectrical signal recognition technology," *J. Inter-discipl. Math.*, vol. 21, no. 5, pp. 1049–1054, Jul. 2018. DOI: 10.1080/09720502.2018.1493027

[17]. L. H. Hiep, "Study to design of automatic bean sprout growing machine ICTU_ASM_2019", *TNU Journal of Science and Technology*, vol. 204, no. 11, pp. 39-45, 2019.

[18]. L. H. Hiep and N. T. B. Nga, "Study to improve automatic control system in Tea black production ferment processing by applying of digital image processing technology", *TNU Journal of Science and Technology*, vol. 225, no. 06, pp. 338-395, 2020.

[19]. L. H. Hiep and H. M. Viet, "Study to build a control and monitoring system of poultry incubator based on Internet of Things", *TNU Journal of Science and Technology*, vol. 227, no. 08, pp. 20 - 28, 2022.

[20]. L. H. Hiep, "Study to design of intelligent lighting control and monitoring systems", *TNU Journal of Science and Technology*, vol. 189, no. 13, pp. 99-105, 2018.

[21] Pham Van Phi, Dao Thi Hang, Mai Thi Them, Le Hoang Hiep, "Study to build a warning and monitoring system for smart home through mobile devices," *Vinh University Journal of Science (VUJS)*, 52(2A), pp. 34-45, 2023. DOI: 10.56824/vujs.2023a045

[22] Nguyen Thi Duyen, Vu Tien Lap, Pham Thi Thoa, Nghiem Thi Hung, Ho Mau Viet, Le Hoang Hiep, "Study to build a goods arranging and classification system based on internet of things," *Vinh University Journal of Science (VUJS)*, 52(3A), pp. 72-83, 2023. DOI: 10.56824/vujs.2023a060

TÓM TẮT

NGHIÊN CỨU XÂY DỰNG THIẾT BỊ HỖ TRỢ QUÁ TRÌNH LUYỆN TẬP PHỤC HỒI CHẤN THƯƠNG CỔ TAY

Điền Thị Hồng Hà
Trường Đại học Kinh tế - Kỹ thuật công nghiệp, Hà Nội, Việt Nam
Ngày nhận bài 15/9/2023, ngày nhận đăng 15/10/2023

Bài báo tập trung nghiên cứu, xây dựng một thiết bị có chức năng theo dõi quá trình luyện tập phục hồi chấn thương ở tay. Sản phẩm được thiết kế bao gồm hệ thống dây kháng lực để phục vụ cho quá trình luyện tập phục hồi chức năng tay của bệnh nhân. Trong quá trình luyện tập, bệnh nhân thực hiện việc kéo dây kháng lực để luyện tập, lúc này hệ thống dây kháng lực sẽ tác dụng lên khối cảm biến của sản phẩm. Khối cảm biến có khả năng đo thông số khi có lực tác dụng lên qua đó có thể tính toán được lực tay trong quá trình luyện tập của bệnh nhân. Các thông số về lực tay sau khi thu được từ khối cảm biến sau đó sẽ được gửi lên ứng dụng phần mềm được thiết kế riêng biệt cho sản phẩm thông qua việc ứng dụng công nghệ mạng kết nối vạn vật. Ngoài ra sản phẩm còn được thiết kế với chức năng đo góc để định vị tọa độ chuyển động trong quá trình luyện tập tay của bệnh nhân. Sản phẩm được thiết kế phù hợp với thể trạng của người Việt Nam. Kết quả luyện tập của bệnh nhân được lưu trữ lại trên Internet, đồng thời hiển thị lên ứng dụng điện thoại sẽ thuận tiện cho việc theo dõi kết quả luyện tập, so sánh kết quả luyện tập của bệnh nhân với dữ liệu chuẩn, đồng thời cũng cho phép người nhà bệnh nhân hoặc các bác sĩ có thể theo dõi, giám sát quá trình luyện tập phục hồi của bệnh nhân từ xa.

Từ khóa: Thiết bị hỗ trợ bệnh nhân; luyện tập; phục hồi chấn thương; phục hồi bằng robot; mạng kết nối vạn vật