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THE DEVELOPMENT OF WRIST JOINT REHABILITATION WITH SERVO MOTOR DRIVE FOR STROKE HANDED

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Abstract

A stroke begins when the blood flow to the brain is stopped or diminished because of a blockage (ischemic stroke) or a blood vessel rupture (hemorrhagic stroke) that prevents him or her from performing activities that other healthy people can do. Stroke victims typically experience paralysis with one of their arms, lose dexterity and interaction with their affected hand. However, most wrist rehabilitation devices are still manually operated and required a therapist to assist them. Furthermore, the increasing number of stroke patients among the elderly are challenging to find low-cost rehabilitation tools. In order to overcome this problem, a wrist joint rehabilitation device with servo motor drive is developed. This device consists of three MG996R servo motors using predefined Arduino IDE programming so that the device start rotating automatically and the patient can perform their rehabilitation sessions individually. The designing process of this device is done by using an online 3D modeling program, Tinkercad. The MG996R servo motor was physically modeled, and the parameters were identified during the implementation of the device. Testing of the hardware and software was undertaken to analyze the usability of the wrist joint rehabilitation for the stroke patients undergo the rehabilitation exercise according to the basic movement of wrist by comparing the normal ROM of the wrist and achieved ROM of the device can be delivered. As a result, the prototype design has proven to be effective because it can achieve a ROM that close to the normal wrist. It can be concluded that an automatic wrist rehabilitation device can be used to assist post-stroke patients in their rehabilitation sessions by performing regular wrist exercises.

Keywords: Stroke, wrist, rehabilitation device, MG996R servo motor.

1. **Introduction**

A stroke can occur when the blood flow to the brain is stopped or diminished due to a blockage that called ischemic stroke or a blood vessel rupture, haemorrhagic stroke. Without blood, the brain would be deprived of oxygen, causing cells in various parts of the brain to die. Citing to the Malaysian National Burden of Diseases Study and study on vital registration system in 2000, stroke was the second highest cause of death in Malaysia (National Institute of Health, 2017). Most stroke survivors will experience problems with one of their arms, lose upper-limb motor function, or maybe have limb paralysis (Activities, n.d.). It is well known that effective post-traumatic care and rehabilitation therapy are required for patients to regain their lost abilities and return to their usual daily activities (Bonita & Beaglehole, 1988). After a patient has recovered from a stroke, rehabilitation is usually done through physiotherapy (Ferrarello et al., 2011). Wrist is one of the most critical regions of the body that is damaged by stroke.

This project designs and develop a wrist rehabilitation device powered by a servo motor so that patients can perform the therapy individually. Flexion and extension, radial and ulnar deviation, and pronation and supination in Figure 1 are the three types of movements performed by this device. The rehabilitation session can be performed at the patient's house, which is especially beneficial for those who have transportation issues or live far from the hospital. Wrist training, wrist stretching, and other activities are designed to improve or rehabilitate the patient's wrist range of motion. An article state that although these natural wrist exercises are useful for developing hand strength and preventing future injuries, normal rehabilitation exercises are boring and prolonging full recovery (Hsieh et al., 2016).

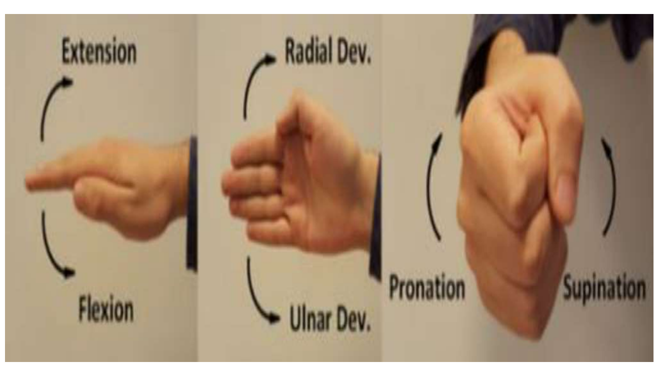

Figure 1: The movements of the wrist

The effects of a stroke can vary depending on which of these areas of the brain it happens in. When a section of the brain is destroyed by a stroke, it is possible that a section of the body will lose its usual function. If the stroke occurs in the left side of the brain, the right side of the body will be affected and paralysis. Meanwhile, if the stroke occurs in the

right side of the brain, the left side of the body will be affected and paralysis (Foucher & Faure, 2020). The overall goal of post-stroke rehabilitation is to help stroke survivors regain as much physical, psychological, social, and financial independence as possible (Senes, 2006).

According to the Encyclopaedia Britannica 2009, the wrist is made up of a group of tiny bones, muscles, and component joints that connect the five metacarpal bones of the hand to the ulna and radius bones of the forearm, allowing it incredible flexibility and range of motion (Encyclopaedia Britannica 2009). The eight tiny carpal bones of the wrist that connect the metacarpals to the forearm are seen in Figure 2. The eight carpal bones are roughly divided into two rows, referred to as the proximal and distal rows.

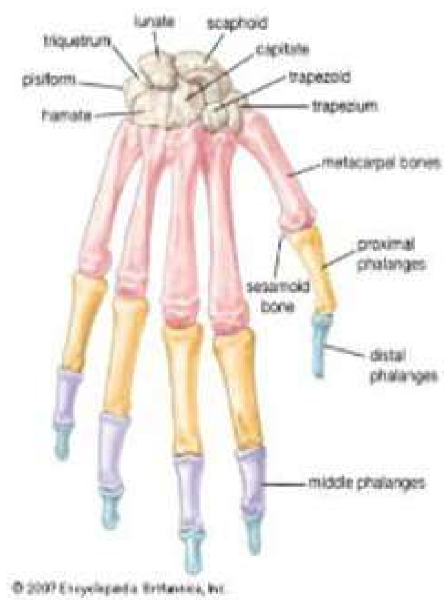

Figure 2: Bones of the Hand, Including The Carpal Bones

2. Methodology

This chapter is descripted and explained about the process and the method to implementing this project with successful. Designing and developing the mechanical part of the wrist joint rehabilitation with servo motor, drawing block diagram of the operating system, making flow chart of the operation device, and making servo motor speed settings are all the stages of this research. The data collection has been done to analyze the usability of the wrist joint rehabilitation. These method are used to achieve the objective of the project that accomplish a perfect result.

2. Designing the mechanical part of the Wrist Joint Rehabilitation with Servo Motor Drive

The wrist joint rehabilitation in Figure 3, has three movements where each joint has one servo motor. The components of the device in this project are, one (1) ESP 32 Wi-Fi module, one (1) LM2596 power supply step down, one (1) power supply 5A, one (1) buzzer and three (3) MG996R servo motors. The frame of the device is made from the PVC pipe since this material are easy to design into any shape.

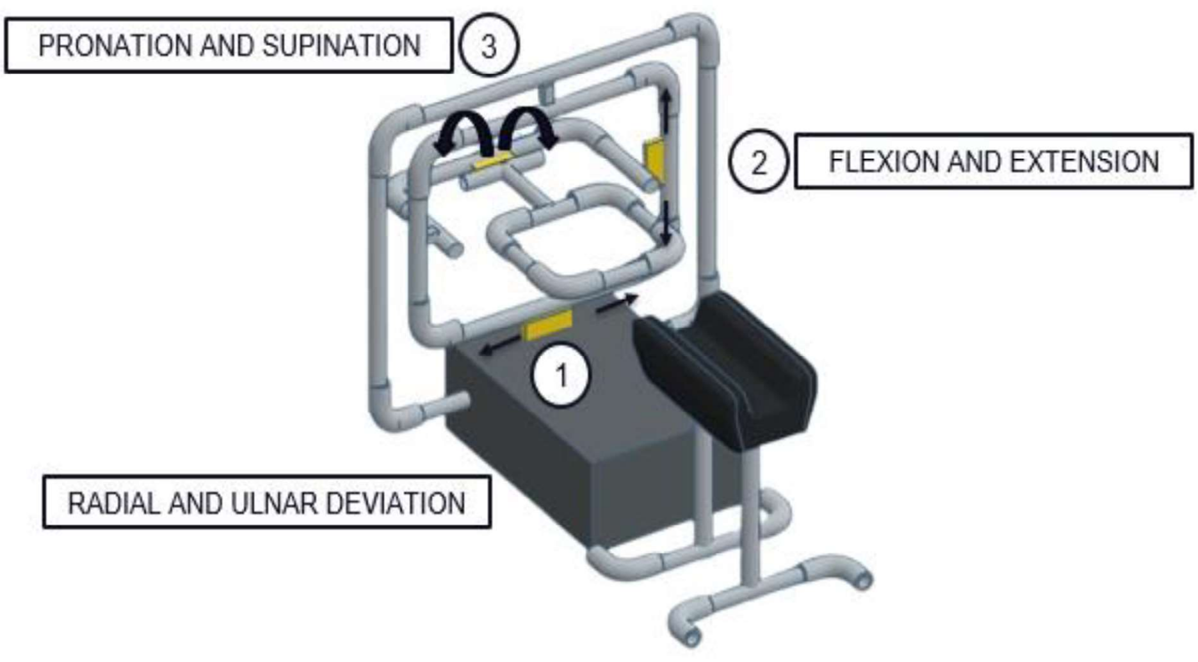

Figure 3: Mechanical Design of The Wrist Joint Rehabilitation using Tinkercad

2. **Developing the hardware and IoT implementation of the Wrist Joint Rehabilitation with Servo Motor Drive**

Figure 4 illustrates the system of circuit installation of the Wrist Joint Rehabilitation with Servo Motor Drive. ESP32 Wi-Fi module work as device controller which is programs can be loaded onto it from the Arduino IDE programming. The USB cable connection is used to upload the verified coding from the Arduino IDE to the circuit of device.

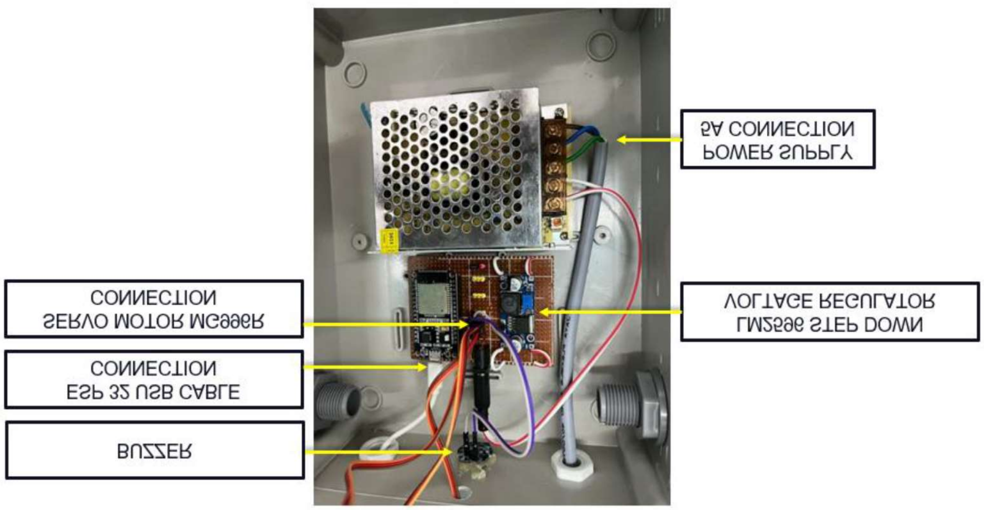

Figure 4: Circuit Installation of The Wrist Joint Rehabilitation

Figure 5 had showed the development of electronic and mechanical part the wrist joint rehabilitation. The hand of the patient is passed through two untied belts before being locked to the arm rest. Tighten the belt at the arm then turn on the device. Through the Blynk application, patients can select the basic wrist movement mode and the desired number of rotations. Since the ESP32 is turned on, the servo motor will begin rotating automatically. This device performs the wrist motions for patients undergoing rehabilitation exercises.

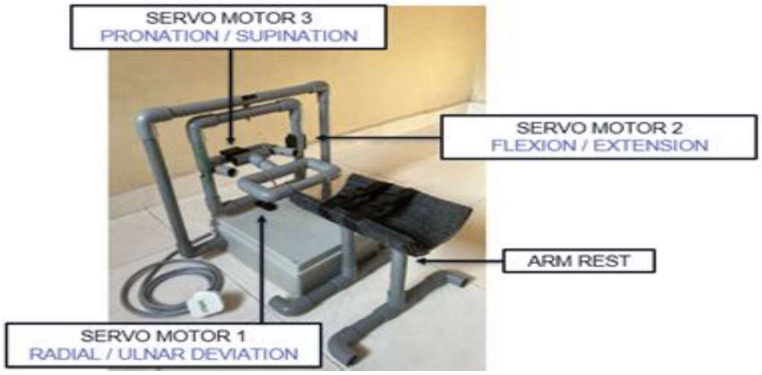

Figure 5: Development of electronic and mechanical part of The Wrist Joint Rehabilitation

Referring to Figure 6, the interface of IoT implementation using Blynk application for controlling the movement of servo motor. The Blynk application is easy to download for the IOS and android system user's that can make them easy to control the movement of basic exercises of wrist without forgetting a step, even if the therapist is not around and display the angle of device can deliver. Based on Table 1, shows the function of each button of Blynk application during using the device.

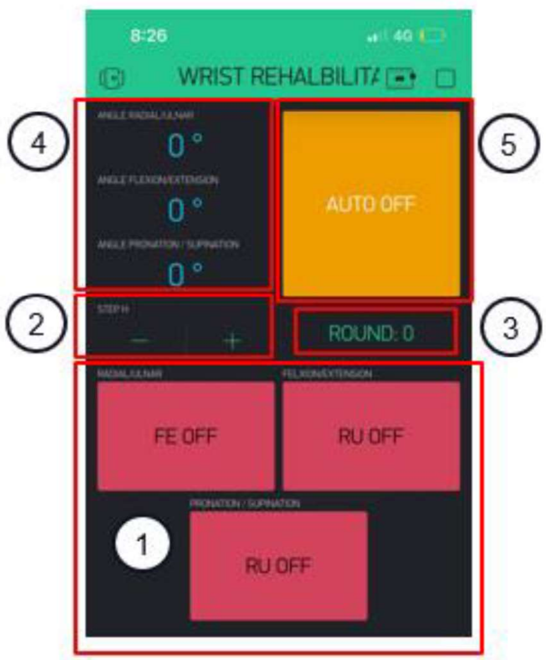

Figure 6: Interface of IoT implementation using Blynk application for controlling the movement of servo motor

Table 1: Function of the button of Blynk application

NO	Button
1	Controlling servo motor for the wrist movement one by one
2	Adjusting the number of rotation of the wrist movement that the patient required
3	Display the number of rotation of the movement
4	Display the angle of each movement
5	Stop and start button rotation of the wrist movement

2. **Block Diagram of the Operating System**

Each block has a specific purpose, and the block diagram in Figure 7 presents how each process is connected. This operating system's block diagram has three sections: input, processer, and output. The input section when the device is connected by the power supply and the patient's forearm is placed through an adhesive belt. During processing section, turning on the plug and make sure Wi-Fi connection is on and in stable condition. After that, the ESP32 is ready to start in real-time through a mobile application. Lastly, in output section is where the servo motor begins to rotate automatically, which can be controlled using the training programme at the mobile phone through Blynk Application.

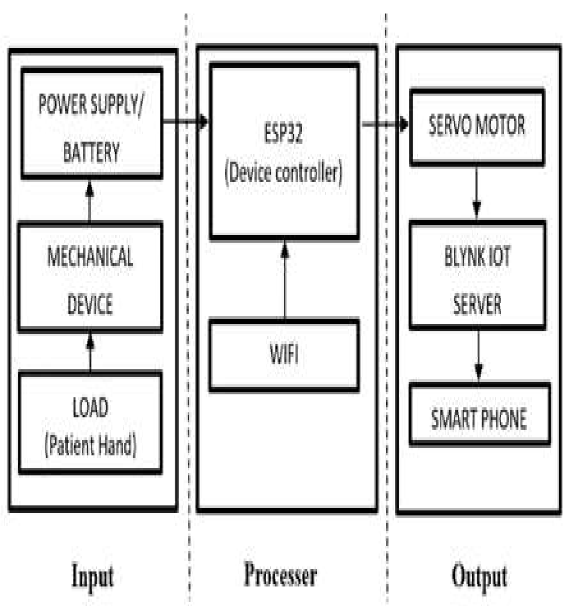

Figure 7: Block Diagram of The Wrist Joint Rehabilitation

2. **Making Flow Chart of the Operation Device**

Flow Chart in Figure 8 had shown the operation of the wrist joint rehabilitation. The patient's hand is placed through two loose belts then tighten the belt. Switch on the device and at the same time connect the device to the Blynk Application using smartphone. Patients can choose the mode of the wrist movement and select how many turns they want to do. The servo motor will start rotating automatically since the ESP32 is turned on. The wrist motions such as flexion and extension, radial and ulnar deviation, and pronation and supination are recognized by this device for the post stroke survivors undergo the rehabilitation exercise. The session will be finished according to the programmed that have been done. The degree of the angle of wrist movement will be display in Blynk Application.

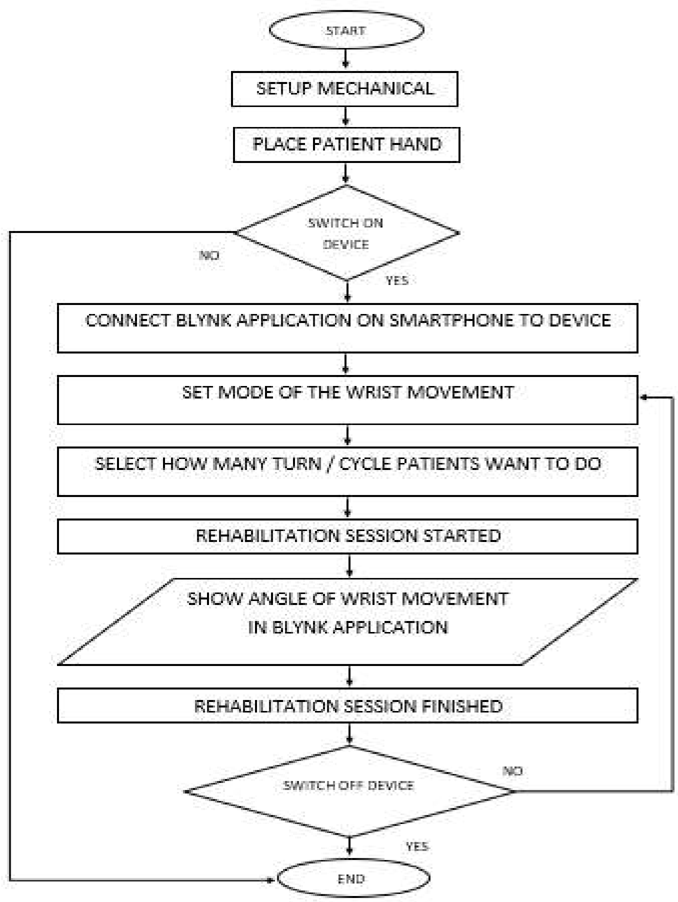

Figure 8: Flow Chart of The Wrist Joint Rehabilitation

2. **Making Servo Motor Speed Settings**

(1)

To manage the servo motor's speed, first determine how far the turning angle will be turned. The turning angle is calculated using the formula below.

Δ

$\Delta T = T_1 - T_0 \Delta T = T1 - T0$

(3)

where,

[Equation]: angle difference

[Equation] : angle at the end of movement / final angle

[Equation] : angle at the beginning

(2)

[Equation] then

[Equation]

[Equation] then

[Equation]

where,

[Equation]: angle difference (pulse)

[Equation]: duration each pulse (mS/pulse)

[Equation]: total time to reach the final angle (1000 mS)

2. **Data Collection Method**

After the final hardware prototype is completed, the results are collected from testing the performance of the device. Testing of the hardware and software was undertaken to analyze the usability of the wrist joint rehabilitation for the stroke patients undergo the rehabilitation exercise according to the basic movement of wrist. As shown in Figure 9, the device has been tested by a subject. The evaluated data are important in determining the usability of the wrist joint rehabilitation for the stroke patients undergo the rehabilitation and gathering feedback from professionals and the public.

Figure 9: Testing of the hardware and software of the device

3. Result and Discussion

This device must be able to accommodate the range of motion wrist movement. By comparing the achieved ROM of the device and normal ROM for the wrist, it can figure out the usability of the wrist joint rehabilitation for the stroke patients undergo the rehabilitation exercise according to the basic movement of wrist. Figure 10 shows how to measure the ROM of the device using goniometer.

Figure 10: Measure the ROM of the device using goniometer

Table 2: Comparison ROM of device between normal ROM of the wrist

Movement	Range of Motion		
	Normal	Achieved	Comparison
Radial deviation	[Equation]	[Equation]	[Equation]
Ulnar deviation	[Equation]	[Equation]	[Equation]
Flexion	[Equation]	[Equation]	[Equation]
Extension	[Equation]	[Equation]	[Equation]
Pronation	[Equation]	[Equation]	[Equation]
Supination	[Equation]	[Equation]	[Equation]

As shown Table 2, the range of motion of the device comfortably exceeds the normal ROM required to perform activities of daily living and accommodates the entire normal range of wrist and forearm motion except for flexion/extension, which is slightly 6° comparison between normal and achieved ROM. Nevertheless, for the device to accommodate all the ranges of motion at any rotational position of the forearm, required to adjust the programming for additional degree of flexion/extension movement. These modifications represent the movement of servo motor. Due to its ability to generate a ROM that closely matches the normal wrist, the prototype design has proven to be successful. Referring to Figure 11 shows the comparison of device's ROM and normal ROM of the wrist.

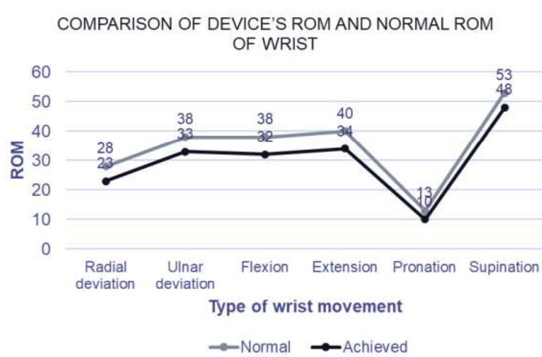

Figure 11: Comparison of device's ROM and normal ROM of wrist

4. **Conclusion**

The wrist joint rehabilitation device was designed and developed to be 38cm length, 25cm width, and 38cm height according to the specifications. To drive the servo motor for the wrist movements flexion and extension, radial and ulnar deviation, and pronation and supination, the Arduino IDE program (UNO Program) can be adjusted according patients' needs. IoT is successfully implemented to the device using Blynk application so that the patient can undergoing wrist therapy without forgetting a step, even if the therapist is not around. Next, this project helps the stroke survivors to get physiotherapy sessions at home without supervision from the physiotherapist. The proposed system for biomechanics movements, uses real-time measurements of wrist joint angles enable users to get physiotherapy sessions at home without supervision from the physiotherapist.

5. Acknowledgment

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