Automatic Control of Wrist Rehabilitation Therapy (Wrist-T) device for Post-Ischemic Stroke Patient

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***Abstract*—Since a decade, the wrist rehabilitation services in Malaysia has been operated by the physiotherapist (PT). Throughout the rehabilitative procedure, PT commonly used a conventional method which later triggered some problems related to the effectiveness of the rehab services. Time-consuming, long-waiting time, lack of human power and all those leading to exhaustion, both for the patient and the provider. Patients could not commit to the therapy session due to logistic and domestic problems. This problem can be greatly solved with rehabilitation robot, but the current product in the market is expensive and not affordable especially for low-income earners family. In this paper, an automatic control of wrist rehabilitation therapy; called WRist-T device has been developed. There are based on three different modes of exercises that can be carried out by the device which is the flexion/extension, radial/ulnar deviation and pronation/supination. By using this device, the patient can easily receive physiotherapy session with minor supervision from the physiotherapist at the hospital or rehabilitation centre and also can be conducted at patient home.**

***Index Terms*—Rehabilitation; Wrist; Automatic Control; Ischemic Stroke Patient; Physiotherapist.**

I. INTRODUCTION

An ischemic stroke is a blood vessel becomes blocked, usually by a blood clot and a portion of the brain becomes destitute of oxygen and will stop functioning. Ischemic strokes account for 80% of overall strokes patients. The fatality rate is high, but it is not the current issue for this product development. Therefore, this current study will emphasise on the method to rapidly increased the survivability of the post-stroke patient during the rehabilitation. The stroke is one of the major factors leading to the decreased motor function of the human upper limbs. Such patients are expressively restricted in their daily social and household activities. It is known that appropriate post-traumatic care and rehabilitation therapy is required for convalescing patient's lost abilities and their return to normal daily activities [1-3].

Nowadays, automated therapy using the robotic rehabilitation platform is a promising part of post-stroke rehabilitation process [4]. There are many variations of robot-assisted devices, some are using soft actuator [5-7] and some developed software, so it can further assist and improve the rehabilitation process [7-9]. One of the significant parts that affected by stroke is the wrist. Nevertheless, the natural wrist exercises are helpful for improving hand strength and preventing future injuries, conventional rehabilitation exercise is quite boring, so patients find it tough to regularly perform the exercise, thus delaying full recovery [7].

The common exercises include the wrist, strengthening, wrist stretches, etc. The exercises primarily convalesce or enhance the patient's range of motion of the wrist, including wrist flexion/extension, wrist radial/ulnar deviation and pronation/supination movements. Though these natural wrist exercises are helpful for improving hand strength and preventing future injuries, conventional rehabilitation exercise is quite boring, so patients find it tough to perform the exercise, thus delaying full recovery regularly. By [10], the conventional therapy demands specific medical instruments and occupational therapist, which is not convenient and a huge economic burden for patients. Meanwhile, the assisted robots described above focus on strength training and sensitivity training but neglect the importance of neurological rehabilitation.

In this paper, a new wrist rehabilitation therapy; namely WRist-T device based on automatic control has been proposed. The functionality of the device is also to be observed. There are three different modes of exercises that can be carried out by the device which is the flexion/extension, radial/ulnar deviation and pronation/supination.

II. SPECIFICATION OF THE DEVICE

The initial prototype of the WRist-T device applied an automatic control system. Figure 1 shows the design and an embodiment of the invention of WRist-T device. It consisted of a channel (1) for supporting the wrist; a pair of platform arms, (2) pivotally connected to two sides of the channel; a Nema 23 Steppers motor, (3) operatively connected to each of the platform arms; and a hand support, and (4) detachably attached to the pair of platform arms. The hand support is being constructed to allow multiple hand positions (see Figure 2) that cooperate with the rotation of the platform arms for multiple-degree-of-movement of the wrist.

The Arduino Uno microcontroller (5) based on the ATmega328 provided with a power button (7) and LCD (8). When the power button is on, the LCD starts showing the parameters for setup.

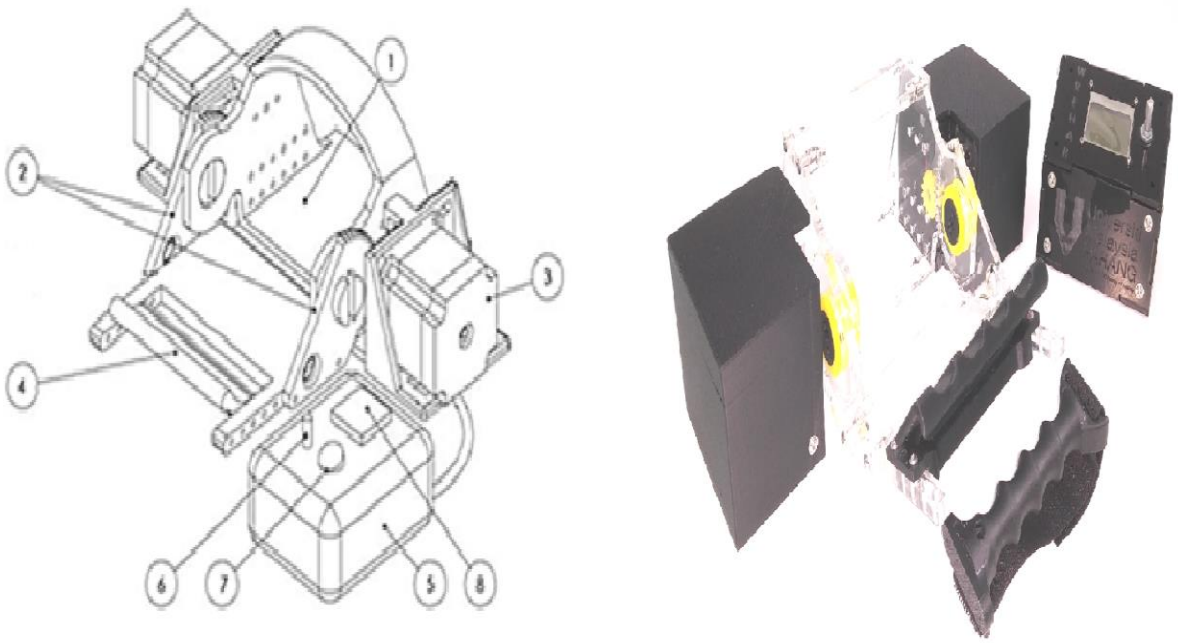

Figure 1: *Right*-Illustrated an embodiment of the WRist-T device. *Left*-The prototype of the wrist rehabilitation therapy (WRist-T) device. Notes: Description of the reference numerals used in the accompanying drawings according to the WRist-T device; (1) channel; (2) platform arm; (3) motor; (4) hand support; (5) controller; (6) toggle switch; (7) power button; (8) LCD display.

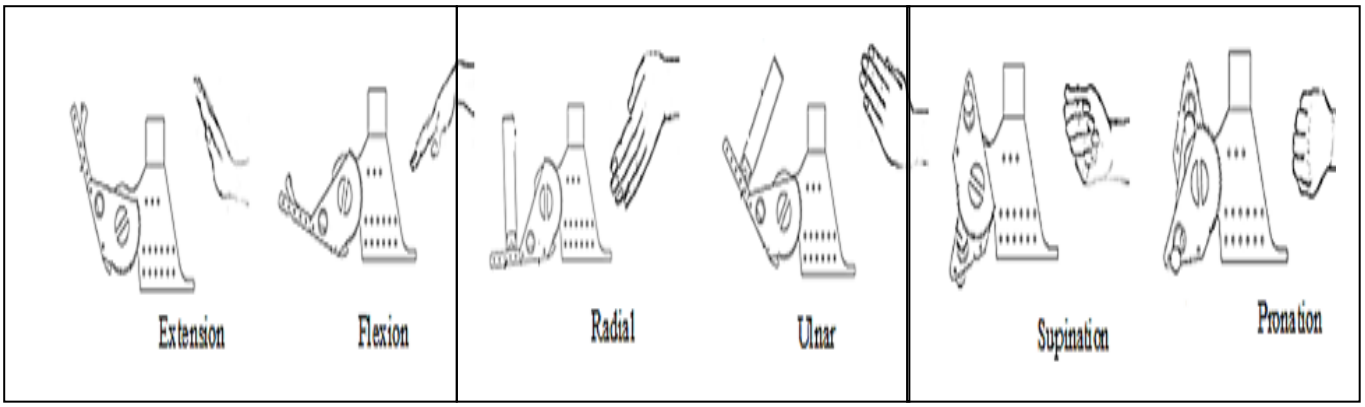

Figure 2: A perspective views of the device in an embodiment to give (a) Motion forextension/flexion; (b) Radial/ulna deviation; and (c). Supination/pronation of the wrist.

Moreover, since it is programmed through the open source Arduino Software, this Inertial Measurement Unit (IMU) of 3 DoFs outputs its roll, pitch, and yaw data, characterising the orientation of the wrist, via serial. We used Arduino IDE to program our code onto the 3 DoF, connecting to the serial TX and RX pins. Figure 3 shows the flowchart of the WRist-T device function.

There are two methods to control the setup. The first one is the toggle switch (6), which sets the parameters manually on the central processing unit (CPU). The mode of exercise is selected based on the 30 mechanical assemblies. The next step is the parameter setup. The parameter setup includes session time, speed and time delay, which need to be keyed in before starting the rehabilitation session/exercise. The toggle switch needed to be rotated anticlockwise or counter clockwise to obtain the desired value and pushed to accept the selected value.

The same process needs to be done for other parameter setups. The last push will start the rehabilitation session. After that, the motor will start running continuously and stop automatically when the time for that session ends. The set up can be reset again by a re-pushing toggle switch. The main problem that essentials to be properly addressed is the high impedance of electric motors that can be potentially harmful to patients. This can be simply overcome by executing in advanced of algorithms control.

The second method of setting up the parameters is by using a computer, tablet or a smartphone. The application is developed with a user-friendly interface. After all the setup is done, the application is connected to the wireless device inside the central processing unit (CPU) via Bluetooth or wireless module inside the central processing unit. Once the wireless connection is established, a button inside the application is pressed, and the rehabilitation session will take part. Once the session is finished, the CPU will send a confirmation button and the details in the setup such as parameters, session details, and patient particulars then will be stored on the computer or the smartphone.

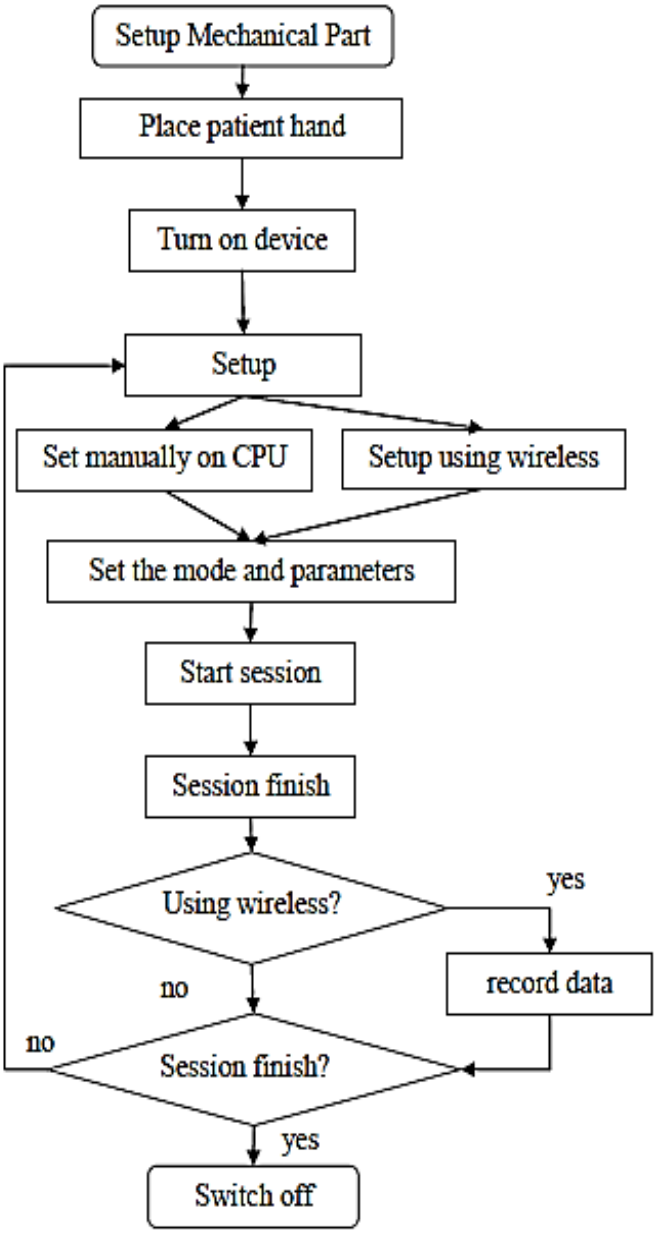

Figure 3: The flowchart of the WRist-T device function.

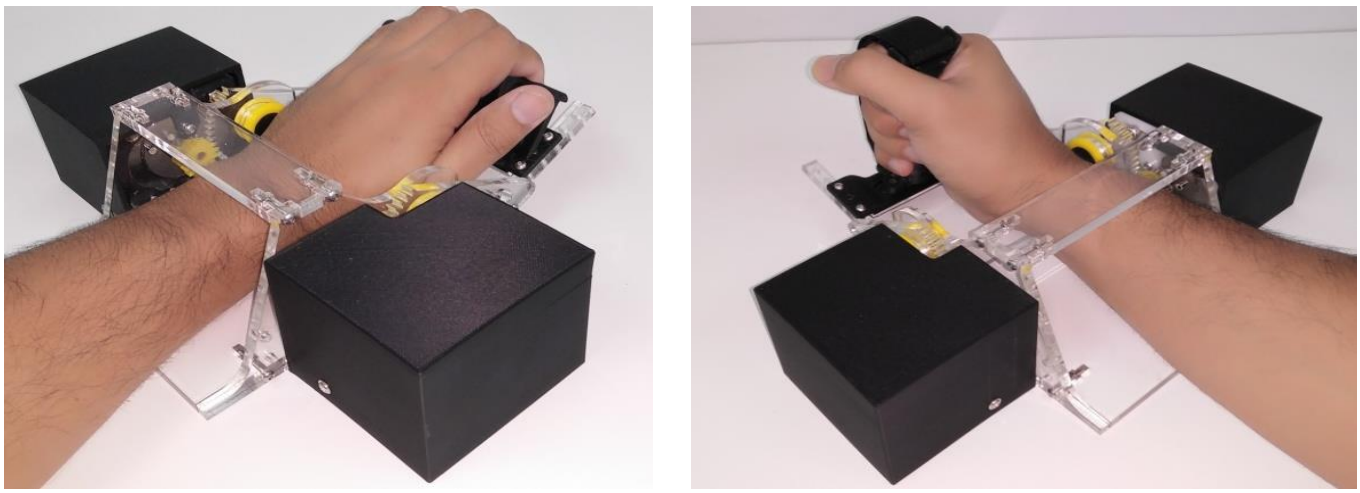

Figure 4: A 3D printed prototype of WRist-T device tested to an ischemic stroke patient. The figure shows details the example wrist of motion on extension/flexion and radial/ulnar deviation exercise.

III. FUNCTIONALITY VALIDATION

To validate the functionality of the proposed device the first prototype has been manufactured using 3D printing technology (Zortax M200) as presented in Figure4. Preliminary investigation has been completed focusing on evaluating of kinematic and dynamic parameters required for proper functional use of the designed WRist-T device. The device well reproduced the subject motion, thus demonstrating repetitive passive therapy action. Figure 5 shows out of 8 patients presented comfortable feeling when used the WRist-T device and Figure 6 shows only four patients compliant bad in handling the WRist-T device.

The same preliminary tests conducted with a post-ischemic stroke patient confirm that the compliant handle link mechanism of the WRist-T device shows well inbending to either of the three configurations of the motion during active exercises. The subjects did not feel any discomfort or applied interaction forces imposed by the device and could freely work with the device.

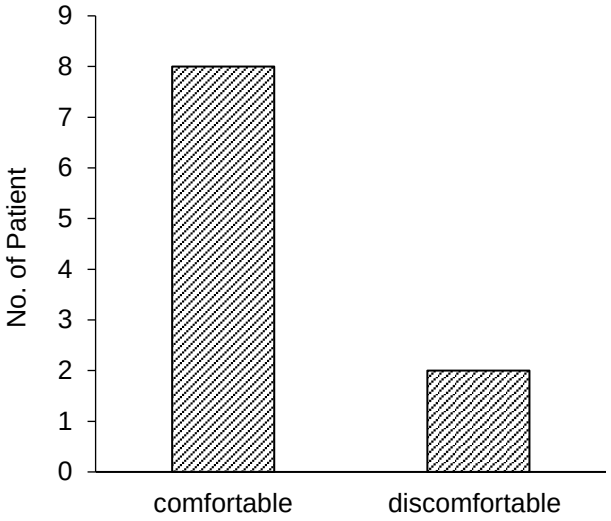

Figure 5: The comfortable and discomfort able feel of the patient when used WRist-T device.

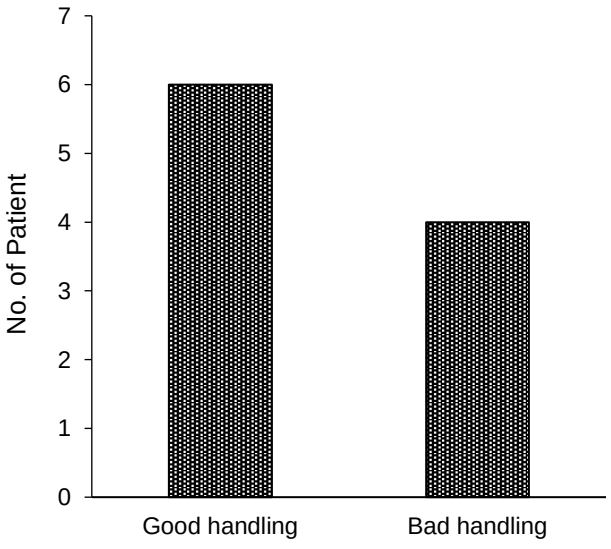

Figure 6: Represented the compliant handle link mechanism of the WRist-T device for post-ischemic stroke patients.

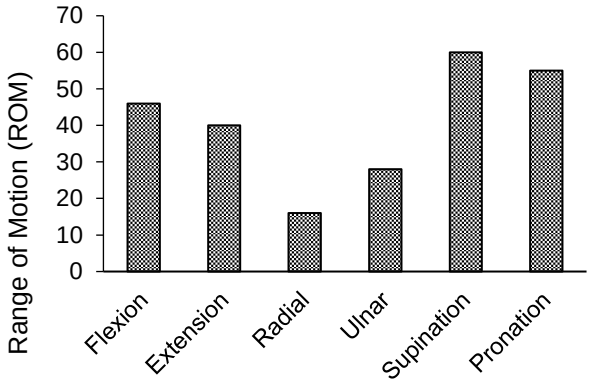

Figure 7: Preliminary ROM outcome measures are testing results of the patients.

The performance evaluation was measured at the limit when patients did not feel pain in flexion, extension, radial, ulnar, supination and pronation. Figure 7 shows that the preliminary ROM of ten patients with impaired wrist function. Consequently, the patients showed obvious improvement in each of these measures. The WRist-T device developed for this study automatically setting especially the angle, the speed of motion and delay of the time. After the preliminary study, all the patient's wrist ROM was performed better than the beginning of the physical therapy, showing that the WRist-T device with automatic control has positive effects and is commendable of further study.

IV. CONCLUSION AND FUTURE WORKS

This paper proposed the new of automatic control wrist rehabilitation therapy (WRist-T) device for an ischemic stroke patient. The present invention device provides a device which has multiple degrees of freedom. This device also provides a portable, small and lightweight wrist movements. In overall, it can be confirmed that the prototype of the WRist-T device meets the imposed design objectives which are offered the cooperative and flexible training or exercises among patients.

In the future works, the authors plan to improve the design and functionality of the device, exclusively for the operation and safety aspects. Additionally, to conduct the clinical study and expand the efficiency of therapy treatments as patients will remain more focused through the frequently extended rehabilitation process.

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