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# Prototyping of Remote-Controlled Robotic Hand Based on Flex Sensor, a Preliminary Research for the Development of Post-Stroke Therapy Assistive Device

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***Abstract* - Most of the stroke survivor is defined by motor impairment which involves movements of the face, arm, and leg on one side of the body. The survivor needs to take a therapy in order to restore the motor function. Several studies show that assistive device improve the quality in therapy process. Hence, long-term research was conducted to develop a Post-Stroke Therapy Assistive Device which focused in hand recovery. The current paper was focused to build a mechatronic system which facilitated a wireless communication between a controller glove that will be used by the therapist to a device that will be used by the patient which represented as the robotic hand. Based on the performance test, it is known that the robotic hand was able to mimic the hand gesture of the controller. Distance test also show the reliability of current microcontroller to perform the wireless communication.**

***Keywords:*** robotic, stroke, assistive-device.

## I. INTRODUCTION

Based on the World Health Organization (WHO) in 2019, at a global level, stroke was placed as the 2nd in disease that caused death and ranked 3rd in disease that caused disability [1]. In Indonesia, there were 2.565.601 stroke patients recorded in 2018 [2]. These high numbers must be concerning. The outcome after stroke is mainly defined by motor impairment. It affects about 80% of stroke survivors and typically involves movements of the face, arm, and leg on one side of the body [3]. In order to restore the motor function, post-stroke patients had to take a therapy program. A therapy that includes intensive, high-repetition, task-oriented was known able to improve the motor function of post-stroke patients [4].

Recently, robotic technology was implemented as an assistive device in post-stroke therapy practice. There was several research which had been done in these field. One of examples was RUPERT (Robotic Upper Extremity Repetitive Therapy) which developed in 2007. RUPERT was an exoskeleton-based robot which focused to assist upper limb recovery with several movement like flexion-extension, abduction-adduction & rotation [5]. In 2013, collaboration between researcher from Germany, Austria, Italy, and Swiss resulted an assistive device named MUNDUS (Multimodal Neuro-prosthesis for daily Upper limb Support). MUNDUS was developed in order to assist the rehabilitation process for several basic movement in daily activities [6]The research of post-stroke assistive therapy devices still continues and become more specified in several body parts like ExStRA[7], REFLEX[8], RobHand[9], RAGT [10], Marsi Active Knee (MAK) [11], ExoAtlet [12] Robotic Exoskeleton (REs) [13], Harmony [14] and many more. These previous researches indicated about the seriousness of international community about the development of post-stroke assistive device in order to improve the recovery process. Thus, due to the high number of stroke patient in Indonesia, domestic assistive device also must be developed.

The current research has a long-term objective to develop a Post-Stroke Therapy Assistive Device which focused in hand recovery. The main idea of the research was to create a wearable exoskeleton device which later can be equipped on patient's hand and can be controlled wirelessly by the therapist so the device can mimic the movement of therapist's hand. This paper focused on the initial development of the research which to create and proof the reliability of the mechatronic system that will be implemented in future works.

## II. METHOD

The current research was focused to build a mechatronic system which facilitated a wireless communication between a device that will be used by the therapist to a device that will be used by the patient. Hence, there were several components needed.

 

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### Mechanical Component

Since the mechanical component only to represent the movement response of the future exoskeleton parts and for the simplicity purpose, a robotic hand developed by Wahid Hasyim University was used instead. The robotic hand can be seen on Figure 1. The moving mechanism of the robotic hand was used a nylon string attached to each finger from a respected motor servo.

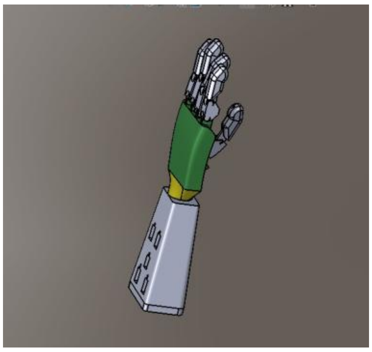

**Figure 1: Robotic hand used in current research**

In order to manufacture the body of the robotic hand, Fused Deposition Modeling (FDM) 3D printing method was selected with polylactic acid (PLA) as the main material. Figure 2 shows the 3D printing process and Figure 3 shows the printing result.

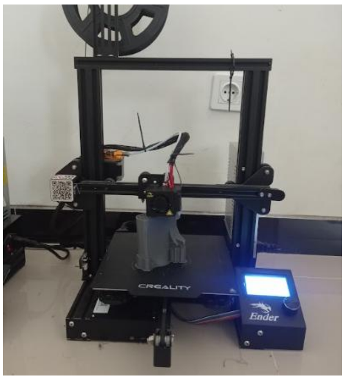

**Figure 2: 3D printing process**

**Figure 3: Printed components**

### Sensor Component

Flex sensor was chosen as the main sensor for the prototype in current research. Flex sensor is a sensor which able to detect deflection or bend on a surface by the changing value of resistance based on the sensor state (compress and tensile) [15]. Since the flex sensor was aimed to detect the flexion movement of a human finger, the flex sensor was attached to a glove as shown in Figure 4.

**Figure 4: Attachment of Flex sensor on glove**

In order to use the flex sensor properly as an input, a voltage divider must be implemented. The voltage divider is a circuit consisting of two series resistors, a flex sensor, and a fixed 47k ohm resistor. The voltage divider will allow the microcontroller to detect the changing value of the output voltage so it can be used as the input signal. The equation of the output voltage of the voltage divider circuit can be seen in Equation 1.

$$V_{out} = V_{in}\left(\frac{R_1}{R_1+R_2}\right) \quad (1)$$

Where,

$V_{out}$ = Analog output voltage
$V_{in}$ = Voltage Supply
$R_1$ = Flex sensor
$R_2$ = Fixed resistor

### Microcontroller

Since the communication was expected to be done wirelessly, at least 2 microcontrollers must be used as a master-slave configuration. The slave microcontroller has the function to read the value of the flex sensor on the glove and later send the value to the master. The master microcontroller has the function to receive the value from the slave and later process the value to control the position of the servo attached on robotic hand.

ESP32 was chosen as the microcontroller in current research due to the ability to communicate between boards

 

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wirelessly using ESP-NOW protocol. ESP-NOW is a communication protocol defined by Espressif which enable direct, quick and low-power communication between ESP32 board. Figure 5 shows the schematic of the ESP32 which served as a slave and figure 6 show the schematic of the ESP32 which served as a master in current configuration.

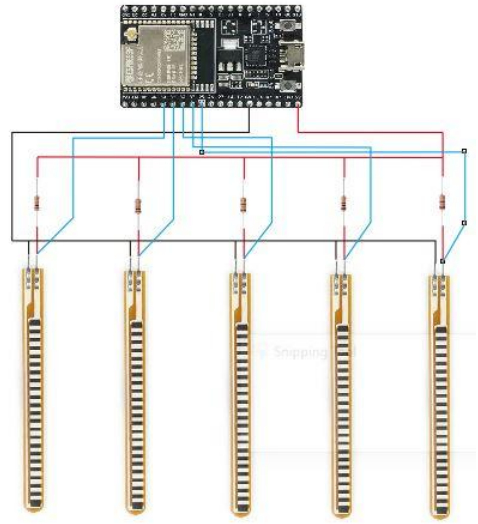

**Figure 5: The schematic of the ESP32 which served as a slave in current configuration**

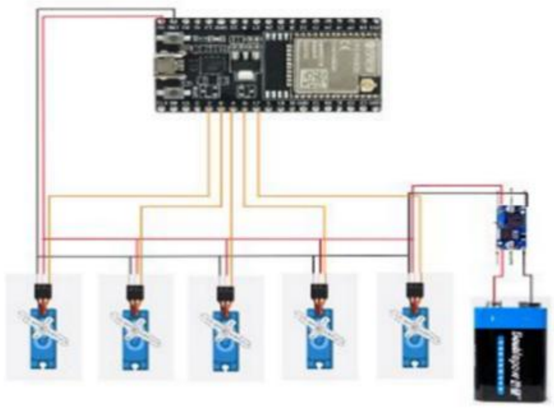

**Figure 6: The schematic of the ESP32 which served as a master in current configuration**

## III. RESULT AND DISCUSSION

### Defining the Sensor Value

Since each of human finger has a different length, each flex sensor also produced different values respected to the finger its attached to. In order to set the movement of the motor servo properly, each maximum and minimum value produced by the flex sensor must be defined. Grasping movement was used to identify the maximum and minimum values produced by the flex sensor on each finger. Figure 7 show the default state of the hand and Figure 8 shows the hand in a flexion state of the grasping movement.

**Figure 7: Default state of the hand**

**Figure 8: Flexion state of the grasping movement**

The result of the sensor reading in a repeated movement can be seen on the Figure 9. Based on the Figure 9, it can be seen that the default state of the hand will produce a higher value than the full flexion state, later this value will be averaged in order to define the upper value and the lower value. The upper value and the lower value will be mapped into the degree of the servo in the master microcontroller. The converted value can be seen on table 1.

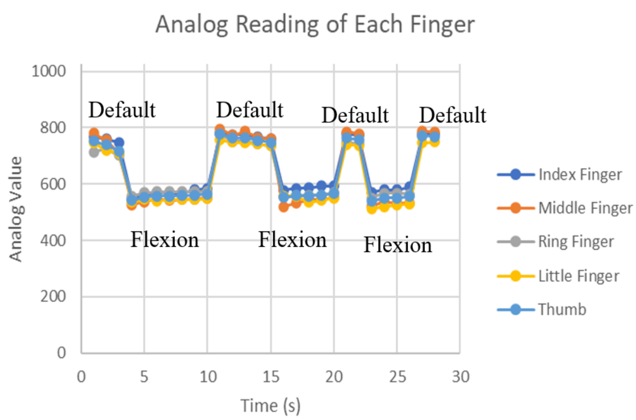


**Figure 9: Sensor reading from each finger**

 

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**Table 1: Mapped value of the flex sensor into servo position**

| | Upper Value | Servo Degree | Lower Value | Servo Degree |
|---|---|---|---|---|
| Index Finger | 771 | 0 | 577 | 180 |
| Middle Finger | 772 | 0 | 538 | 180 |
| Ring Finger | 744 | 0 | 566 | 180 |
| Little Finger | 740 | 0 | 540 | 180 |
| Thumb Finger | 760 | 0 | 555 | 180 |

### Performance Test

The performance test was done by testing the movement of each finger of the robotic hand based on the movement of the controller glove. Measuring the response of the robotic hand by comparing the value of the finger's angle with the angle value of the user finger in the control glove. Figure 10 show the measurement process and table 2 shows the measured valued.

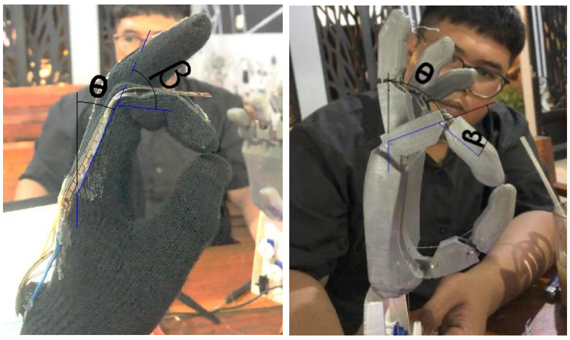


**Figure 10: Angle measurement of controller glove and robotic hand**

**Table 2: Measured value**

| | Controller Hand | | Robotic Hand | | Error | | |
|---|---|---|---|---|---|---|---|
| | $\beta$ ($^0$) | $\theta$ ($^0$) | $\beta$ ($^0$) | $\theta$ ($^0$) | $\beta$ (%) | $\theta$ (%) | Average |
| Little Finger | 45 | 65 | 58 | 80 | 29 | 24 | 27% |
| Ring Finger | 67 | 67 | 65 | 52 | 3 | 23 | 13% |
| Middle Finger | 39 | 68 | 47 | 67 | 20 | 3 | 12% |
| Index Finger | 55 | 83 | 65 | 70 | 18 | 16 | 17% |
| Thumb | 55 | 60 | 38 | 46 | 31 | 24 | 28% |
| Total Average Error | | | | | | | 19% |

Based on the table 2, it can be seen that the robotic hand can response the control glove movement with total average error of 19%. The highest error was occurred at the thumb finger with average error of 28%. This error was occurred due to the faulty mechanism of the finger component; later this finding will be used as the correction for the mechanism of the robotic hand. Despite of the error value, the communication between control gloves with the robotic hand was running smoothly. Figure 11 show the information of transmitted data and received data via serial monitor. Based on the Figure 11, it can be known that the data was transmitted almost immediately.

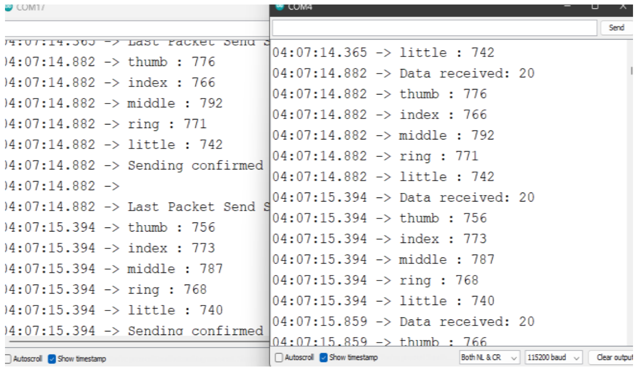


**Figure 11: Monitoring data transmission via Serial Monitor**

### Distance Test

The prototype was later tested to find out the maximum range which can be achieved using current communication protocol. The video of the distance test can be accessed on this link (pengujian jarak (youtube.com). Based on the distance test, it is known that the robotic hand still give a response to the controller glove up to 650 m in distance with no barrier condition. Figure 12 show the distance covered during the test. Although the long-distance communication ability is unnecessary for the current prototype, but it proof the reliability of the ESP-NOW as a wireless communication protocol on ESP32 board.

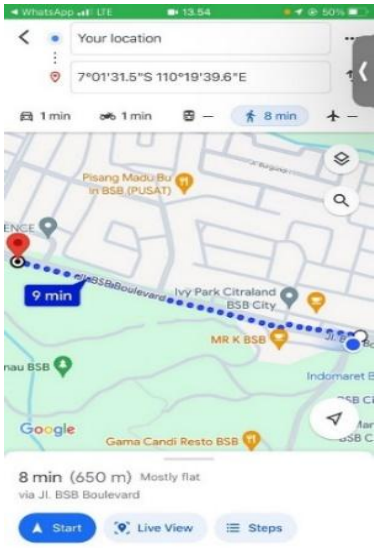


**Figure 12: Distance coverage during the test**

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## IV. CONCLUSION

Prototype of robotic hand controlled by flex sensor has been successfully built with the capability of wireless data transmission. Based on the result, it is known that the robotic hand can mimic the gesture of the controller hand with average error of 19%. The value of the error will be used as a consideration in the future research. Distance test also conducted, which resulted the information about the maximum distance achieved by current prototype is 650 m. Although long-distance capability is not necessary for current research, but it is providing a proof about the reliability of ESP-NOW as communication protocol. Hence, the mechatronic system of current research considered reliable to be used in the future development of wireless post-stroke therapy assistive device.

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