Design of Fabric-Based Soft Robotic Glove for Hand

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Design of Fabric-Based Soft Robotic Glove for Hand Function Assistance

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***Abstract*—This research presents design and development of prototype fabric-based wearable soft exoskeleton. The soft glove employs motor-tendon for assisting the flexion and extension motion of the user's hand. Two linear actuators are used as the motor-tendon actuator system. On-off control is designed for controlling the displacement of a linear actuator connected by nylon strings to the soft glove. Step input is given to test the performance of the proposed on-off control. Based on the experimental result, the on-off control produced very small steady-state error. The resulted soft glove is attached on human healthy hand for assisting the finger flexion and extension to grasp designated objects. Based on the test result, the proposed soft glove can assist the user/wearer in grasping three different objects.**

Keywords*—*fabric, soft exoskeleton, motor-tendon, linear actuator

I. INTRODUCTION

In its development, robotics technology has experienced many developments. If grouped based on the material used, robots can be divided into two groups, namely hard robots and soft robots. In this type of hard robot, the material supporting robot is made of rigid material and has a limited degree of freedom (DOF). While soft robots are made of materials that have a lot of DOF. Soft robots are inspired by animals such as worms, starfish, snails or animal body parts such as the elephant's trunk, octopus arms, and tongue of mammals [1].

Hard robots consisting of hard material, sometimes very uncomfortable when used by humans/users. Many researchers in the world have developed exoskeleton robots that use hard robot technology. The hard robot type of hand exoskeleton is used to provide mechanical support for users whose hands are paralyzed. This exoskeleton hand has successfully helped the disabled hand to grasp the object [2]–[8].

Therefore, scientists in the world have developed soft robot technology using soft materials. This allows soft robots to have a very large amount of DOF and are difficult to combine. Soft robots can work with humans safely because soft robot compilations manage collisions, the flexible nature of the robot can be avoided or used to prevent potential damage. Soft robot can be applied in the medical world, specifically for invasive surgeries. Soft robots can be utilized to assist medical operations because they support excellent shape changes, especially in bending movements.

In its application, soft robotic cannot always replace conventional robots (hard robotic). However, for some applications, especially for robotic rehabilitation or assistive devices, soft robotic is ideal for applications. The development of wearable robotic exoskeleton in medicine is currently experiencing rapid progress. The main function of the wearable exoskeleton robot in medicine is as a rehabilitation aid for sufferers with paralysis that can be caused by various diseases such as stroke, brachial plexus injury, other impaired hands. Researchers who are experts in the field of soft robots have succeeded in developing soft exoskeleton glove to help people who lost their hand function. Actuators that are widely used in soft exoskeleton glove are motor-tendons, smart memory alloy (SMA), and pneumatic networks [9]–[14]. Soft robot provides convenience to the user as it is easy to install and remove to the user, besides soft robot is also comfortable to use.

In this study, a fabric-based soft exoskeleton hand is developed by using two mini linear actuators and motor-tendon based actuation system. The resulted prototype of the soft glove is implemented on the normal healthy hand to test the performance of the glove for assisting the grasping of various objects. On/off control is embedded in the soft glove system for controlling the motion of linear actuators. Nylon string is used to connect the linear actuator and the glove. Based on the experimental result, the robotic glove can be used to assist user/wearer to grasp the various objects.

II. FABRIC-BASED GLOVE DESIGN

In developing health aids or assisting devices, aspects that guarantee the safety of its users are needed. From the Medical

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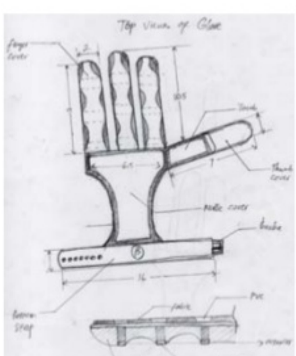
side, a health aid device must meet certain criteria to ensure the feasibility of a tool/device. The criteria that must be possessed are in addition to the feasibility of the function in accordance with its designation, the auxiliary equipment must be made of material that is safe to use by humans and does not require workmanship on its users. Apart from that, it should not be burdensome both physically and mentally. Meanwhile, if viewed from the patient's side, in this case, consumers will consider the device in terms of ease of use, affordable and durable prices. In this study, the development of soft robotic glove prototype, the design aspects related to user convenience would be applied when selecting the chosen design concept.

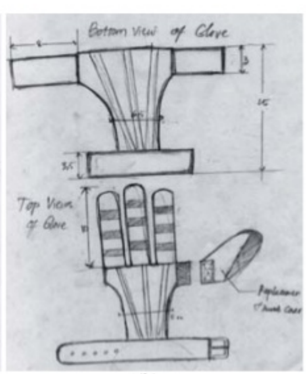
The wearable fabric-based soft robotic glove was made based on the dimensions of the average human hand size in Indonesia. In this study, researchers used the hand size of respondents who suffered from brachialis plexus injury as a reference dimension, so that the design results could be used and tested on the patient/study participant.

Motor-tendon actuator system was chosen in the study, this actuator will reduce the glove dimension so that it can be made a compact soft exoskeleton glove. In motor-tendon type actuator, a rope was needed which functions as a pulling device that works like a muscle (tendon) in a human hand. The string/tendon on the motor-tendon actuator was used to pull the fingers so that the finger segments can bend and extend (flexion and extension). Nylon was used as a tendon in the soft robotic glove because of its ability to withstand large pulling forces, the material is quite durable and has a small size as well as it is easy to install. This nylon tendon would be used as a connector between the hooks on the finger segments with a linear actuator that pulls and stretches the movement on the finger.

The application of soft robotic exoskeleton for assistive devices is quite new to be used as a wearable robot. In this study, the main material for making glove is fabric. Therefore, it is necessary to make a base glove design. If reviewed in function, the base glove will be a blanket for the fingers and palms wherein there is a hose for the tendon path. The shape of the base glove will affect soft glove performance and aesthetics. There are four designs for the base glove that are developed in this study. The four proposed 2-D design of the soft glove base is presented in Fig. 1.



(a)



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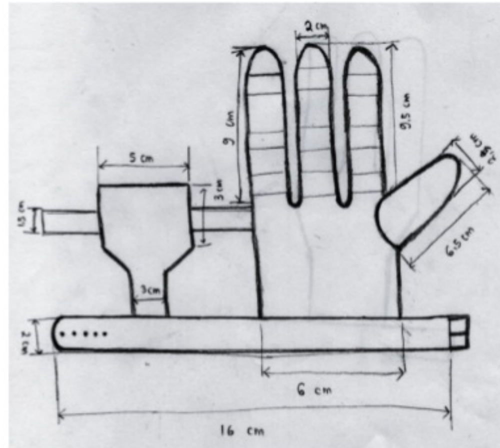

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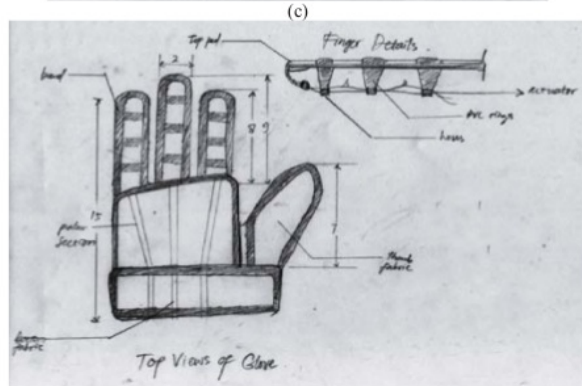

(d)

Fig. 1. Base glove design, (a) First design, (b) Second design, (c) Third design, (d) Fourth design

From the manufacturing process, the results of the first and second designs, the advantage is that the manufacturing process is easy because the minimalist shape and the shape of the glove does not make it easy for the hand to be fully mounted or removed. However, this overly minimalist shape makes the soft glove becomes stiff, so they are easily shifted and are unable to hold the segments. Then in the second design, the thumb section is designed so that the thumb can be removed to make it easy to use when using the glove. However, the place where the thumb is removed is not strong enough to hold the thumb segment even though the thumb segment is conditioned to be hard when the glove is used for gripping object. As for the third design, the glove design is designed to make it easier for the entire surface to keep the gloves from getting loose. However, there is a lack of a hand tie because the size is too small and it makes the glove easily shift back and forth or shifts sideways. In addition, because the glove made from fabric surface can be used quickly. Therefore, we choose the fourth design where in this design the thumb and glove parts have been joined together not to cover all the hands like gloves in general. This is necessary so that the glove is easier to remove, attach install and revise so that we do not sweat quickly when using the glove for a long time but the stiffness of the glove is still good. Besides that, the hand is made wider so that the strength of the glove's position when it is used is not easy to shift. The final result of the fabric-based glove can be seen in Fig.2.

For the glove-soft exoskeleton material, if viewed from the comfort of the material when used, cotton fabric is certainly the most comfortable because this material is soft, cool and easy to absorb sweat compared to SR 10 type fabrics and jeans. However, the cotton material has a weakness that is easily torn due to the thin material. For a type of denim is stiffer and thicker than cotton or SR 10. However, because the fabric texture is quite rough if used as a glove where the fabric will often rub against the skin it will cause blisters on the skin and can cause irritation. As for the SR 10 type fabric, this fabric has a tight fabric texture. Therefore, making this fabric is not easy to tear and the texture is soft so it is best to be used as glove material in this study.

Fig. 2. The prototype of Soft glove base

III. HARDWARE SYSTEM

The proposed soft exoskeleton glove utilizes two Arduino Nano microcontrollers, as the main controller on the soft glove and transmitter/joystick as a user input command. The Arduino Nano is selected because it has small size that will suit into the soft glove system. Two linear actuators from Actuonix are implemented as the motor-tendon actuator system. L293D DC motor driver is employed for controlling speed and direction of the linear actuators. NRF24L01 Transceiver Module is applied in the hardware system for wireless communication between glove system and computer or command joystick.

After all the electrical components to be used have been determined, the next step is to make an electric circuit scheme on the project board. Fritzing software is used to create project board drawings. In this study, there are two electrical components, namely the transmitter of electrical circuits and electric receivers. This transmitter circuit serves to read the sensor input (potentiometer) and send it to the glove system. In the transmitter, there is a potentiometer to provide an input signal that regulates linear actuator movements. As for sending data, a wireless module is used that uses RF 2.4 GHz waves, NRF24L01. The of the proposed transmitter component is shown in Fig. 3 and the result of the transmitter hardware component circuit can be seen in Fig. 4.

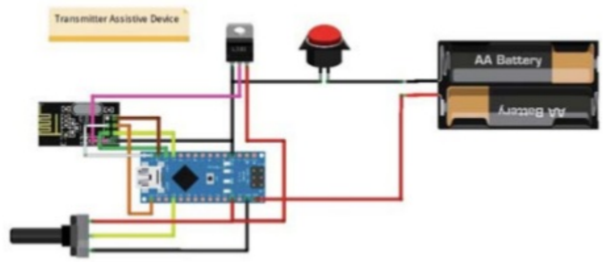

Fig. 3. Proposed transmitter hardware system

Fig. 4. The prototype of the transmitter hardware system (remote control)

In the receiver circuit, it functions as the recipient of data sent by the transmitter circuit to give motion commands to two linear actuators. To control the movement of the two actuators, the L293D motor driver is used. The NRF24L01 module also has a set of receivers so that the microcontroller in the receiver circuit can receive data sent by the transmitter. The details of the connecting electrical components can be seen in Fig. 5 and the result of the receiver hardware system is seen in Fig. 6.

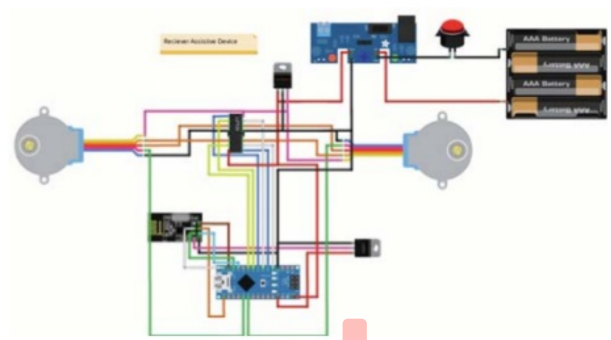

Fig. 5. Proposed receiver hardware system on the soft glove

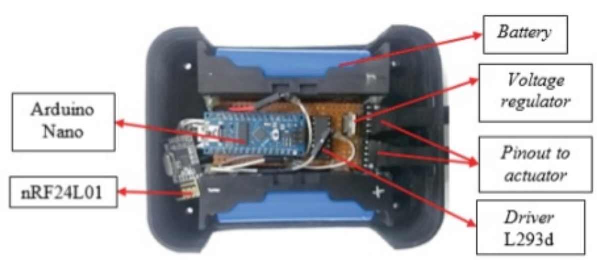

Fig. 6. The prototype of receiver hardware system on the soft glove (controller box)

IV. Result and Discussion

In the part of the glove and actuator base, the BPI patient is attached to the hand, then the controller box is attached to the upper arm/shoulder of the BPI sufferer. The proposed remote control can be held by a normal BPI patient's hand. Quantitatively the total weight of the component Wearable Assistive Soft Robotic Glove is less than 600 grams. The prototype that has been completed is then tried to be worn by a BPI patient to find out how the results are given. Fig. 7 shows Wearable Assistive Soft Robotic Glove when used.

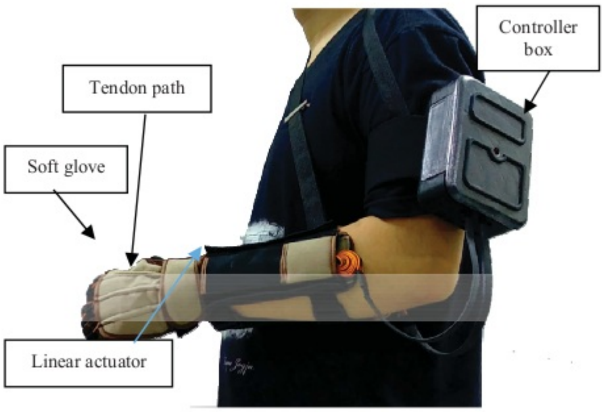

Fig. 7. The prototype of a final wearable soft robotic glove

This soft glove must have a high level of comfort when used because this tool will be used in daily activities with a long duration of use. In this study, it was found that the prototype of Wearable Assistive Soft Robotic Glove is quite comfortable to use for a long time. This tool does not overload the body of a BPI sufferer because the total weight of the device is only 600 grams. The shape of a semi-open glove does not make the wearer's hands sweat much like when using a closed glove in full. Then the operation of the glove is quite easy to do, which is to move the user to simply rotate the potentiometer on the remote control.

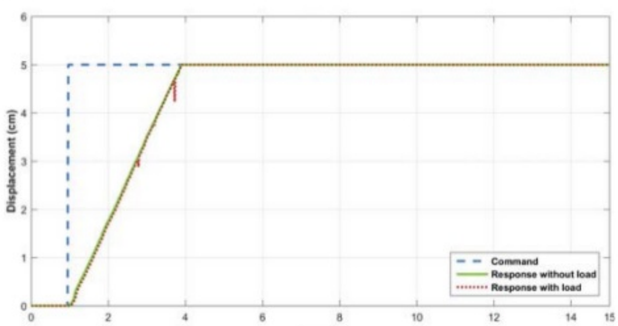

Fig. 8. Step response of soft exoskeleton glove

To find out how the response from the actuator when using on / off control, input step signal is used as the command given. The following is the result of testing the performance on/off control to get a comparison between the command and the output that is generated. The step signal graph obtained can be seen in Fig. 8.

To find out the extent to which Soft Robotic Glove Wearable Assistive can adapt when holding various forms of handheld objects that are given then testing the motion with the load. Testing is done by giving a hand object to the tool being used then being moved from a neutral state to reach a full holding state. The handheld object used has cylindrical shapes and irregular shapes. Comparison of the test results is presented in Fig. 9 which shows the movement test by carrying out activities in the form of movements holding several types of objects.

Fig. 9. Performance of the proposed wearable soft robotic glove for assisting various object grasping tests

V. CONCLUSION

In this study, prototype fabric-based wearable soft exoskeleton has been successfully developed. The soft glove utilized motor-tendon actuation system for assisting the finger flexion and finger extension motion. The motion of the soft glove can be controlled by using customized joystick control wirelessly. On-off control was employed for controlling the motion of two linear actuators on the soft glove. The on-off control produced very small steady-state error. Based on the test, the proposed soft glove can assist the user/wearer in grasping three different objects. In the future, electromyography (EMG) will be used as the sensor that is attached to the healthy user hand muscle below the elbow as the signal control input instead of potentiometer/customized joystick box.

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