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Design and Manufacture of Robotic Exoskeleton Hands Using 3-D Printer

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ABSTRACT

Robotic exoskeletons are kind of wearable robots enabling operators to amplify the force. There are several possible applications in plenty of options: to put very heavy products into right positions for assemblies, to rescue people from natural disasters, and to work for medical rehabilitation etc. In this study, the exoskeleton hands were designed and fabricated using 3-D printer. It would be the good case of application of 3-D printer to design and fabricate the exoskeleton hands.

Keywords: Exoskeleton; Wearable robots; 3-D printer

I. Introduction

1. Background of Study

Powered exoskeleton is a mechanically assembled exo-framework or exo-suit made wearable to support the wearer's muscle power under various circumstances[1]. It can be classified into 2 types of power assistance and of power augmentation. For the purpose of power assistance, it would take over the assistant performance of wearers such as old or feeble person and/or disabled person. And for the purpose of power augmentation, it would amplify the wearer's muscle power to handle heavy objects. So it can be applied to construction sites or to military fields[2].

Powered exoskeletons wearable on hands are normally developed to support the muscle power for people who are unable to move fingers due to stroke(cerebral apoplexy) or having functional problems in fingers.

In hand, there are 19 bones and 14 joints. And the radiocarpal, intercarpal, metacarpal phalangeal(MCP), proximal interphalangeal(PIP), and distal interphalangeal(DIP) joints constitutes the hand. Each IP(=interphalangeal) joint of four fingers has a DOF(Degree of Freedom) of 1 where the thumb has only one IP joint. Plane articulation of thumb is connected to the carpus in different way from those of other fingers of which articulation enables the human hand to grasp objects.

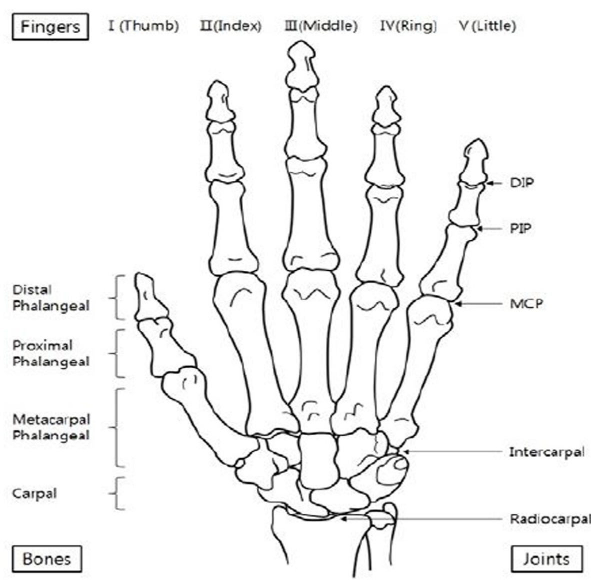

Fig. 1 Bones and Joints in Human Hand[3]

2. Purpose of Study

Purpose of this study was to design and to fabricate

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the exoskeleton for hands using 3-D printer. 3-D printing is the technology showed rapid improvement recently that enabled users to produce three dimensional figures. This feature would also enable the design and fabrication of personalized and differentiated exoskeleton for hands.

II. System Design

The exoskeleton for hand designed and fabricated in this study was consisted of 4 parts. The 'SolidWorks 2013' was employed for the modeling and three dimensional design of each part. Exoskeleton for 2 fingers of index and middle finger was designed and fabricated. For the exoskeleton for thumb, it was precluded because the Degree Of Freedom of thumb was too high that made the design and fabrication difficult. The wire was adopted for the power transmission.

1. Part A

Tips of index and middle finger will be inserted into Part 'A' at which point the wires will be fixed thus it was designed simply to improve the durability. Finger tips will be inserted into the groove placed in the middle of the part 'A' while the 2 strands of wires will pass through the 4 holes.

2. Part B

Part 'B' will be placed behind the proximal interphalangeal (PIP) joint of index and middle finger. It supports the wires connected from part 'A' to part 'C', and will keep the wires always to be connected along the fingers. Contrary to other parts, the part 'B' may move along the fingers. To prevent such movement of part 'B', the upper clearance of each part of 'B' will be fastened by bolt and the parts of 'A' and 'B' will be connected concurrently with other wire. So the 8 holes on part 'B' were needed to pass through the wires.

2.3 Part C

Part 'C' will be placed right behind the metacarpal phalangeal(MCP) joints. Similar to part 'B', it will also support the wires. And wires above and beneath of each finger are guided and get together by part 'C' to be connected to the part 'D' which is connected to the motor. There are total 8 holes drilled in part 'C' to gather wires from four fingers except thumb. And the elliptical hole of which minor axis located toward the middle finger is provided in part 'C' to take into account the thickness in the middle of each hand compared bigger to those of edge part.

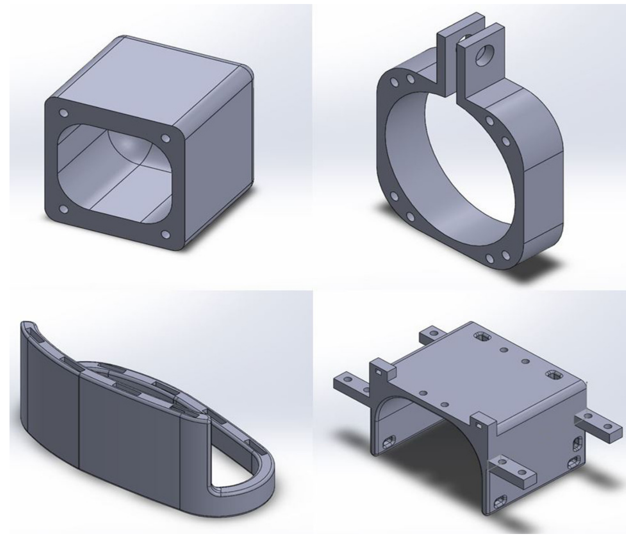

Fig. 2 3-D Design of each part

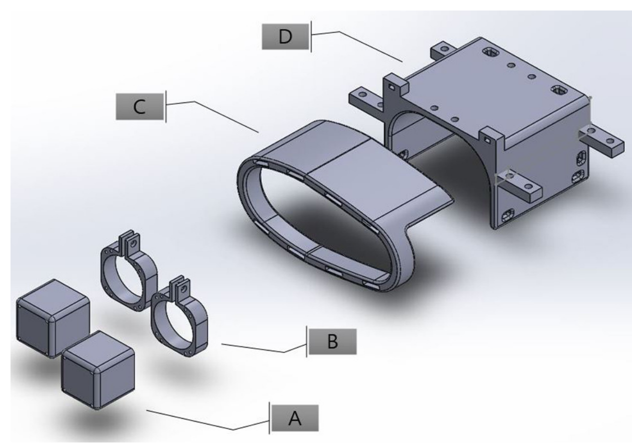

Fig. 3 The Final 3-D Design of each part

2.4 Part D

The part 'D' supports the whole exoskeleton and accommodates the battery and MCU. In one part of ‘D’, the 2 servomotors will be mounted to control the motion of two fingers. If the control of motion of 4 fingers is required then 2 parts of ‘D’ can be used. Holes on the backside of ‘D’ were provided to connect 2 ‘D’s with each other. The hole provided on the front side of ‘D’ is to connect the total 4 strands of wires from ‘C’ to each servomotor. At the bottom of ‘D’, the hole to fix the ‘D’ to the lower arm is provided.

III. Fabrication and Implementation of the Designed Exoskeleton

To make each part, the 3-D modeling files created by the 3-D design works from ‘SolidWorks 2013’ were converted into files tailed the ‘.stl’ extension and put into 3-D printers of ‘Makerbot 2X’ & ‘Makerbot Replicator’ and then printed out. The nylon fishing line was employed for the wire, and the 2 rubber bands of 5mm width were used to fix the part ‘D’ to the lower arm. And sponge tapes were also used to enhance the contact of each wearable part to the limb. The ‘Arduino Uno’ was adopted as a MCU to control the exoskeleton. And the two servomotors pulled each wire to bend or to stretch corresponding fingers. For the exoskeleton designed and fabricated in this study, no intentional sensing method was applied, so the drive was controlled by ‘Arduino Uno’ connected to the dedicated computer through serial communication to control motions of each finger.

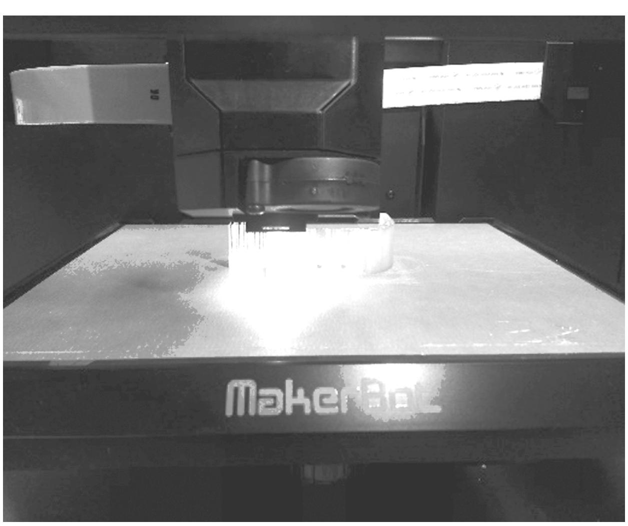

Fig. 4 Application of the 3-D Printer to produce the Exoskeleton

IV. Suggestions

Fig. 5 illustrates the finalized exoskeleton made through the 3-D design and printing. With results obtained from this study, the suggestion upon input device was proposed. Possible input devices might be those exploited methods of FSR(Force Sensing Resistance), EMG(electromyogram), and EEG(electroencephalogram). Among them, the device adopted the method of EMG would be most preferable because it would be active than the one adopted the method of FSR with less noise than the one adopted the EEG method[4]. The nylon adopted for the material of wire also left us the proposition. The nylon got elongated due to the tensile force applied for a long time thus materials endurable and resistant to tensile force should be employed.

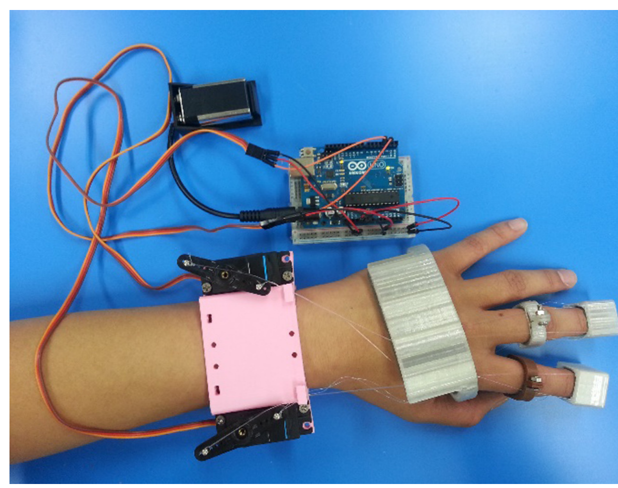

Fig. 5 Figure of the finalized exoskeleton

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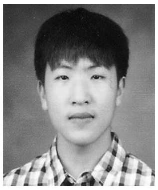

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