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Design, Development and Control of a Portable Hand Exoskeleton Splint for People with Partial Disabilities

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Abstract

Claw hand is a condition in which the fingers are noticeably curved or bent. The main characteristic of claw hand is the hyperextension of MetaCarpoPhalangeal (MCP) joints along with flexion of Proximal InterPhalangeal (PIP) joints and Distal InterPhalangeal (DIP) joints. This condition can affect one or more fingers, on one or both hands. Depending on the severity of the condition, you may have difficulty using your hands to pick up and grasp items. In this work we present an exoskeleton splint for people that face the “Claw Hand” problem. The device consists of two parts, an exoskeleton glove for the damaged hand and an actuation unit that houses the necessary electronic circuits, a microcontroller, batteries and five RC-servo motors in order to drive the glove. The actuation unit is portable, lightweight with friendly interface and power autonomy. Finally experimental results are given to evaluate the practicability and effectiveness of the exoskeleton splint in grasping objects and mimicking human gestures.

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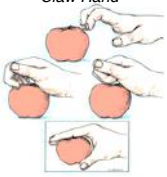
Problem statement

Claw hand is a condition in which the fingers are noticeably curved or bent. The main characteristic of claw hand is the hyperextension of MetaCarpoPhalangeal (MCP) joints along with flexion of Proximal InterPhalangeal (PIP) joints and Distal InterPhalangeal (DIP) joints. This condition can affect one or more fingers, on one or both hands. The condition gets its name from the curvature of the fingers, which makes the hands resemble a bear's claw. Claw hand can be a congenital defect, a defect present at birth, or it may be due to certain disorders or injuries. Depending on the severity of the condition, you may have difficulty using your hands to pick up and grasp items.

Claw Hand



Loss of Grasp

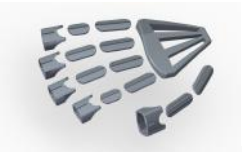
Objectives

- Design and manufacture an easy to wear exoskeleton splint for people that face the "Claw Hand" problem.
- The exoskeleton splint must be able to help people grasping objects or achieve simple gestures.
- The actuation unit of the exoskeleton splint must be portable, lightweight with friendly interface and power autonomy.

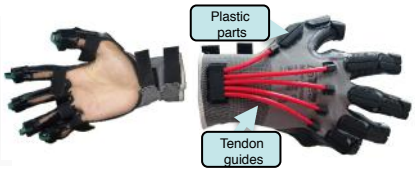
Exoskeleton splint with its drive unit

Methods – System's architecture

The main idea is to use artificial tendons driven by linear RC-Servo motors in such way that they can pull the user's fingers and force them to open. To achieve this we designed an exoskeleton splint that consists of twenty plastic parts specifically placed on a heavy duty glove along with a driving unit that houses the motors as well as the necessary electronics, microcontroller and power supplies.



3d model of exoskeleton splint

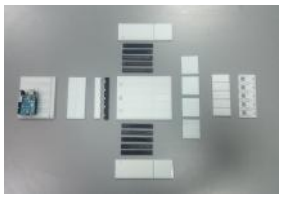


Bottom view of exoskeleton splint

Top view of exoskeleton splint

The plastic parts are designed in such way so that they can be easily adapted on the back side of the hand in order to guide the artificial tendons from the tip holders to the driving unit. They have been fabricated by using the fused deposition modeling (FDM) process with a Dimension Elite 3D-printer. The heavy duty glove was modified to be hollow on the palm region in order to be easily wearable on a hand with closed fingers, seven Velcro straps where used to hold the splint in place, one on each finger and two on the wrist.

3d model of drive unit

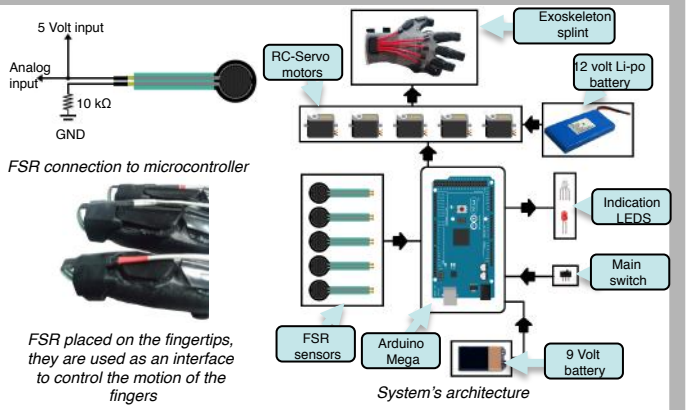


Parts of drive unit

RC-servo motors with warm shafts

The drive unit was designed to be easily assembled and disassembled. The system consists of 5 RC-Servo motors, five worm shafts for converting the rotational movement of the motors into linear displacement, a PCB board that connects all the FSR sensors, the necessary electronics and an Arduino mega microcontroller. Two power supplies are used. The drive unit consists by twenty eight parts made of Ertalon that was manufactured in a computer numerical control (CNC) milling machining center

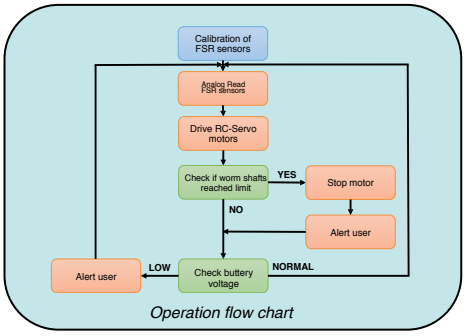
PCB board with Arduino Mega



FSR connection to microcontroller

System's architecture

FSR placed on the fingertips, they are used as an interface to control the motion of the fingers



Operation flow chart

RGB LED	RED LED
Thumb	Finger calibrating
Index	Switch of finger calibration
Middle	
Ring	
Little	

Indications of calibration mode

RGB LED	RED LED
Thumb limit	constant: Sufficient battery level
Index limit	constant: Both batteries low level
Middle limit	Blinking: 12 volt battery low level
Ring limit	Blinking: 9 volt battery low level
Little limit	

Indications of operation mode

Experimental Results

To determine if the exoskeleton splint created in this project was capable of performing the tasks needed we conducted two experiments, the first experiment was designed for gestures and the second for holding objects of different sizes. In the first experiment the user was able to make gestures with his hand and control each finger separately through the FSR sensors of the hand exoskeleton splint. In the second experiment the user was able to grasp and hold objects of different sizes and geometries.

Conclusion

After experimenting with the exoskeleton splint we reached the conclusion that the splint can be used to restore the movement and holding abilities in the hand of a person that faces the "Claw Hand" problem.

Key References

1. Pilwon Heo, Gwang Min Gu, Soo-jin Lee, Kyehan Rhee, Jung Kim, "Current Hand Exoskeleton Technologies for Rehabilitation and Assistive Engineering", Int. .I of Precision Engineering and Manufacturing, 2012, Volume 13, Issue 5, pp 807–824
2. Douglas Martin Linn, W. L., Chris A. Ihrke, H. M., & Myron A. Diftler, H. T. (2012). *USA patent no. US 8,255,079 B2.*

DESIGNING AND MANUFACTURING OF A PORTABLE HAND EXOSKELETON SPLINT FOR PEOPLE WITH PARTIAL DISABILITES

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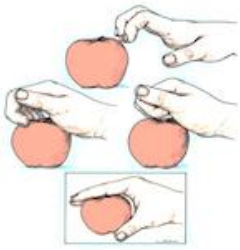
Introduction

❖ **CLAW HAND**

Claw hand is a condition in which the fingers are noticeably curved or bent. The main characteristic of claw hand is the hyperextension of MetaCarpoPhalangeal (MCP) joints along with flexion of Proximal InterPhalangeal (PIP) joints and Distal InterPhalangeal (DIP) joints



❖ **EXOSKELETON SPLINT**

Exoskeleton splints are mechanisms that help the user make moves that originally he couldn't do himself or enhance the movements

Hand-Ex

❖ **EXOSKELETON SPLINT Hand-Ex**

- Uses RC-Servo motors and wire ropes to move the fingers
- Controlled with force sensing resistors in each finger
- Lightweight
- Addressed to people with partial disabilities in hands owing to lose in tendon length

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Designing and Manufacturing of Exoskeleton Glove

❖ **DESIGNING OF EXOSKELETON GLOVE**

- Designed in Creo Parametric of PTC
- Slim design
- Designed to be worn comfortably
- Designed for people how can not open there fingers because of short tendons

3

Designing and Manufacturing of Exoskeleton Glove

❖ **MANUFACTURING OF EXOSKELETON SPLINT**

- Open elastic glove for easy placement on people with short tendons
- Placement of parts on elastic glove
- Restrain of parts on the glove with glue and string
- Restrain of glove on the hand with Velcro on each finger and the wrist
- Suitable placement of force sensing resistors on the tip of the fingers for the optimal monitoring of the forces applied

Designing and Manufacturing of Driving unit for Exoskeleton Splint

❖ **DESIGNING OF THE DRIVING UNIT FOR EXOSKELETON SPLINT**

- Designed in Creo Parametric of PTC
- It consists of simple parts for easy replacement
- Robust manufacture
- Designed to house five RC Servo motors, five endless axes, one pcb board, one microcontroller and two batteries

Designing and Manufacturing of Driving unit for Exoskeleton Splint

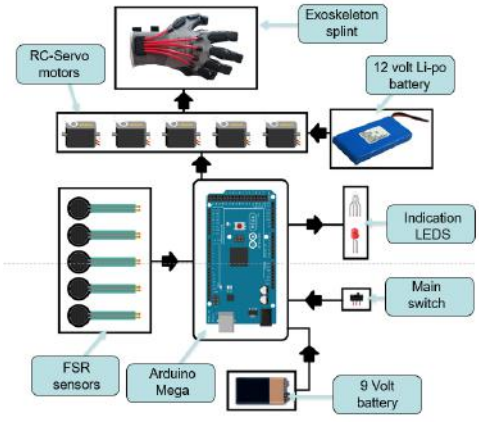
❖ **MANUFACTURING OF DRIVING UNIT**

- Placement of parts with instant glue
- Stainless endless axes
- Restrain of RC Servo motors with screws

Designing and Manufacturing of Driving unit for Exoskeleton Splint

❖**Drive Unit Components**

- Five RC Servo motors
- One microcontroller Arduino Mega/Uno
- One battery for the microcontroller and one battery for the RC Servo motors
- One RGB LED and one red LED



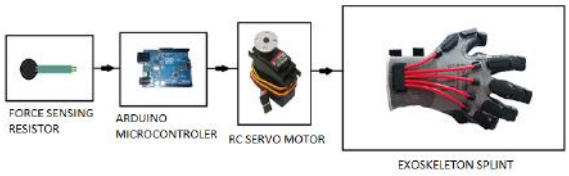
How it works

❖ CALIBRATION OF FORCE SENSING RESISTOR

• a= value of force sensing resistor
• $b=a/2$

❖ MANE FUNCTION

• Monitoring force sensing resistor
• Processing signal
• Driving RC Servo motors



How it works

❖ ILLUMINATED INDICATIONS

Calibration of Force Sensing Resistors

RGB LED		RED LED	
●	THUMB CALIBRATION	○	FINGER CALIBRATION
●	INDEX CALIBRATION	●	CHANGE BETWEEN FINGER CALIBRATION
●	MIDDLE CALIBRATION		
●	RING CALIBRATION		
●	PINKIE CALIBRATION		

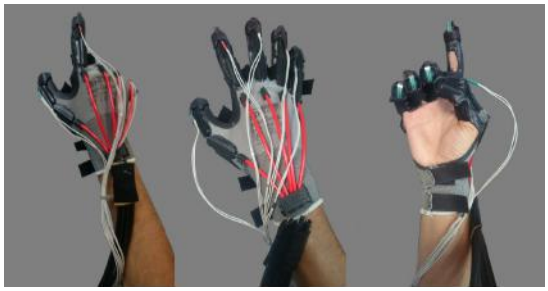
Main Function

RGB LED		RED LED	
●	END COURSE OF THUMB	○ CONTINUING	SUFFICIENT BUTTERY LEVEL
●	END COURSE OF INDEX	● CONTINUING	LOW BUTTERY LEVEL ON BOTH BUTTERIES
●	END COURSE OF MIDDLE	◐ BLINKING 1:1	LOW BUTTERY LEVEL OF SERVO BUTTERY
●	END COURSE OF RING	◐ BLINKING 2:1	LOW BUTTERY LEVEL OF ARDUINO BUTTERY
●	END COURSE OF PINKIE		

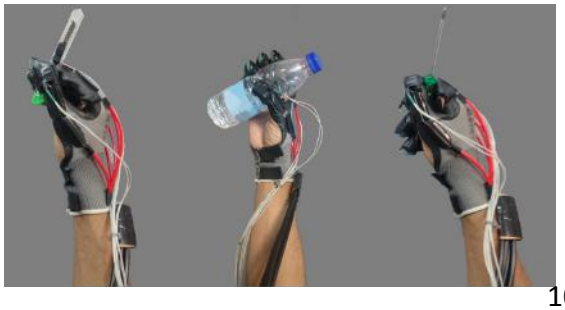
How it works

❖ FEATURES

• Features in movement and gestures

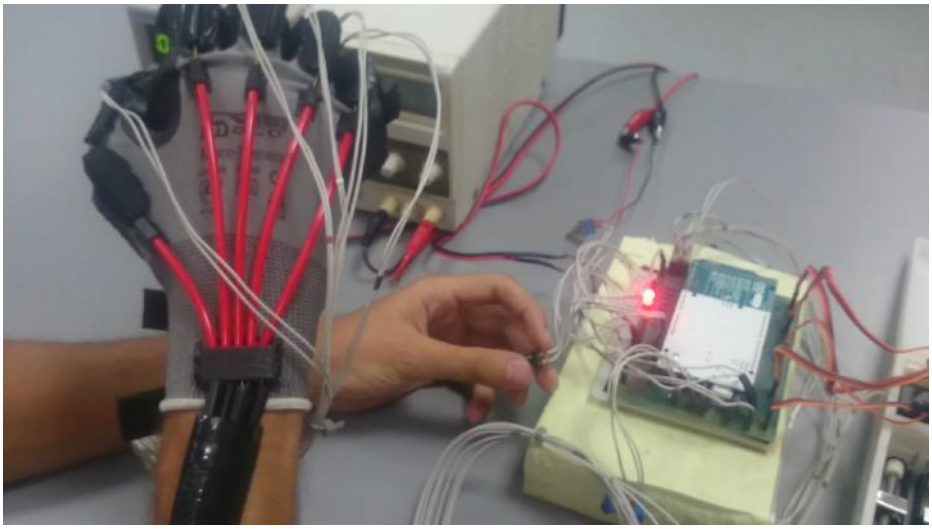


• Features in handle objects

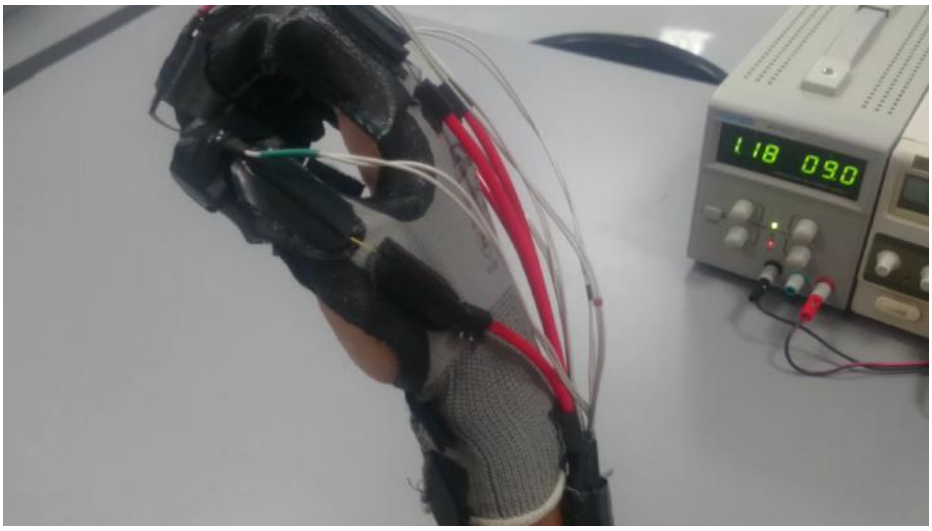


Mechanism

Calibration



Operation



Thank you