Biomechanical Model of the Hand for Upper Limb Prosthesis Evaluation

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ABSTRACT

Prosthetic hands provide amputees with the chance to recover their lost abilities, however, there is no comparison made between the movement of a prosthetic hand versus a biological hand. This project aims to create a biomechanical model that describes the variation and similarity between the kinematics of a biological hand and a prosthetic hand. This project utilizes motion capture through a specific active marker infrared assembly to obtain the kinematic analysis of both prosthetic and biological hands. The results obtained showed a substantial difference between the flexion angles between the biological hand and the prosthetic hand in the distal phalange joints.

INTRODUCTION

The human hand is a definitive differentiator that separates humans from other living beings. The hand allows for precision, dexterity, manipulation, grasp, and communication through sign language (Physiopedia, n.d.). However, some people don't have hands and rely on the use of prosthetic hands to compensate for their lost limb. Nonetheless, there hasn't been a comparison between the movement of a prosthetic hand versus a biological hand. This comparison is important to assure the amputee the most natural and effective movement with a prosthesis. We used a motion capture system (MOCAP), which is an arrangement of technological devices that allow us to register the movements of the segments (anatomical or not) of a physical system, which might as well be the human body (Bravo, R. & Grupo de Bioingeniería y Biofísica Aplicada, Dpto. Electrónica y Circuitos, n.d.). For the recording of the anatomical references that define the body segments, optical methods were used that record an identifier (for example, a marker). The method chosen to localize the markers is the Fischer et al. (2020) method. This method consists of placing one marker per segment.

OBJECTIVE

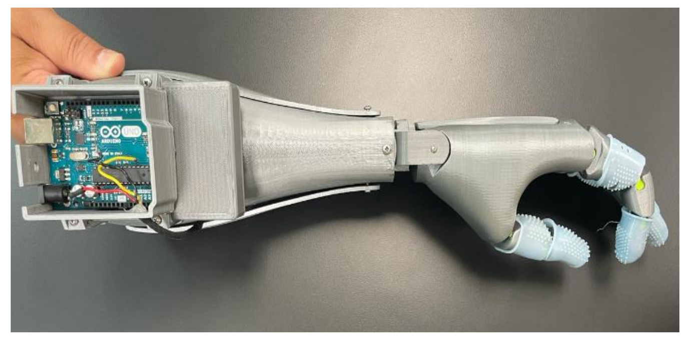
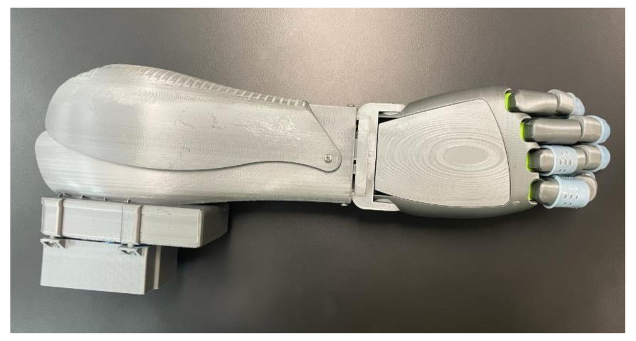
The objective of this project is to create a biomechanical model that describes the kinematics of a biological hand and a prosthetic hand, then use the description made to analyze and compare both systems' kinematics, using the biological hand as the pattern movement in the MOCAP.

METHODOLOGY

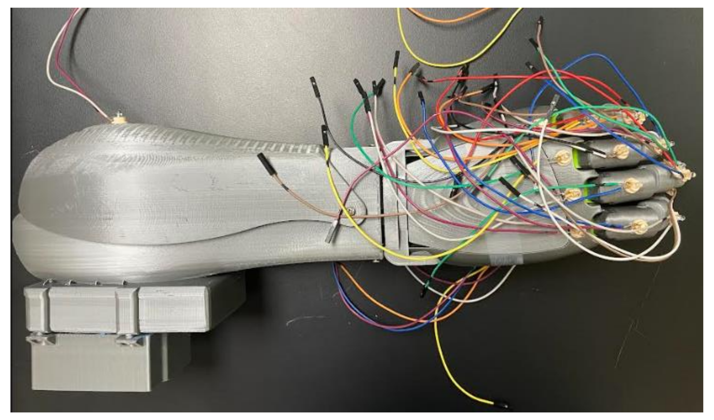
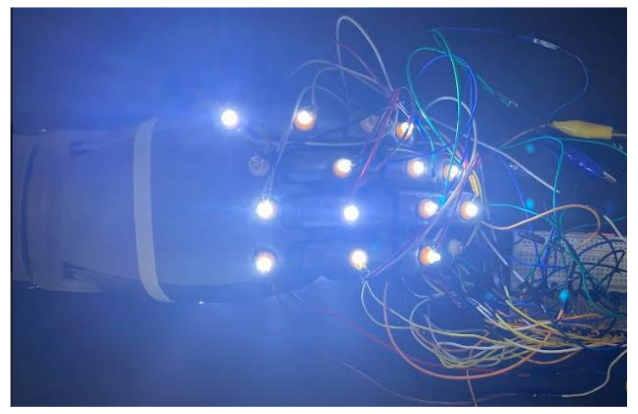
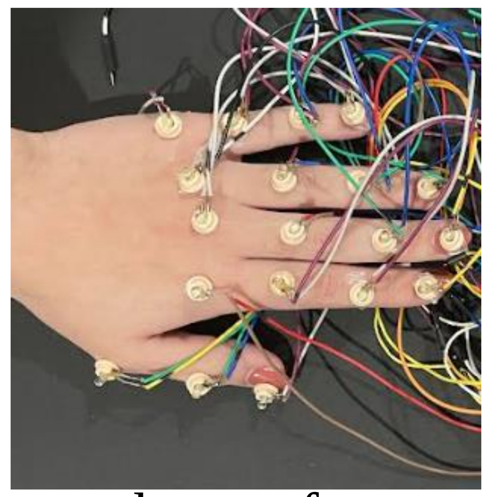
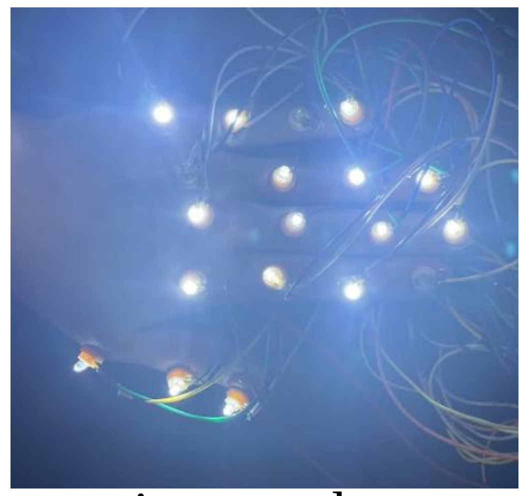
1. Define a biomechanical model for the hand and marker set.

FM1: 1 marker per segment	D2A–D2D D3A–D3D D4A–D4D D5A–D5D	Palm (A) Proximal phalanges II–V (A,B) Intermediate phalanges II–V (B,C) Distal phalanges II–V (C,D)	A: on the metacarpal joint B: on the proximal interphalangeal joint C: on the distal interphalangeal joint D: on the distal and dorsal part of the fingertip

2. Establish the version of hand prosthesis to be evaluated, whether it is a prosthesis with hook or a fully articulated hand prosthesis.

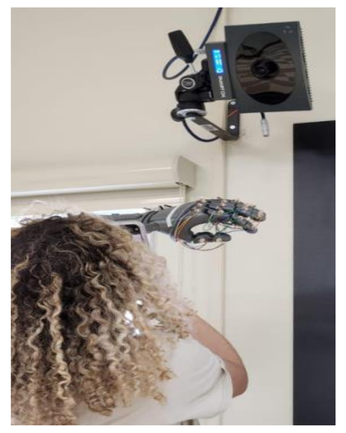
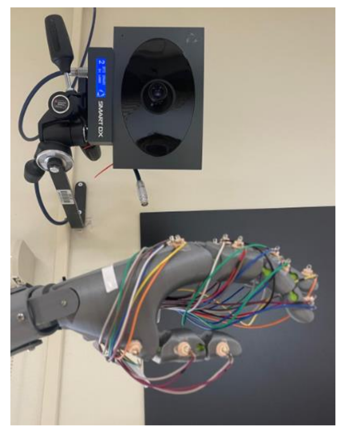



3. Implement an active marker assembly.

4. Evaluate the performance between passive marker set versus active marker assembly in both biological and prosthetic hands.

5. Register the biological and prosthetic hand movement in the execution of flexion and extension of fingers in grasp.

6. Obtain the kinematics of the registers of movement using the biomechanical model selected.
   Kinematics Variables: phalangeal angles of the fingers $\alpha 1$, $\alpha 2$, $\alpha 3$, proximal (knuckles) to distal (tip) assuming 0^{o} at full extension. Thumb only has $\alpha 1$, $\alpha 2$.

7. Compare and analyze the kinematics of the biological hand versus the prosthetic hand.

ANALYSIS AND RESULTS

1 (little finger)			
Internal Angles	Biological Hand	Prosthetic Hand	Difference
α 1	81.1	94.5	13.4
α 2	87.5	146.2	58.7
α 3	86	157.7	71.7

2 (ring finger)			
Internal Angles	Biological Hand	Prosthetic Hand	Difference
α 1	94.9	87.2	-7.7
α 2	81.1	142.8	61.7
α 3	91.1	138.4	47.3

3 (middle finger)			
Internal Angles	Biological Hand	Prosthetic Hand	Difference
α 1	88.2	92.4	4.2
α 2	94.1	119.1	25
α 3	87.3	146.1	58.8

4 (index finger)			
Internal Angles	Biological Hand	Prosthetic Hand	Difference
α 1	96.1	114.1	18
α 2	73.9	117.3	43.4
α 3	94.9	131.4	36.5

5 (thumb)			
Internal Angles	Biological Hand	Prosthetic Hand	Difference
α 1	110.8	134.2	23.4
α 2	99.1	138.2	39.1

After measuring the flexion angles in the phalange joints in both the biological and prosthetic hands, it is observed that the flexion angles in the prosthetic hand differ from the biological hand the more distal it becomes from the metacarpals.

In the prosthetic hand, the thumb's positioning affected the full extent of flexion from the other fingers. Only two flexion angles were measured in the thumb, due to it only containing two phalange joints.

CONCLUSIONS AND RECOMMENDATIONS

The results demonstrate that the flexion angles of the prosthetic hand differ from the flexion angles of the biological hand the more distal it is from the metacarpals. These data will help to improve the design of the prosthetic hand; by changing the thumb's positioning in a way it does not affect the flexion angles of the other fingers. Also, improve the flexion mechanism of the prosthetic hand to reduce the flexion angle difference from the biological hand. A recommendation for a more detailed and clearer capture of the active marker assembly is to bring closer the MOCAP cameras.

FUTURE WORK

The same technique of motion capture can be applied to a larger range of motion of the hand. For example, instead of only measuring the flexion angles of the fingers, the lateral movements of each finger could be measured, as well as the wrist's angles and their relation to the angles of the fingers.

REFERENCES

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