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Modeling Of Human Hand For Robotic Application

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***Abstract*— In this work, modeling of human hand for robotic application is presented. The main objective of developing robotic hands is not intended to replicate actual human hand working principle, but to mimic the kinematics for effective grasping and manipulation performance. Essential features that are found on the human hand was considered in the development of the robotic hand. Such considerations include: lengths of the fingers, applied couplings and degrees of freedom at the joints, the thumb position and the hand kinematics. The hand that was developed in this study was actuated by 12 electric motors which was driven by the Arduino controller. The robot hand considered in this study is meant to serve demonstration purposes only. The links on the hand was made of low-density 3D printed components. The housing of the robot, which contains the control electronics was fabricated from mild steel. The electronics and drive components were bought-out items. After the design and modelling, the robotic hand was 3D printed, low-density material which contributed to lightweight design but reduces mechanical strength. Future designs should explore composite materials for durability.**

***Keywords*— Human Hand, Robotic Application, Actuators, Bionic Hands, Degree of Freedom**

1. Introduction

The human hand is a very important human body part (Romero, Tzionas and Black, 2022). If the human hand is lost through accident or by any other means, its effect on the individual could be devastating. Imagine a person who is the bread winner of a household rendered unable to work to earn a living; the effect could be colossal. Unfortunately, studies show that men are more likely to lose their hand than women (Stroebe and Stroebe, 2021; Rahiem, Rahim and Ersing, 2021; Clement, Bugler and Oliver, 2011).

Historically, a hand amputee only had an option of using a hook prosthesis; this had limited function and there was a significant level of social stigma associated with it (Heli, 2024; Savsani, Singh and Mali, 2023; Oporto-Tejerina and Tapia-Siles, 2023). In the modern society however, advancements in medical engineering has made it possible to have bionic hands that closely resemble the human hand in every way, in appearance and function (Pandarinath and Bensmaia, 2022; Ng, Nazari and Alam 2021; Clement et al, 2011; UNESCO Courier, 2018). Modern bionic hands are lightweight and are driven by battery embedded in it (Akpan, Orazulume and Essien, 2024; Adani, Widasari and Setiawan, 2023; Keogh, 2022). Most limb users can use their hand for at least 8 hours per day, before having to recharge. The actuators that control the hand are driven by electrical ("motor") signals in the human body ((Shoman, Karlsson, and Yeh, 2022; Clement et al, 2011).

In order to contribute to the growing body of knowledge in this bionic hand and hand for robotic applications, this study focus on modeling of human hand along with some aspects of the hand actuation and control mechanisms. The modelled hand is eventually printed using 3D printer.

2. Methodology

2.1 Design and Modelling of the Hand

The main objective of developing robotic hands is not intended to replicate actual human hand working principle, but to mimic the kinematics for effective grasping and manipulation performance. This is due to the fact that packaging constraints hinder the number of actuators that can be used and the robotic mechanism requires the use of technology that is not a biological equivalent. Essential features that are found

on the human hand was considered in the development of the robotic hand. Such considerations include: lengths of the fingers, applied couplings and degrees of freedom at the joints, the thumb position and the hand kinematics.

The robot hand was produced based on dimensions of a typical human hand. The dimensions are as shown in Figure 1. Also, Figure 2 shows a computer-aided 3D model of the human hand derived from the standard range of dimensions of the human hand. The lengths of the hand links was developed based on the dimensions on the CAD model. These dimensions are based on actual measurement of a human hand. The model hand has 24 degrees of freedom which is generated from 19 links, as it is in a typical of a human hand.

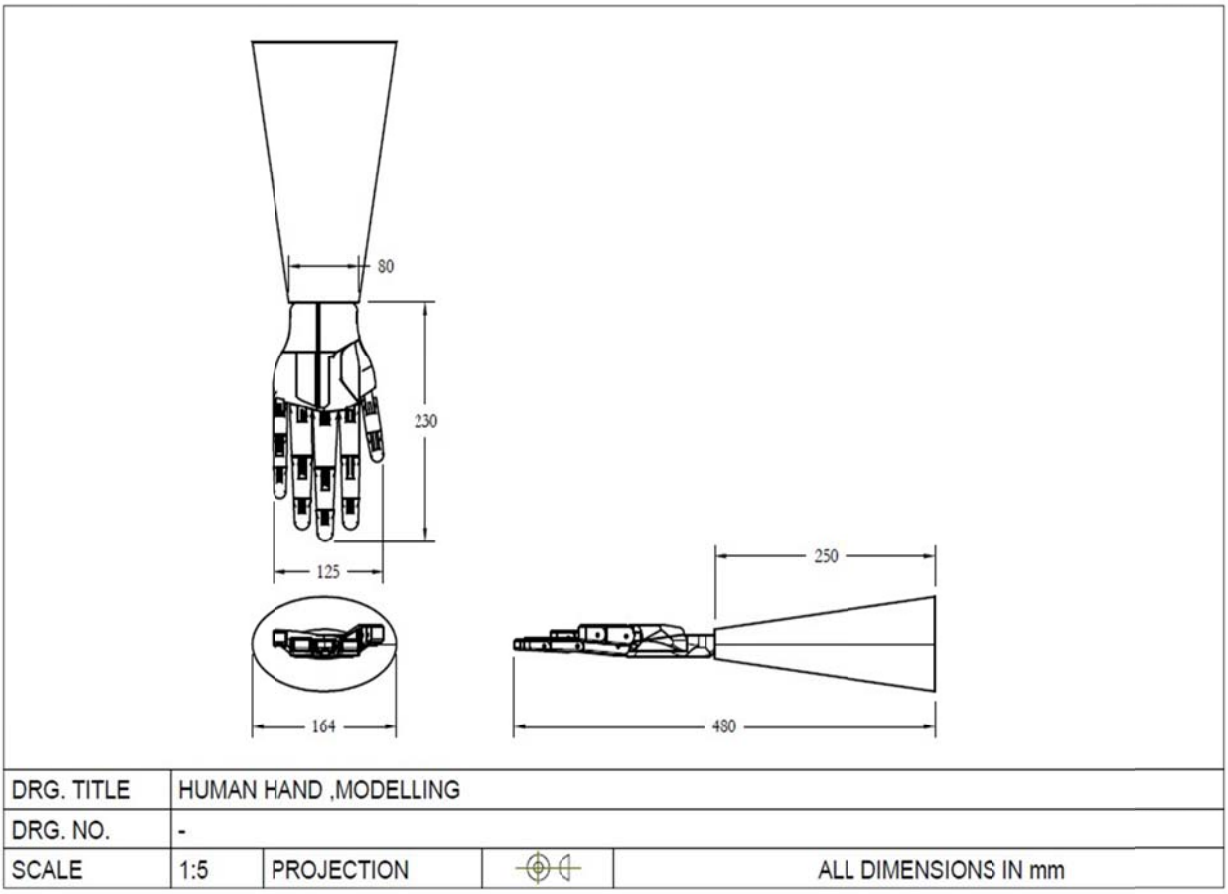

Figure 1: The Dimensions of the Human Hand

Figure 2: The 3D Model of the Human Hand

2.2 The Hand Actuation and Control Mechanism

Antagonistically driven joints have actuators connected to either sides of the joint. Tensioning in this case is provided by the drive train itself. Figure 3. shows the antagonistic actuation method which was implemented in this design. The hand that was developed in this study was actuated by 12 electric

motors which was driven by the Arduino controller. In Figure 3, it can be seen that for each link, two servo motors are used to provide requisite operating force. θ_1 and θ_2 are the angular positions of the first and second motors respectively, where k (δ) represents the stiffness characteristics. P indicates the link position.

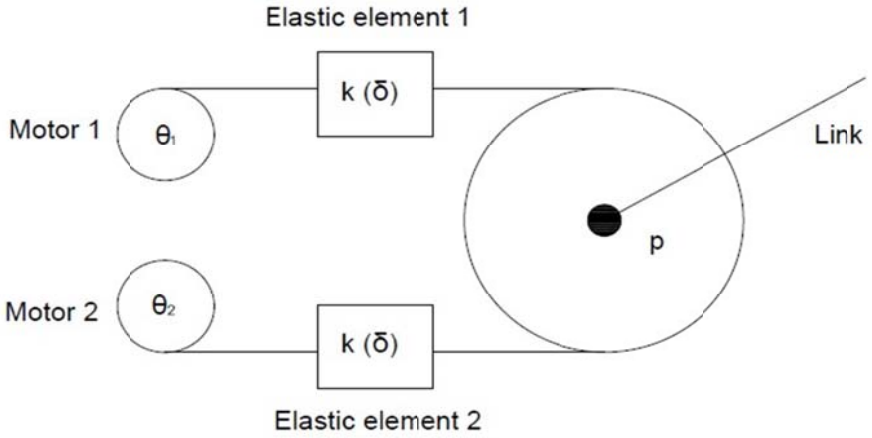

Figure 3.: The Joints Antagonistic Control Scheme

2.3 Materials Selection and Fabrication

The robot hand considered in this study is meant to serve demonstration purposes only. The links on the hand was made of low-density 3D printed components. The housing of the robot, which contains the control electronics was fabricated from mild steel. The electronics and drive components were bought-out items.

3. Results and discussion

After the design and modelling, the robotic hand was 3D printed, as shown in Figure 4. The material used in printing the modelled human hand is a low-density material which contributed to lightweight design but reduces mechanical strength. Future designs should explore composite materials for durability.

Figure 4: The Assembled Human Hand Model

4. Conclusion

The modelling of human hand is presented. Also, some aspects of the hand actuation and control mechanisms are modeled. The modelled hand is eventually printed using 3D printer. Low-density material was used in the printing of the modelled human hand. This contributed to lightweight design but reduces mechanical strength. As such, it is recommended that future designs should explore composite materials for durability.

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