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Abstract

This research presents a computational–biomechanical development of a patient-specific myoelectric prosthetic hand based on tomographic segmentation. Anatomical reconstruction of healthy and amputated hand segments was performed to generate accurate digital models used for parametric design integration. Geometric refinement and surface optimization enabled the generation of high-fidelity STL models suitable for biomechanical analysis and digital fabrication. The proposed framework establishes anatomical reference points that ensure geometric congruence, functional articulation, and biomechanical compatibility with patient. This approach demonstrates the feasibility of integrating medical imaging, reverse engineering, and computational design to produce personalized prosthetic solutions with enhanced anatomical fidelity and functional adaptability.

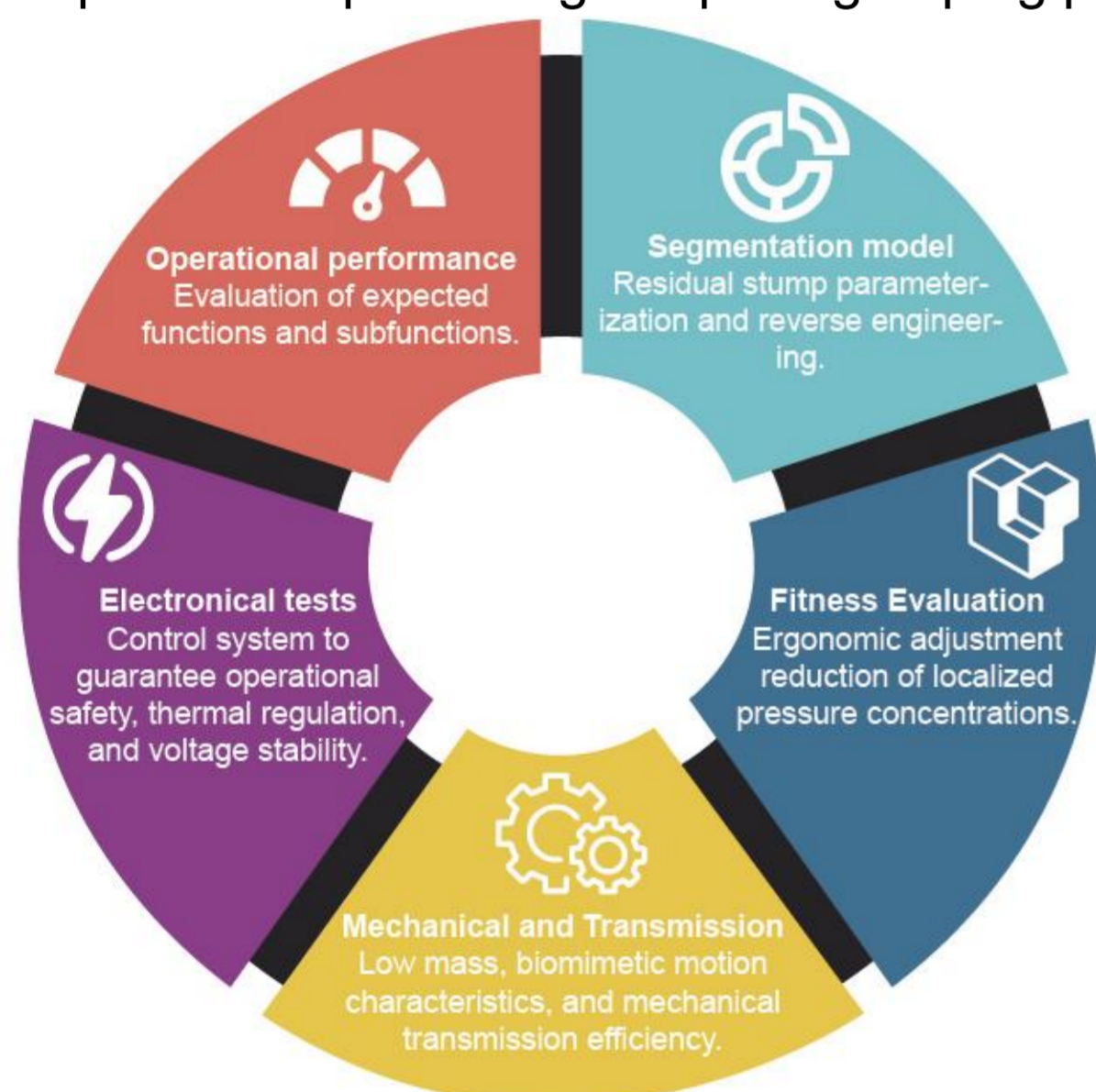
Keywords: Myoelectric prosthesis, reverse engineering, tomography segmentation, parametric design.

Introduction

Upper-limb amputations compromise over 40% and 80% motor functionality, biomechanical performance, and quality of life. Commercial myoelectric prostheses frequently present limitations associated with limited ergonomic adaptation, insufficient anthropomorphic congruence. These limitations often contribute to reduced usability and increased cognitive adaptation requirements in amputee patients. [1] Reverse engineering methodologies, and additive manufacturing have enabled the development of personalized prosthetic systems with improved anatomical compatibility. [2]

Methodology

Reverse engineering and biomechanical design methodologies for the development of an anthropomorphic myoelectric prosthesis capable of reproducing adaptive grasping patterns.



The methodology is a process that employs creative and biomechanical tools to support decision-making and is oriented toward solutions that address the end-user needs. [3]

Mechanical Design and Methods

Prosthetic geometry was developed from anatomical segmentation and CAD parametrization from upper-limb morphological analysis. Anthropomorphic adaptation was optimized through geometric congruence criteria between the residual limb and the prosthetic interface. The congruence index was evaluated using volumetric and surface-comparison metrics to quantify anatomical compatibility.

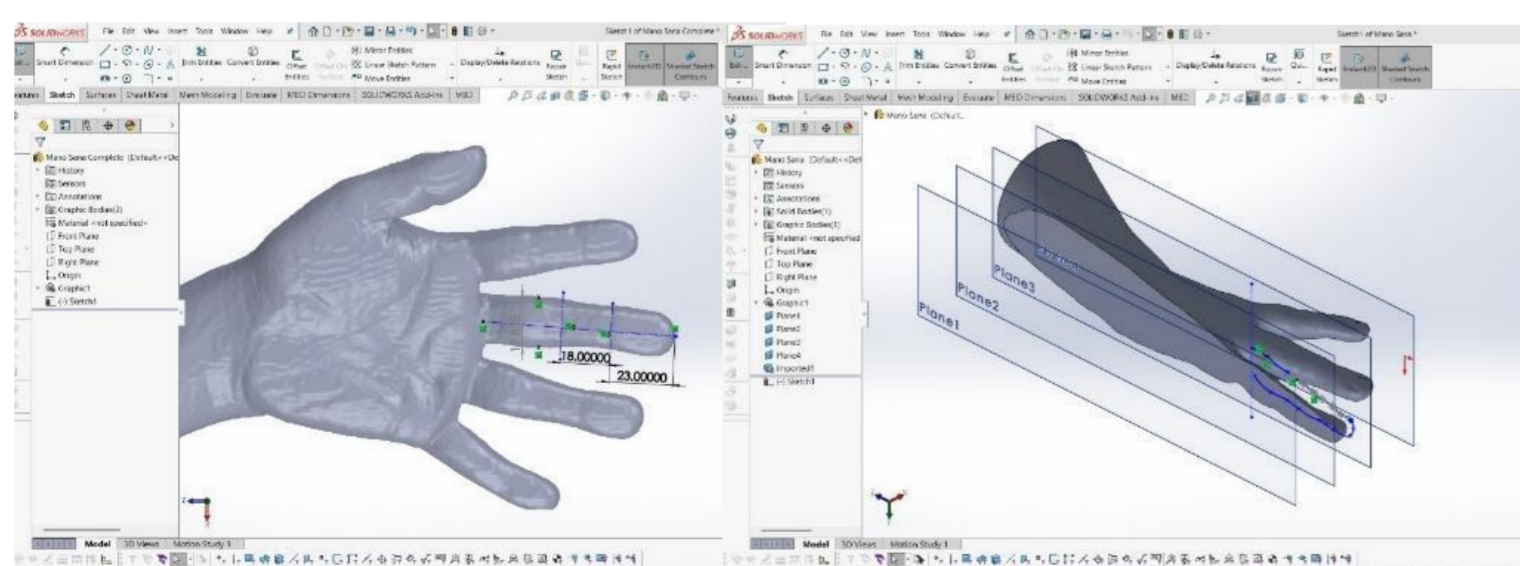


Fig. 1. Segmentation and anatomical reference of healthy hand.

An ergonomic fitting index was defined as the ratio between effective contact area and total expected contact area, allowing the evaluation of pressure distribution and anatomical coupling efficiency.

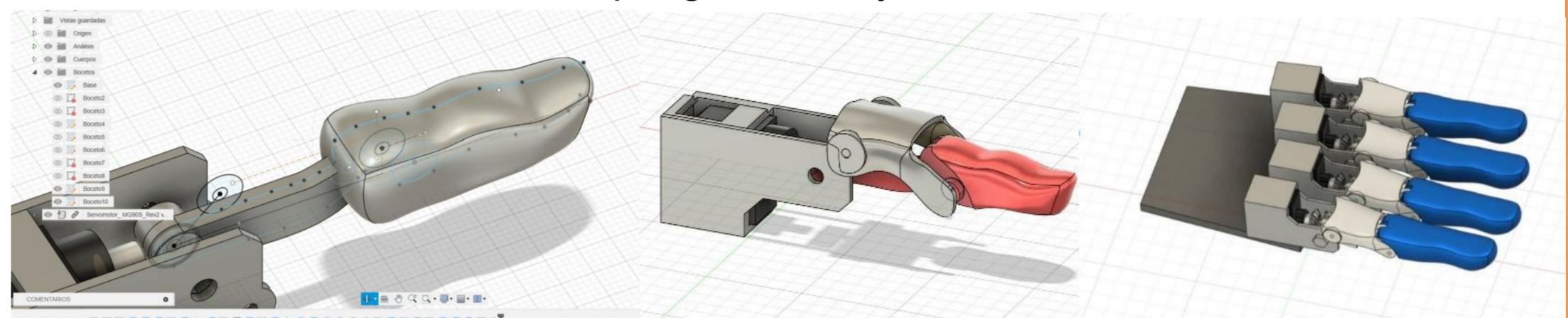


Fig. 2. Parametric modeling of the phalanges and hand assembly.



Fig. 3. Anatomical fitting and Arduino code for control tests.

- High-torque digital servomotors (~25 kg·cm)
- Arduino Nano microcontroller incorporate EMG signal acquisition and analog-to-digital conversion. DC-DC Buck converters to reduce electrical noise and improve actuator stability. [3]
- 2S Li-ion battery configuration with integrated Battery Management System protection to guarantee operational safety, thermal regulation, and voltage stability. [4]
- Control and torque tests for proper operation under consistent loads for safer indirect contact with the user.
- 1.0 mm Dyneema fiber for tendons. Optimal balance with its capabilities, precision, low elongation, low friction and optimal resistance according to the safety margin. [5]

Evaluation of 1.0 mm diameter (1.0 mm → ~300–400 N)

$$F_s = 300 / 81.6 = 3.67$$

$$F_s = 400 / 81.6 = 4.9$$

$$81.6 / 300 = 27\%$$



Fig. 4. Dyneema UHMWPE fiber for tendons.

Results

- Demonstrated biomechanical compatibility and anthropomorphic adaptability. Geometric validation indicated improved congruence between the prosthetic interface and residual limb geometry, contributing to enhanced ergonomic adjustment and reduction of localized pressure concentrations.
- The electronic system achieved stable EMG signal acquisition with reduced noise interference due to independent power regulation. Furthermore, the proposed power-distribution strategy minimized erratic actuator behavior caused by transient current peaks.
- The tendon-pulley transmission system exhibited favorable mechanical efficiency due to the low elongation characteristics. The transmission can reproduced adaptive grasping patterns including cylindrical grasp, pinch grasp, claw grasp, and index-pointing configurations.

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