# Anthropomorphic robot hand design

Design and Ergonomics of the Medical Products

Faculty of Biomedical Engineering

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## Contents

# 1 Prosthetic design

Although my original idea was different, which is described in the last subsection, I decided to sculpt a forearm prosthesis according to my own hand. Since I am working on a project where we are developing software to fusion and reconstruct images from 3D scanners and I have a couple of them borrowed at home, I used one to scan my hand. The process of scanning and prosthesis creation is further discussed in the following two subsections.

## 1.1 Scanning and preprocessing

Scanning my left hand around with my other hand was one of the more challenging tasks of this project. Scanned model can be seen in the Figure 3. After scanning the hand, I corrected the appropriate artifacts, holes, etc. in

(a) Raw scan

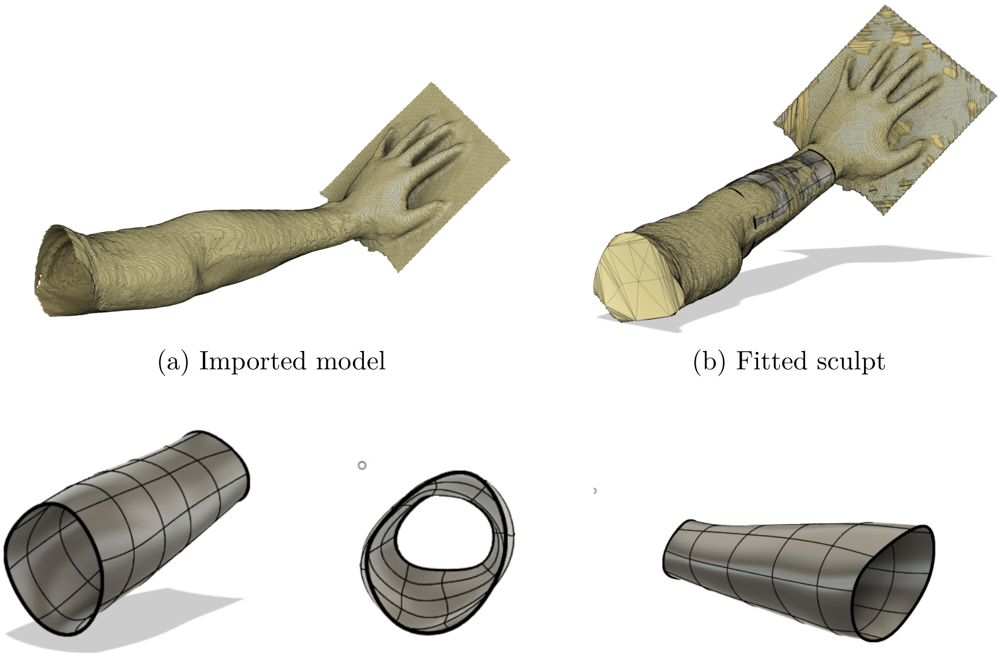
(b) Edited scan

Figure 1: Scanned models

the *Sense* software, while cropping the scan to just the desired piece. The resulting model was then exported to stl format and imported into *Fusion360* software.

## 1.2 Sculpting

After importing the model of my hand, I started sculpting. It was not a special process. I chose and measured the part I was going to model according to my hand. I then created a cylindrical form around that part, which I edited to the shape of the forearm. The fitted form can be seen in the Figure 2b. Unfortunately, I did not pay much attention to this prosthesis after modelling

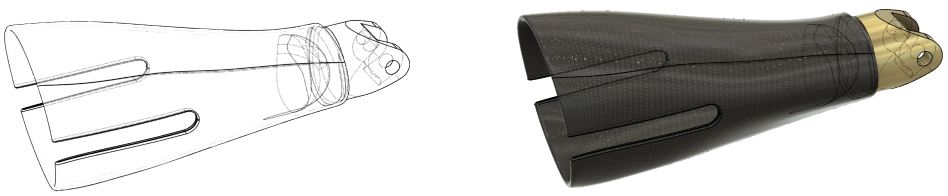


(a) Imported model (b) Fitted sculpt

(c) Perspective view (d) Back view (e) Side view

Figure 2: Forearm sculpting according to imported model

it, especially in terms of some stress tests in conjunction with the choice of suitable material or perhaps the use of generative design. I miss these things myself and plan to revisit them in the future. I am attaching at least the final form with a simple wrist joint. Since in this concept the design of a wrist with at least two degrees of freedom is a relatively simple matter, I didn't pay much attention to it because my original idea was completely different.

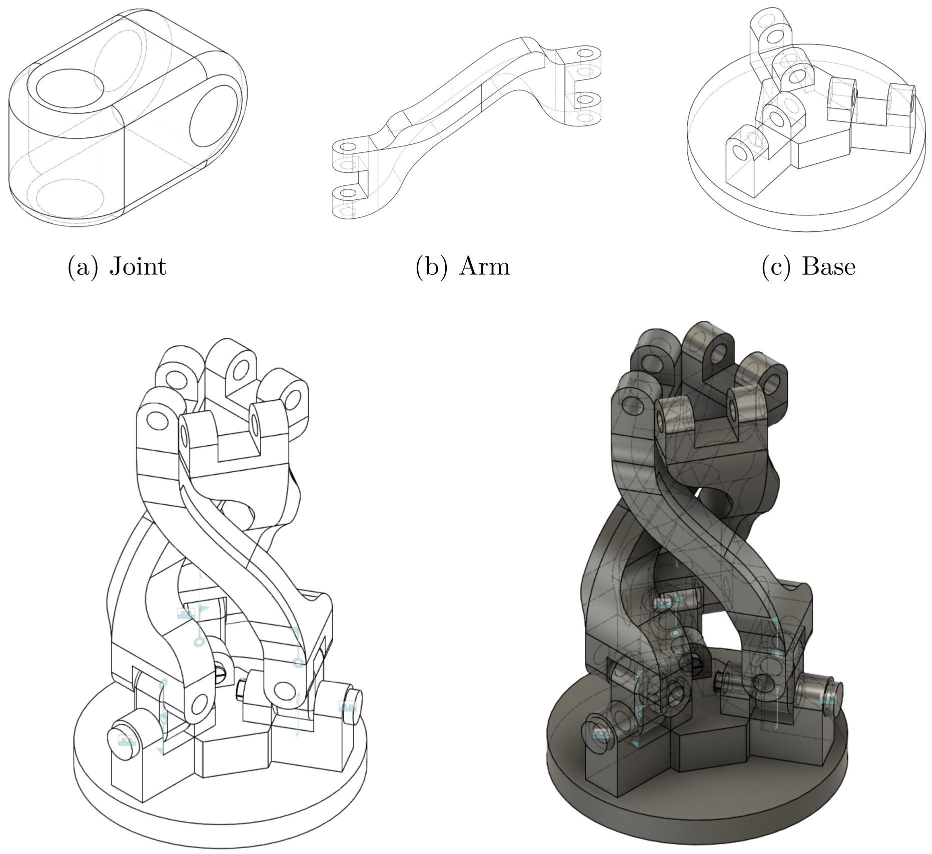


(a) Blueprint (b) Model

Figure 3: Final model of the forearm prosthesis

## 1.3 Original idea

My original plan was inspired by the *LIMS2-AMBIDEX* mechanical wrist design with three degrees of freedom [1]. I tried to change the design a bit, make it smaller and simpler. But since I didn't have time for that, I switched to a version with a prosthesis. I have made some basic parts though and they can be seen in the Figure 4.



(a) Joint (b) Arm (c) Base

(d) Assembly blueprint (e) Assembly

Figure 4: Forearm mechanical design

# 2 Anthropomorphic robot hand design

There have been ongoing attempts in the industry to produce anthropomorphic robot hands for a variety of applications. Many people have been paying attention to prosthetic robot hands, especially since there are so many upper limb amputees. Electric motors with reduction gears are commonly used as actuators in these robot hands but they have a general disadvantage in terms of mobility and compactness, which is essential for prosthetic devices. Given that an adult hand weighs around 400g and can generate a maximum gripping force of 400N with a flexion speed of 2,290 degrees per second, electrical motors with reduction gears are far too heavy and unwieldy to match the human hand's capability. To tackle this challenge, a variety of actuators have been used in the construction of the robot hand, including shape memory alloy, super-coiled polymers, pneumatic, and hydraulic actuators [2–4].

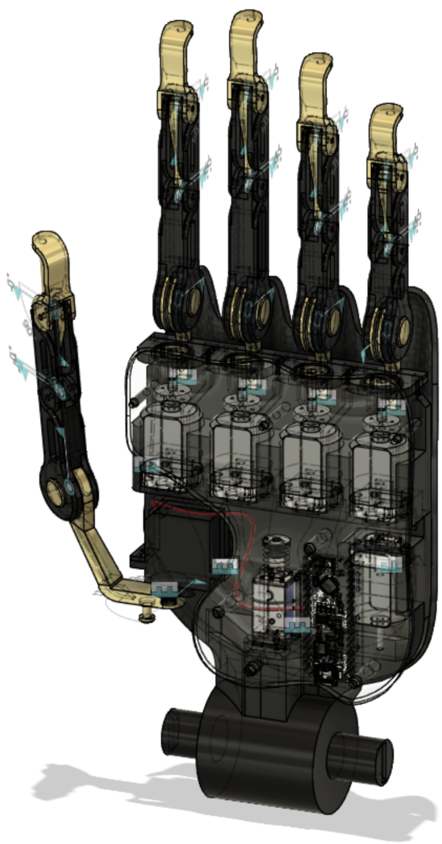


Figure 5: Hand design

## 2.1 Active dual-mode twisted string actuation mechanism

As part of my research into existing studies on anthropomorphic robot hands, I have tried to come up with a new concept that presents a simpler locking mechanism for the main motor twisting string actuation mechanism (TSA) and eliminates the need for extra clutch motors. The TSA is mechanically simple and light since it does not utilize stiff gears. I've sketched most of the concepts and that's why I'll use them here even though they make the most sense to me (I'm no Davinci). Since I'm much more into design

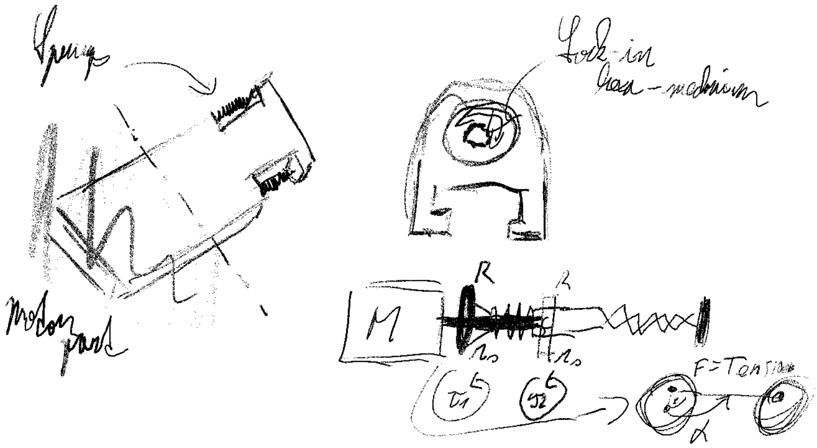


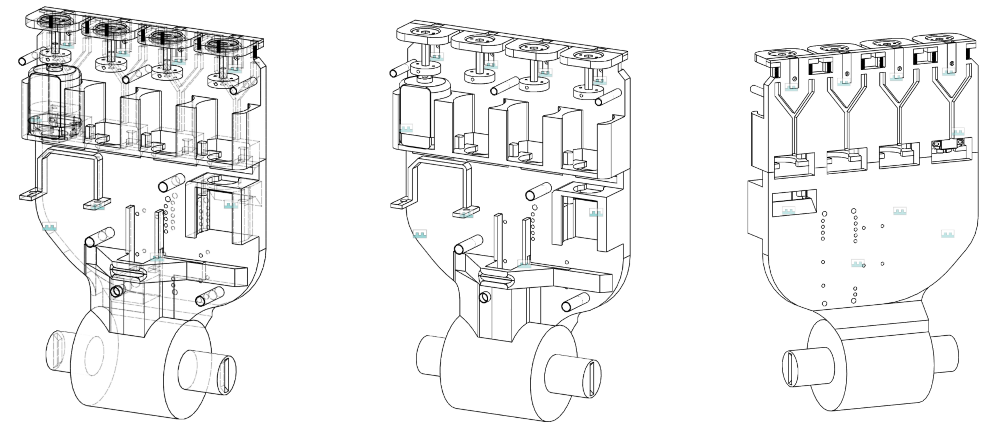

Figure 6: First concept of a TSA locking mechanism

optimization than modeling, this reflects a lot on the progress of the model itself. So I missed a lot of modelling and spent much more time on theory and optimization, which I will outline here. In most cases it is more or less the basics of mechanics and biomechanics. One wonders what all can actually be calculated after converting it into a simplified beam system. The torsional moments applied to the main shaft and the locking gate in our system without clutch motor can be expressed as follows:

$$\tau_1 = (R + r_s) \cdot F_t \cdot sin\ \alpha$$
$$\tau_2 = (R + r_s) \cdot F_t \cdot sin\ \alpha - r_s \cdot sin\ \alpha$$

Then it is easy to calculate things like the maximum tension of the string or its necessary length for individual sections of the mechanism system. Anyway, I'm not going to overwhelm this with the formulas and mechanics that the internet is full of and I'd rather move on to the pictures that everyone likes. In

Figure 7 you can see the base for the arm with the motors hidden except for one, the first one. The locking mechanism works on the principle of applying



(a) Front view outlined (b) Front view (c) Back view

Figure 7: Arm base with locking mechanism

pressure to the springs that hold the locking gate off the hexagonal key of the shaft. In this case, the mechanism is in speed mode. Otherwise, when pressure is exerted on the springs via the tension rods at the rear of the base, the gate will move towards the motor and the hexagonal shaft will engage the gate and lock it. Then the rope torsion occurs in case of adduction behind the gate and the mechanism is in force mode.

## 2.2 Four-bar linkage finger mechanism

A four-bar linkage is the simplest closed-chain movable linkage in mechanics. It is made up of four bodies, known as bars or links, that are linked together in a loop by four joints. The joints are usually set up such that the links move in parallel planes. I used this four-bar mechanism in the design of the fingers. Simply put, the movement of the distal interphalangeal joint (DIP) depends on the movement of the proximal interphalangeal joint (PIP). On the one hand, we will relieve the stress acting on the distal phalanx within the rope and the join, but on the other hand, we will increase the stress acting on the new joints used by the linkage bar, which must be taken into account in the design.

While modeling the finger, however, I missed one important thing that I carry in my mind. It's all about kinematics and dynamics. Whether it would be some benchmarks of the finger mechanism or other real analysis, it

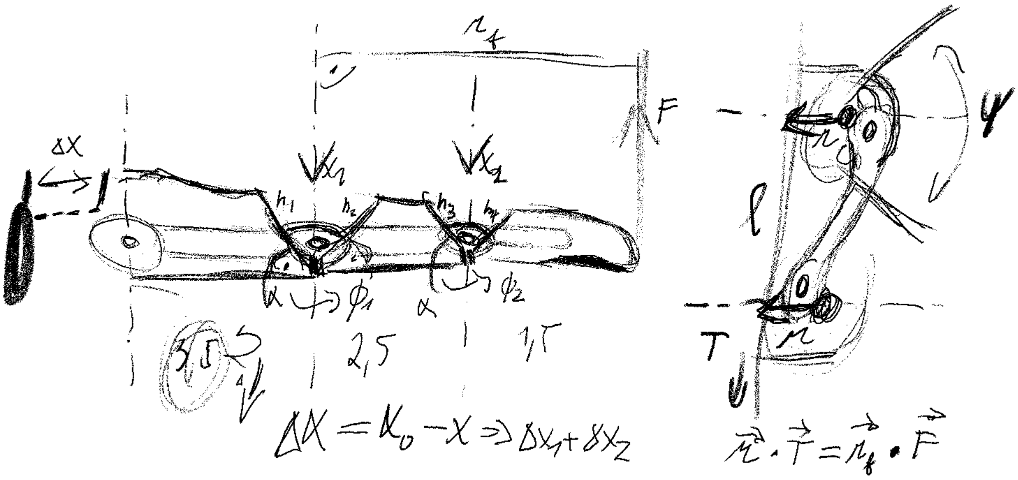
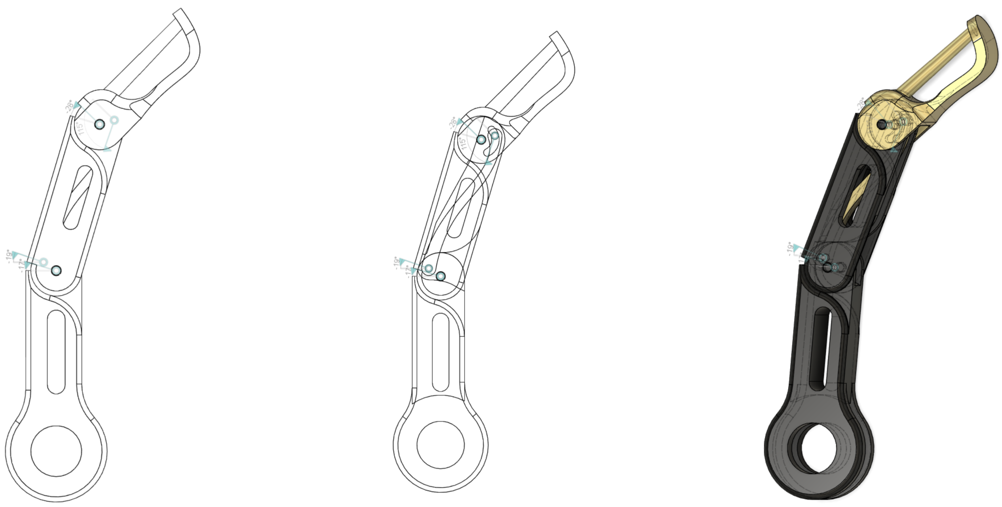



Figure 8: Concept of a finger mechanism

would be useful to use rotary encoders within the joint and also some force sensor. Mainly it would bring a lot of advantages in terms of mathematical modeling, because then we can simply derive for example the bending angles of each joint caused by string contraction, as well as the relationship between fingertip force, string tension, and joint angles.



(a) Side view (b) Side view outlined (c) Model side view

Figure 9: Finger final design

Figure 9 shows the final design of the finger. However, this is only their skeleton not their final form. My idea is that I would like to create some stylish covers for them as well, to add some aesthetics and a futuristic look. Maybe I'm just playing too much Deus Ex and this way it would even be enough, who knows.

## 2.3 Motion of metacarpophalangeal joint

Unfortunately, in my current design, metacarpophalangeal (MCP) joints have a limited range of motion. So limited, in fact, that there is none. However, I have devised a locking mechanism for the next version, which I would like to first think about and simplify and finally apply. So far, I am trying to optimize and derive the optimal parameters of the differential mechanism according to the abduction motion of the MCP joint.

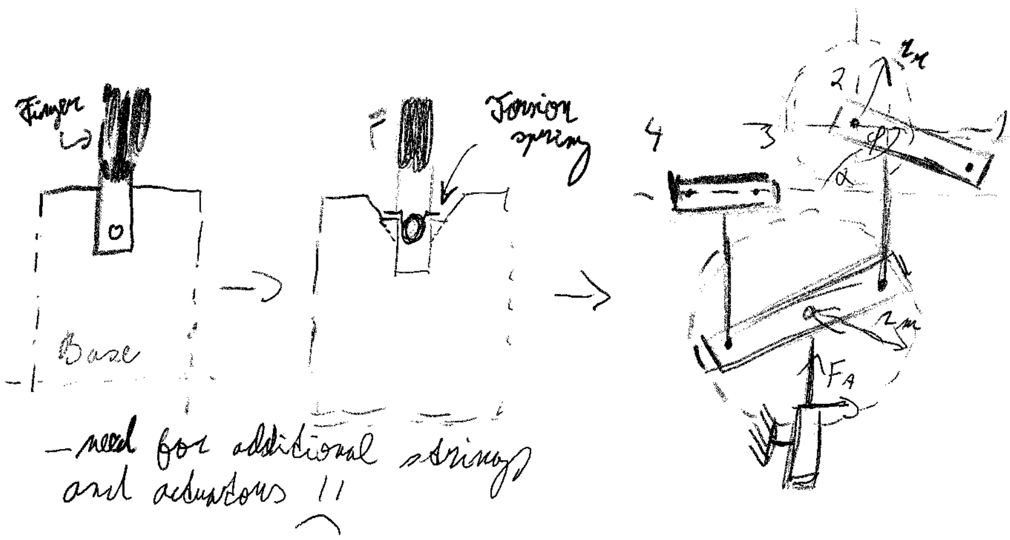


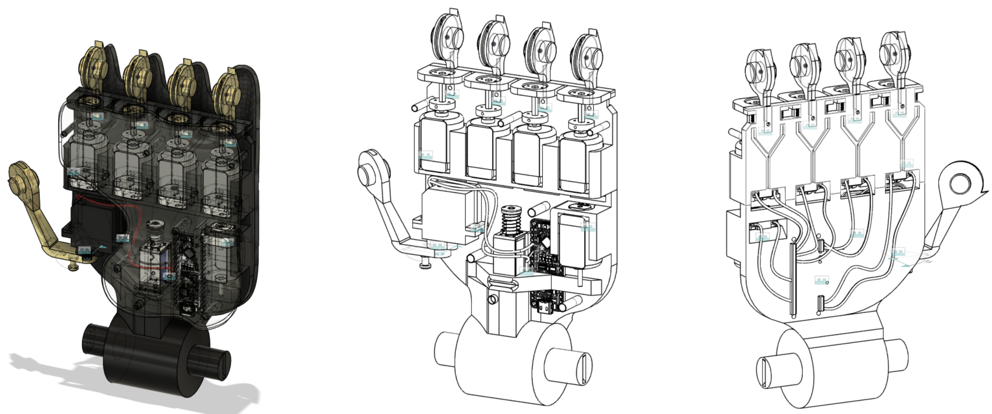

Figure 10: Concept of a MCP joint motion

This approach will require the use of additional strings (tendons) and probably also actuators that will act as antagonists to the tension of the main motors. Alternatively, one extra actuator could be used to create a joint locking mechanism for each MCP at the torsion spring, and by kinematic analysis we can build a model and calculate what force ratio will be needed at a particular locked joint to get a specific resulting MCP abduction by solving a nonlinear equality constraint optimization scheme.

## 2.4 Thumb design

As for the thumb design, I probably neglected it the most because I did it at the end and didn't have time to think and model it properly. I have a worm gear idea in my head but I'll probably save that for the summer. For one thing, the thumb doesn't need to be fast and therefore doesn't need to use the TSA mechanism but it needs to be robust as well as its mechanism.

In my current concept I just conveniently connected it to the servo and rotated it roughly to handle contact and grip with all fingers. Otherwise, as a finger itself, it has the same range of motion as the other fingers except for the trapeziometacarpal joint.



(a) Model front view (b) Front view outlined (c) Back view

Figure 11: Arm base with thumb

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