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3D PRINTED PROSTHETIC FINGER: DESIGN, MODEL AND SIMULATION

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ABSTRACT

This report gives details on design, model and simulation for a 3D printed prosthetic finger using Ultimaker 2+ printer at the robotics lab. The primary objective for this finger is to help those missing on 1 or 2 knuckles and make it functional. The design files originally came from the OpenSCAD which were then loaded on the Cura Ultimaker 2+ sd card to start printing the parts layer-by-layer. The basic technique behind the printing is FDM where PLA is raw material used. The aluminum wire is used to pin the knuckle joints and the elastic cord to connect one knuckle to the other to give flexibility. Finally, a linkage is attached to the finger via a fishing line and a band to give the desired movements to the finger.

1. NOMENCLATURE

FDM – Fused Deposition Modelling
PLA – Polylactic acid
D.O.F. – Degrees of Freedom
WHO – World Health Organization

2. INTRODUCTION

3D printing also called as additive manufacturing has become more significant in healthcare since the last decade. Prosthetics can involve a lot of work and expertise to produce and fit and the WHO says there is currently a shortage of 40,000 trained prosthetists in poorer countries. There is also the time and financial cost to patients, who may have to travel long distances for treatment that can take five days – to assess their need, produce a prosthesis and fit it to the residual finger or limbs. The result is that braces and artificial fingers and limbs are among the most desperately needed medical devices. However, technology may be hurtling to the rescue – in the shape of 3D printing. Thus, 3D printing is an easy, cheap, fast and functional method towards producing prosthetics. The parts can be printed with much ease and cost will also be on a lower end.

3. METHODS

3.1. Design

The design for the prosthetic finger was taken from the open source which is free to use, create and modify. To start with modifying the existing files you first need to take measurements for both the left full finger and the right residual finger for which the prosthetics is designed. From figure 1, the finger measurements were taken with precision to create a perfect fit for the prosthetics. These measurements were then used as an input for the OpenSCAD software which generated a 3D view of the various parts to be created as showed in figure 2. Once the views are created the files are exported as an STL file which then acts as an input for the Cura 3.0.4 software for the Ultimaker 2+ 3D printer.

3.2 Calibration

Before started to print the parts the print head nozzle and the built plate needs to be calibrated so that the error minimizes. To calibrate the built plate, the calibration card is used to make the surface even that way the first layer is nicely squished into the glass plate and sticks well. If the distance between the nozzle and build plate is too big, your print will not stick properly to the glass plate. While under extrusion appears, it is recommended to use the Atomic Method to clean the nozzle and other hot end parts. This method is done using a transparent filament which is inserted in the nozzle and allowed to melt until a clear transparent filament is seen coming out from the nozzle.

3.3. Methods

Usually a robotic hand model uses a four-link manipulator to simulate hand movement. In this case, a simplified model of a robotic finger is used after Berceanu et al [3] (Figure 3). This proposed model uses a three-link manipulator with three revolute joints (3 D.O.F.). Link “0” considers the palm of the hand and it has no movement. Also, no lateral movement is considered at angle θ1, simplifying inverse kinematics calculations.

Static model was created in MATLAB to simulate the actual measurements for a normal left-hand finger, and right-hand prosthetic finger. As shown in Figure 4, right-hand prosthetic finger has a link 1 (in red color) longer than left-hand finger link 1. There is a difference of 1.4 cm between both fingers; therefore, right hand prosthetic finger having a greater total length.

In Figure 5, two workspaces were created using the left-hand finger and right-hand prosthetic finger. (a) The two individual workspaces are shown. (b) Workspaces were overlapped on same plot, and the left-hand finger workspace (blue contour line) was move forward and extruded to see the right-hand prosthetic finger workspace on the back of the plot. Clearly, there is a difference between both workspaces that needs to be minimized by determining the optimum length for the middle and top section of prosthetic finger.

Three dynamic models using inverse kinematics, created in MATLAB, were used to illustrate to find the optimum middle and top section of prosthetic finger. For all models, three constraints were used for the angle theta: θ1 = 0 to π/2, θ2 = 0 to π/2, θ3= 0 to π/4. In addition, the left-hand workspace is used as the baseline to determine the optimum length.

4. RESULTS

On Figure 6, a dynamic model uses the normal length measurements of the left-hand finger, and matches it perfectly inside the workspace as intended. The length of links are as follows: a1 = 5.0 cm, a2 = 2.8 cm, and a3 = 2.5 cm.

On Figure 7, a dynamic model uses the normal length measurements of the right-hand finger. Clearly this model illustrates the right-hand prosthetic finger is not matching the workspace, indicating the length is not the optimum length, and needs adjustments. The length of links are as follows: a1 = 6.4 cm, a2 = 3.2 cm, and a3 = 2.0 cm.

On Figure 8, a dynamic model uses the normal length measurements of the right-hand finger. In addition to the angle theta constraints, the total length of the three links is fixed at a value of 10.3 cm, and the length of link 1, a1, at a fixed value of 6.4 cm. Clearly this model illustrates the right-hand prosthetic finger is within the workspace, indicating the length is an optimum length. The length of links are as follows: a_1 = 6.4 cm, a_2 = 1.5 cm, and a_3 = 2.4 cm.

5. LESSONS LEARNED

After assembling the prosthetic finger, we noticed there was a measurement error in the middle section length of the prosthesis. To avoid time and material to 3D print, we decided to create a static and dynamic model using MATLAB. For future work, we need to create a model of prosthesis and simulate its motion before assembling the parts together.

6. FUTURE WORK

1. Automatically optimize length of middle and top section using MATLAB
2. Re-design of prosthetic finger using SolidWorks

ACKNOWLEDGEMENTS

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FIGURES

Figure 1. Finger measurements

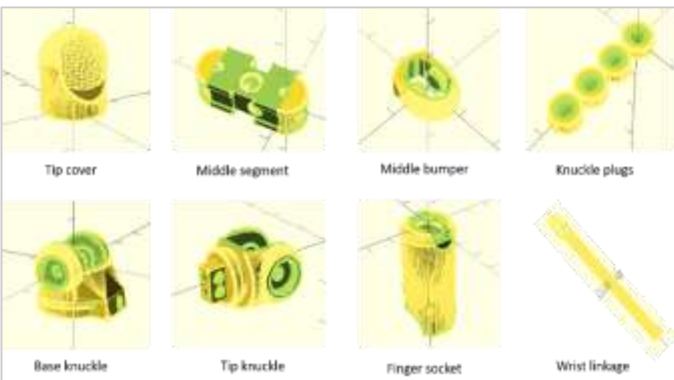

Figure 2. 3D view assembly parts from OpenSCAD

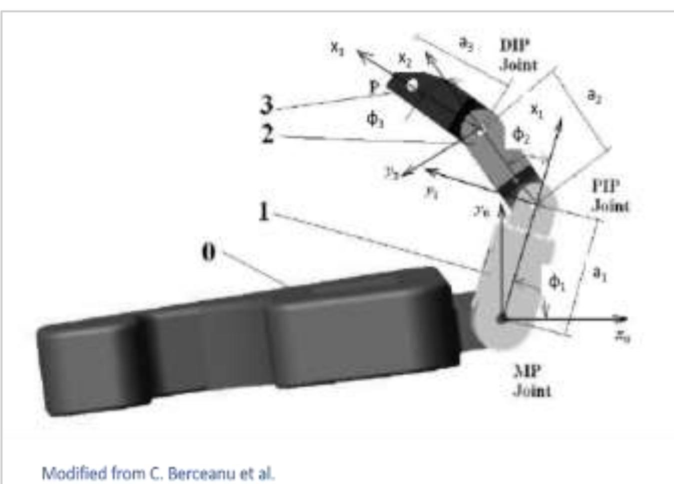

Figure 3. Literature proposed finger static model

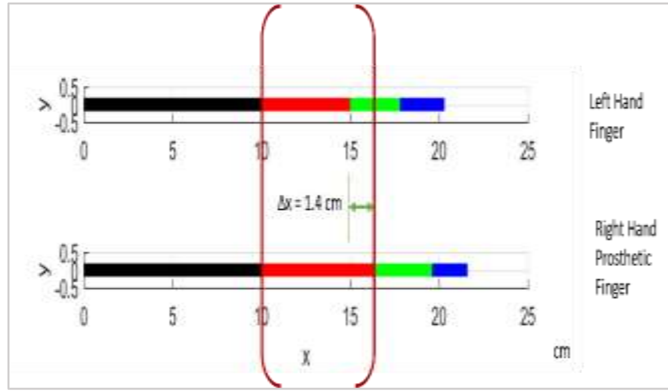

Figure 4. MATLAB static model with finger measurements

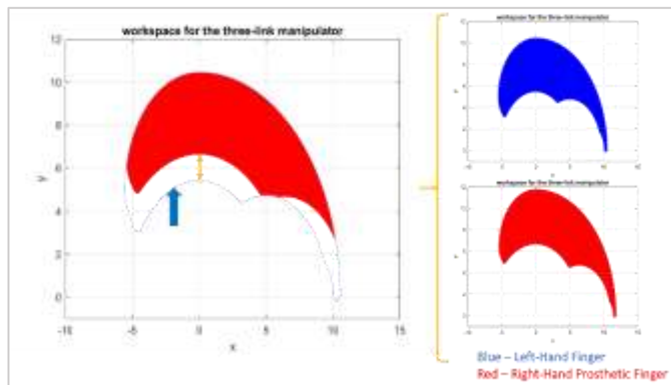

Figure 5. MATLAB created finger workspaces

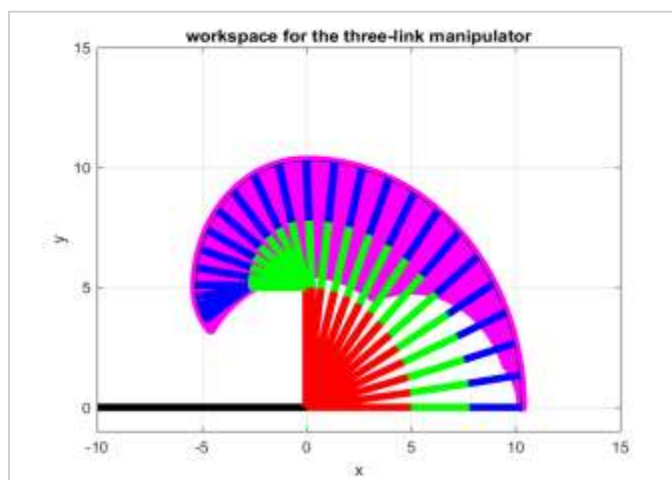

Figure 6. Left-hand finger (normal length) dynamic model

Figure 7. Right-hand prosthetic finger (longer middle section) dynamic model

Figure 8. Right-hand prosthetic finger (optimum design) dynamic mode