Analytical Analysis: Finger Simulation

By: Jannell Broderick

Team: ActiveProsthetic

Section: 005

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Department of Mechanical Engineering
Northern Arizona University
Flagstaff, AZ 86011

1.0 Introduction

This analysis pertains to the position and velocity of each of the fingers of the hand. This is important to the project because the fingers need to be able to grab objects with proper speed and force. The energy used by the motors to produce the velocity of the fingers translates to work. It is also important to know the velocity of the fingers in order to understand response time. In a human body, nerve responses go to and from the brain very quickly. For the active prosthetic the response time will be slower but will still need to be efficient. The motors that power the movement of the fingers and attached to artificial tendons. The tendons are threaded through the fingers and when pulled will move the joints.

2.0 Assumptions

In order to analyze the fingers, many assumptions must be made. First, each segment of the fingers will be treated as rectangles and plotted on the graph as straight lines. This will simplify the motion of the fingers and place the center of mass at the middle of each segment. It was also assumed that each segment starts at the end of the other and there are no gaps in each joint. The middle and distal segments are not jointed but piece that is angled. It is also assumed that the fingers will only bend in one direction.

3.0 Equations of Motion

Since there are many joints in each finger finding the position of each segment becomes challenging. However, the positions can be found if the length of each (l) and the flex angle is known.

$$X = l * cos(\theta) \tag{1}$$

$$Y = l * sin(\theta) \tag{2}$$

Using equations 1 and 2 and the vector tail to tip trick, each segment of the finger can be correctly placed. The segments are represented by vectors in the x and y directions. When placed end to end, the vectors form the entire finger. This was completed for each finger. The results show the finger positions at several different angles within the range of motion.

The following is a sample of code that shows the vectors forming Digit 1.

```
n=100;

B_1_X = 0:(B_1*cos(Theta_B_1))/(n-1):B_1*cos(Theta_B_1); %(in) %Posistion in X of
Rotating Base
B_1_Y = 0:(B_1*sin(Theta_B_1))/(n-1):B_1*sin(Theta_B_1); %(in) %Posistion in Y of
Rotating Base

P_1_X = B_1_X(1,end):(P_1*cos(Theta_P_1))/(n-1):B_1_X(1,end)+P_1*cos(Theta_P_1); %(in)
%Posistion in X of Proximal Segment
P_1_Y = B_1_Y(1,end):(P_1*sin(Theta_P_1))/(n-1):B_1_Y(1,end)+P_1*sin(Theta_P_1); %(in)
%Posistion in Y of Proximal Segment

M_1_X = P_1_X(1,end):(M_1*cos(Theta_M_1))/(n-1):P_1_X(1,end)+M_1*cos(Theta_M_1); %(in)
%Posistion in X of Distal Segment
```

```
M_1_Y = P_1_Y(1,end):(M_1*sin(Theta_M_1))/(n-1):P_1_Y(1,end)+M_1*sin(Theta_M_1); %(in)
%Posistion in Y of Distal Segment

D_1_X = M_1_X(1,end):(D_1*cos(Theta_D_1))/(n-1):M_1_X(1,end)+D_1*cos(Theta_D_1); %(in)
%Posistion in X of Distal Segment
D_1_Y = M_1_Y(1,end):(D_1*sin(Theta_D_1))/(n-1):M_1_Y(1,end)+D_1*sin(Theta_D_1); %(in)
%Posistion in Y of Distal Segment

%Connecting finger segments end to end
Length_X_1 =length(B_1_X)+ length(P_1_X)+length(M_1_X)+length(D_1_X );
X_1 = zeros(1,Length_X_1);
X_1(1:length(B_1_X))= -(B_1_X);
X_1((length(B_1_X)+1):(length(B_1_X)+length(P_1_X)))= -(P_1_X);
X_1((length(B_1_X)+length(P_1_X)+1):(length(B_1_X)+length(P_1_X)+length(M_1_X)))= -
(M_1_X);
X_1((length(B_1_X)+length(P_1_X)+length(M_1_X)+1):Length_X_1)= -(D_1_X);
X_1 = X_1 -1;

Length_Y_1 =length(B_1_Y)+ length(P_1_Y)+length(M_1_Y)+length(D_1_Y);
Y_1 = zeros(1,Length_Y_1);
Y_1(1:length(B_1_Y))= B_1_Y;
Y_1((length(B_1_Y)+1):(length(B_1_Y)+length(P_1_Y)))= P_1_Y;
Y_1((length(B_1_Y)+length(P_1_Y)+1):(length(B_1_Y)+length(P_1_Y)+length(M_1_Y)))= M_1_Y;
Y_1((length(B_1_Y)+length(P_1_Y)+length(M_1_Y)+1):Length_Y_1)= D_1_Y;
```

This was done for each of the fingers. It was plotted to physically show the segments attached.

The center of mass and tips of each finger were found by taking the middle and end of each vector. These positions are also plotted as asterisks and circles respectively.

Once the position of the center of mass and segment ends are found, then the velocity can be determined.

$$V = \frac{dx}{dt} \tag{3}$$

The velocity calculation is the change in position over the change in time. In the code, the final and initial positions of each segment can be extracted and divided by the motor rotation time.

$$a = \frac{dV}{dt} \tag{4}$$

In this case, it can be assumed that the motor rotates at a constant speed. Therefore, so do the fingers. Thus, the acceleration would be equal to zero.

4.0 Results

The results for the position of the fingers can be seen in the figure below. The figure shows the various positions that the fingers can be based on the range of motion of the human hand. The Digits can be seen in various colors. In addition, the center of masses and the end points are displayed in the figure with asterisks and circles respectively.

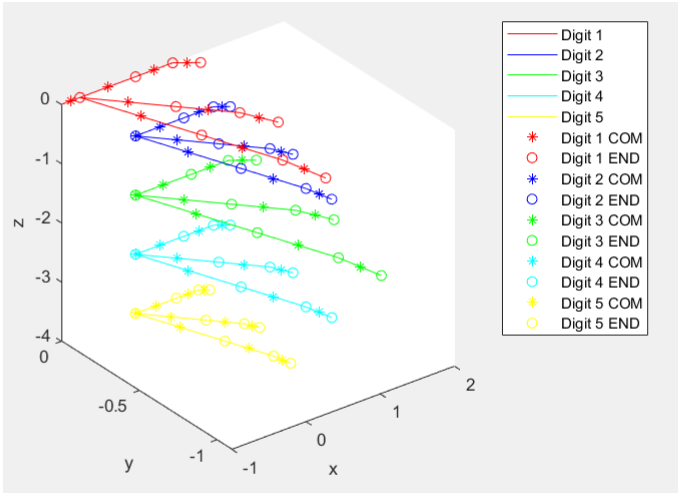

Figure 1: Position of the Digits at Various Joint Angles

The MATLAB Code shows the positions of the fingers at different positions. Over time, each finger will cycle through a few positions within the range of motion and produce the Figure1. The number of positions was kept to a small number to prove the effectiveness of the code and also keep the code from taking large amounts of time to calculate the positions.

Knowing the positions of the fingers is vital in finding the velocity. Unfortunately, the code was not finished in time to incorporate the velocity calculations. This will be done by taking the change in position and dividing it by time. (The position calculations took longer than expected. There were many fingers and I was trying to show their movement over a range of angles.)

Reference

All information is either common knowledge or own work.