**EGR 182 section B —Introductory Mathematics for Engineering Applications**

**Lab 2: Applications of Trigonometry and Robotics**

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**Abstract**

This lab assignment used the software program, MATLAB. It focused on how to use MATLAB as a calculator, with lots of hands-on examples. In this lab students were to use a board with a two-link robot arm to determine different angles. This board was used to take a rough estimate of what the lengths angles were. Also, used in the lab is a NAO robot to measure the distance of the left arm by inputting the shoulder and elbow angles. Then, MATLAB was used to define the actual distance through calculations.

**Introduction**

Engineering students at California Baptist University (CBU) need to use this tool in many of their courses. The first objective was to find the measurements of each angle and the second one was to find the correct angle. Both of these objectives were to be found manually from a board and then also to be found using MATLAB.

**Experimental Setup**

The setup was very simple. Students would first become familiar with the use of the manual planar robot board. This board is used to find different angles with different lengths depending on different preferences. Once the given points are found using the correct angles and length using the manual board, students were then to use MATLAB to get the precise angle and length when inputted into the software.

**Results and Discussion**

The recurring theme within both labs 2A and 2B was finding data by both finding measurements in person and comparing them to data captured with calculations. For all of the data, the calculated data is almost exactly like the measured data. The only calculation that was found to be farthest from the measured value was in the lab 2B portion which was x’ or -137.0018. From the 2A portion, Table 1 can be seen with almost the exact same measurements as the measured with the farthest being x or 86.6025mm. Table 2 has measurements that are almost equal as well. In the 2B portion, Table 1 contains data that displays that the measured x and y are similar measurements to the measurements calculated through Matlab. And table 2 was found with the robot's help after inputting certain values to find the inverse kinematics for the shoulder and elbow angles.

Lab A Tables

**Lab 2A Table 1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Angle (degrees) | Measured x (mm) | Measures y (mm) | Calculated x (mm) | Calculated y  (mm) |
| 30 | 85mm | 50mm | 86.6025mm | 50mm |
| 135 | -70mm | 70mm | -70.70.7107mm | 70.7107mm |
| 240 | -50mm | 85mm | -50mm | -86.6025mm |

**Lab 2A Table 2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| x,y (mm) | Measured L  (mm) | Measured Angle  (degrees) | Calculated L  (mm) | Calculated Angle  (degrees) |
| 55,55 | 77mm | 40 | 77.79mm | 45 |
| -20,-75 | 77mm | 255 | 77.62mm | -104.93 |

**Lab 2A Table 3**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Theta1  (degrees) | Theta1  (degrees) | Measured Values (mm) | | | | | | Calculated values (mm) | |
| Angle 1 | Angle 2 | x1 | y1 | x2 | y2 | x1+x2 | y1+y2 | x | y |
| 0 | 0 | 50mm | 0mm | 50mm | 0mm | 100mm | 0mm | 100mm | 0mm |
| 30 | 45 | 43mm | 25mm | 12mm | 47mm | 55mm | 72mm | 56.2422mm | 73.2963mm |
| 270 | 30 | 0mm | -50mm | 24mm | -42mm | 24mm | -92mm | 25mm | -93.3013mm |

**Lab 2A Table 4**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| X input (mm) | Y input (mm) | Angle 2 (degrees) | Alpha (degrees) | Beta  (degrees) | Angle 1 (degrees) |
| 55 | 75 | 43.1136 | -95.4567 | 4.7579 | 100.2146 |
| 35 | 15 | 135.2349 | 54 | 0.4569 | -53.5359 |

Lab 2B tables

**Lab 2B Table 1**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Measured | (mm) | Calculated | (mm) |  |  |
| Θ1 (°) | Θ2(°) | x | y | x’ | y’ | x | y |
| -15 | -60 | 136 | -119 | 130.8499 | -137.0018 | 134.7322 | -122.5129 |
| 0 | -2 | 217 | 0 | 218.6307 | -3.9681 | 218.6307 | 11.0319 |
| 30 | -30 | 196 | 61 | 204.6327 | 52.5000 | 197.1327 | 65.4904 |

**Lab 2B Table 2**

|  |  |  |
| --- | --- | --- |
| P (x, y) (mm) | Θ1 | Θ2 |
| (135, -120) | -11° | -62° |
| (175, -40) | 13° | -61° |
| (215, 10) | 6° | -14° |

**Conclusion**

This lab was finished in 2 parts. The first part was completed using a One-Link Planar robot arm. Different angles and lengths that were given were measured. This was completed by either a given angle to find the desired lengths or by a given x,y coordinates to find a desired length and angle.

The second part of the lab was completed using basic concepts of robotic kinematic functions using the Robot NAO. Only the left side of the arm and elbow was used in this experiment. The needed movements were performed by the NAO robot using LArmSetJoint, Shoulder angle and Elbow angle functions. For both experiments MATLAB was used to formulate the code to process the correct outputs.

**Appendix**

**Matlab M Files**

**Lab 2A**

function [x,y] = ex1polar2rec(l,theta)

x = l \* cosd(theta)

y = l \* sind(theta)

end

function [theta,l] = ex1rec2polar(x,y)

theta = atan2(y,x);

theta = theta \* (180 / pi)

l1 = cosd(theta) \* x;

l2 = sind(theta) \* y;

l = l1+l2

end

function [x, y] = ex2 (l\_1,l\_2,theta\_1, theta\_2)

theta = theta\_1 + theta\_2;

x1 = l\_1 \* cosd(theta\_1);

y1 = l\_1 \* sind(theta\_1);

x2 = l\_2 \* cosd(theta);

y2 = l\_2 \* sind(theta);

x = x1 + x2

y = y1 + y2

end

function [theta\_1, theta\_2,alpha,beta] = ex3(l\_1,l\_2,x,y)

r = sqrt((x^2)+(y^2))

theta\_2 = 180 - acosd(((l\_1^2)+(l\_2^2)-(r^2))/(2 \* l\_1 \* l\_2))

alpha = r / (sin(180 - theta\_2))

beta = tan(y/x)

theta\_1 = beta - alpha

end

clear all

clc

%% Appendix 2A

% This file will be where the output of each function is located

%% ex1polar2rec

% Output of polar2rec function

e1 = ex1polar2rec(100,30);

e2 = ex1polar2rec(100,135);

e3 = ex1polar2rec(100,240);

%% ex1rec2polar

% Output of rec2polar function

e3 = ex1rec2polar(55,55);

e4 = ex1rec2polar(-20,-75);

%% ex2

% Output of ex2 function

e5 = ex2(50,50,0,0);

e6 = ex2(50,50,30,45);

e7 = ex2(50,50,270,30);

%% ex3

% Output of ex3 function

e8 = ex3(50,50,55,75);

e9 = ex3(50,50,35,15);

**Lab 2B**

%%

clear all;

clc;

UpperArmLength=105;

LowerArmLength=55.95;

HandOffsetX=57.75;

ElbowOffsetY=15;

L1 = UpperArmLength

L2 = LowerArmLength + HandOffsetX

theda1= -15

theda2= -60

x1 = L1\* cosd(theda1)

y1 = L1\* sind(theda1)

x2 = L2\* cosd(theda1 + theda2)

y2 = L2\* sind(theda1 + theda2)

x = x1 + x2

y = y1 + y2

ElbowOffsetY=15;

xx = x - ElbowOffsetY \*sind(theda1)

yy = y - ElbowOffsetY \*cosd(theda1)

%% Lab2B Table 1 Row 1

x1= l1 \* cosd (theda1)

x1 =

101.4222

y1 = l1 \* sind (theda1)

y1 =

-27.1760

x2 = l2 \* cosd(theda1 + theda2)

x2 =

29.4277

y2 = l2 \* sind (theda1 + theda2)

y2 =

-109.8258

xx1= x1+x2

xx1 =

130.8499

yy1= y1+y2

yy1 =

-137.0018

xxx1= 130.8499 - 15 \* sind(theda1)

xxx1 =

134.7322

yyy1= -137.0018 - 15 \* cosd(theda1)

yyy1 =

-122.5129

%% Lab2b Table 1 Row 2

x11= l1 \* cosd(theda11)

x11 =

105

y11= l1 \* cosd(theda11)

y11 =

0

x22 = l2 \* cosd(theda11 + theda22)

x22 =

113.6307

y22 = l2 \* sind(theda11 + theda22)

y22 =

-3.9681

xx11= x11+x22

xx11 =

218.6307

yy11= y11+y22

yy11 =

-3.9681

xxx2= 218.6307 -15 \* sind(theda11)

xxx2 =

218.6307

yyy2= -3.9681+15 \* cosd(theda11)

yyy2 =

11.0319

%% Lab2b Table 1 Row 3

x111 = l1 \* cosd(theda111)

x111 =

90.9327

y111 = l1 \* sind(theda111)

y111 =

52.5000

x222= l2 \* cosd(theda111+theda222)

x222 =

113.7000

y222 = l2 \* sind(theda111+theda222)

y222 =

0

xx111= x111+x222

xx111 =

204.6327

yy111= y111+y222

yy111 =

52.5000

xxx3= 204.6327 -15 \*sind(theda111)

xxx3 =

197.1327

yyy3= 52.5000 +15 \*cosd(theda111)

yyy3 =

65.4904