Robot Mechanisms and User Interfaces WS22/23

MDP Final Report
submitted to

Chair of Autonomous Systems and Mechatronics

Faculty of Electrical Engineering

Friedrich–Alexander University

by

MDP Group 20

Asad Syed, Mat.No. 23237717
Vinoth Kumar, Rangaraj, Mat.No. 23173765
Abhilash Ujwalkumar Dandhare, Mat. No.23215686
Vishal Vilas Shendge, Mat. No. 23230920
Rhitik Raj, Mat.No. 23231655

Date of Submission: January 30, 2023

Professor:
Prof. Dr.-Ing. Philipp Beckerle

Supervisor:
Mehmet Ege Cansev, M.Sc.

Contents

1. Introduction, description and motivation

Introduction:

The purpose of this report is to present the design and implementation of a haptic portable controller for a KUKA robot which is connected with a drilling machine as end effector. The device is designed to enhance the operator's control over the robot and provide haptic feedback through Electromagnetic Field (EMF). The haptic controller is intended to control the position of the KUKA robot end effector and perform drill holes on a wooden plaque. The design of the device incorporates an EMF generation system that is regulated according to the force at the end effector. The poles of the EMF are designed to initiate a repulsive behavior with the permanent magnet in the thumb of the operator, providing resistance to the operator when pressing the drill actuation button. The device also includes a glowing LED on each push button to provide visual indication and glowing diaplay which indicated the drilling operation. The report covers the design and integration of the device with the robot, and includes a comprehensive evaluation of its performance. The compact design of the device allows for easy integration with the robot and the buttons and visual display are positioned for easy access by the operator. The report provides an in-depth analysis of the device's design and implementation.

Description:

The hand held haptic controller is ergonomicaly designed with injection modled plastics which features to easily held by the operator.

The haptic device is a handheld controller with a simple kinematic structure. The controller has buttons that allow the operator to control the robot's movement and rotation. To provide haptic feedback, the controller has an actuator that generates vibrations when the robot's end effector comes into contact with the wooden plaque. Additionally, the controller has a visual display that indicates the position of the robot's end effector, which can be useful for the operator to know about the end effector's position in relation to the wooden plaque.

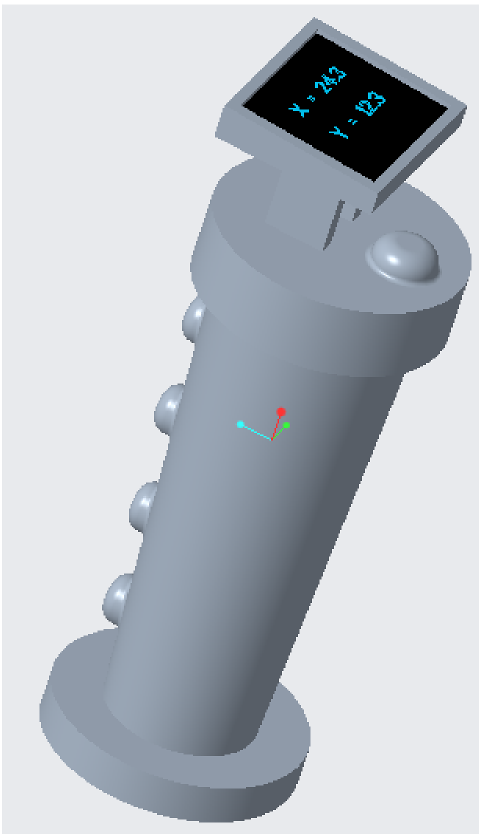
Motivation:
The integration of haptic devices with robots can enhance the capabilities of the robot and improve the precision and intuitive control of the robot. The use of haptic feedback in this device can also increase the quality of physical interaction between the operator and the robot, which can be particularly useful in tasks such as drilling holes in a wooden plaque. The use of low-cost materials and simple kinematic structure makes this design an affordable solution for small-scale projects. Overall, the goal of this project is to design and implement a haptic device that is compliant with the robot's specifications, provides haptic feedback and enhances the operator's control over the robot, all while being affordable.

2. <u>Overview of the design</u>

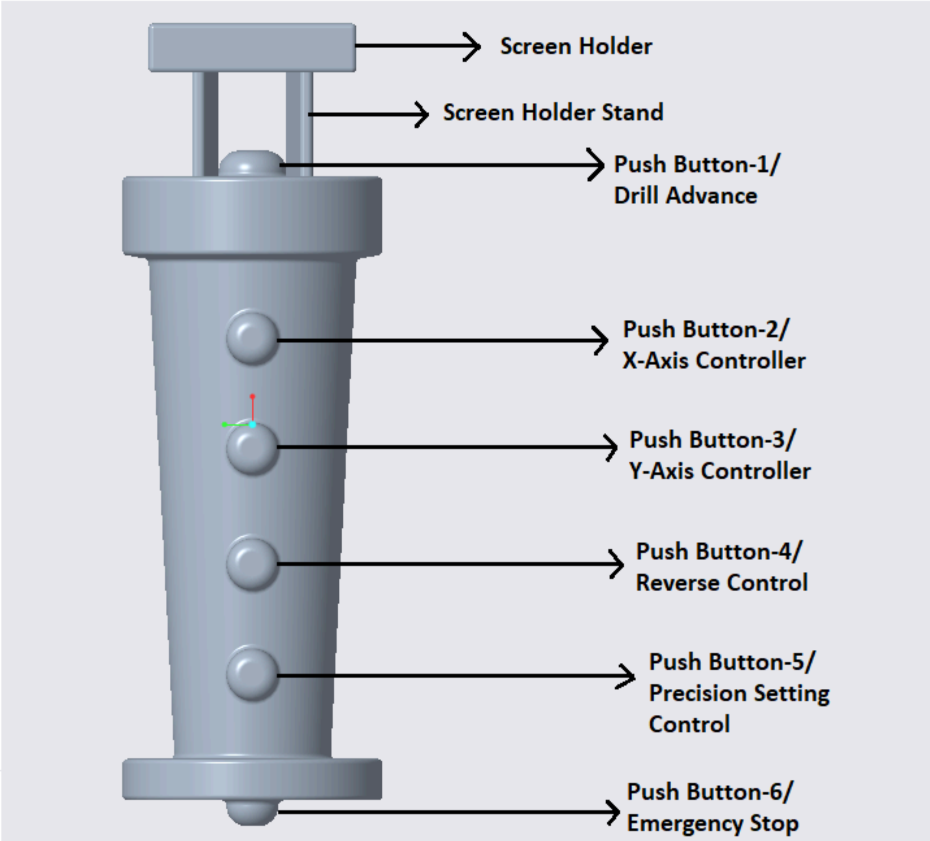
We are designing a haptic portable controller which controls the position of the KUKA robot end effector and makes drill holes on the wooden planque. The operator can move the robot end effector to the required position by pressing buttons on the controller. Additionally, the controller features a visual display that shows the location of the robot's end effector. Knowing the end effector's location in respect to the wooden plaque can be helpful for the operator to precisely reach the desired location.

In this section, the design of a system is presented with an overview of its functional structure. We have designed our Haptic controller device using Creo Parametric - 10 . Visual elements, such as 3D drawings that are included to describe the subsystems of the hardware and software. The design specifications, such as lengths, weights, torques, and resolution of the components to be arrived based on the requirements.

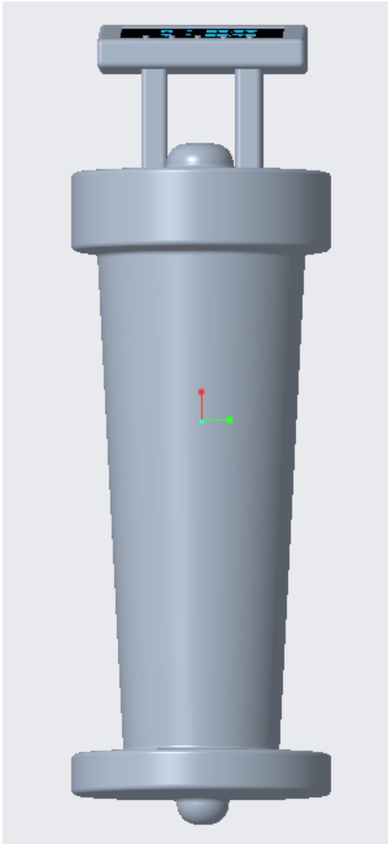
<u>Design diagrams with views</u> :



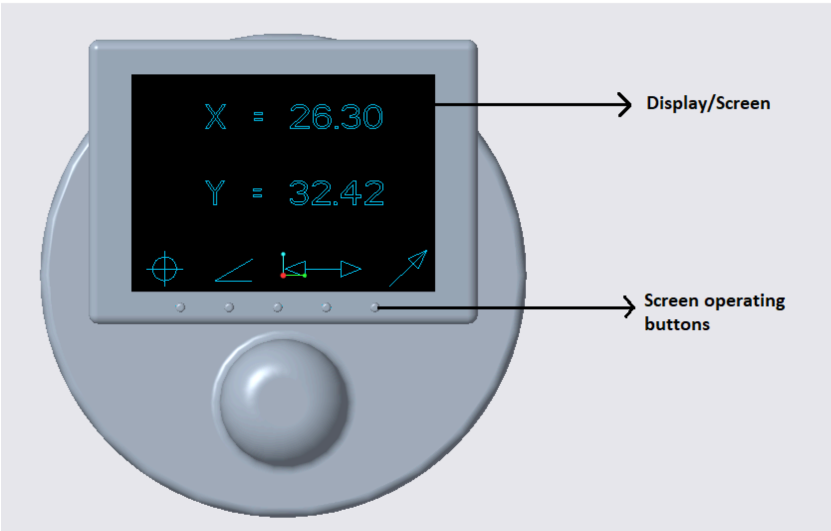
Isometric View



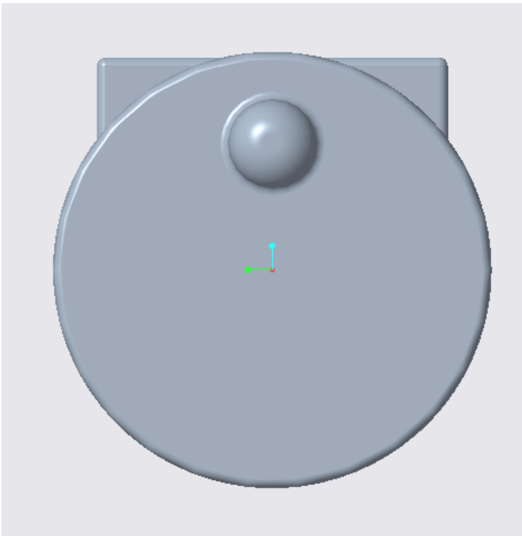
Front View



Back View



Top View



Bottom View

Description :

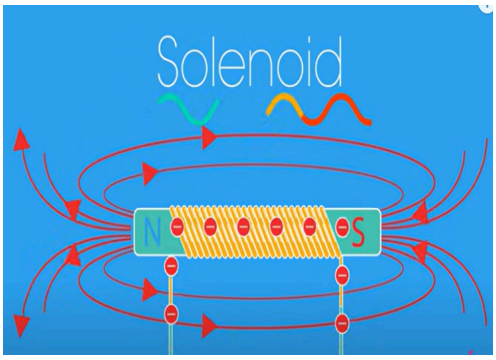
1. Push Button-1: This button is used for advancing the drill bit attached to our KUKA robot's end effector towards the work piece. Operator will be provided with a special thumb cover which will be having specified magnetic pole exposed to top of this button when pressed for advancing this drill bit.

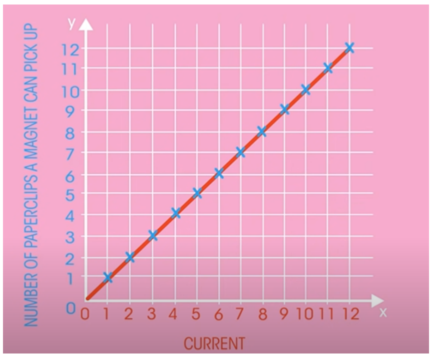
   This push button was enabled with a special EMF Generator whose poles are defined in such a way it generates a repulsive force with the permanent magnet which is housed in the thumb cover.

   End effector force will be estimated as described in section 2.3 and current to the EMF Generator will be regulated to vary the repulsive force. This repulsive force results in Haptic feedback to the user making the drill with this Haptic Controller.

   Haptic Checks

   1. When the drill is advanced without touching wooden planque -> No force at the end effector -> No current to the EMF Generator -> No repulsive force -> No Haptic Feedback -> No light activation on the display (For Visual indication)
   2. When the drill is touching and advancing in the wooden planque -> Force on the end effector keeps on increasing -> Current to the EMF Generator proportional increases with respect to Force -> Repulsive force increases proportionally -> Variable Haptic Feedback -> Repulsive force pushes operator thumb resisting from pushing the button -> Light on the display indicates user the drilling is active





2. Push Button-2: This button is used to move the drill bit in the X-axis in order to make sure. It judges the Time of contact establishment increase the value of X in positive direction.

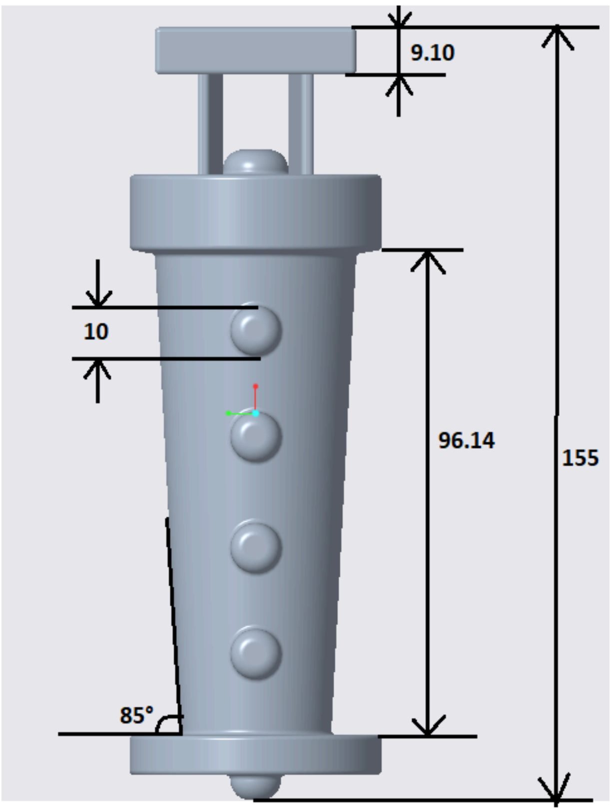
3. Push Button-3: This button is used to move the drill bit in the Y-axis in order to make sure. It judges the Time of contact establishment increase the value of Y in positive direction.

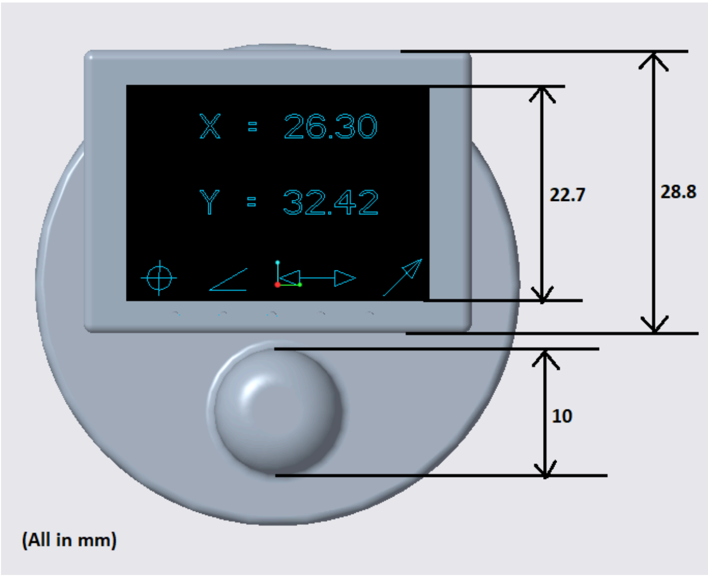
4. Push Button-4: This button is used to reverse the direction of X & Y i.e., after pushing this button once and use buttons 2&3, they will move in negative directions.

5. Push Buton-5: This button is used for precision setting. The instructions for using this button are as follows:
   1 press -> 0.01mm
   2 press -> 0.1mm
   3 press -> 1mm
   Long press 1 Sec -> 10mm
   Long press 2 sec ->100 mm

6. Push Button-6: This is an Emergency stop button. When we press this button, whatever the operation is going on stops immediately.

Specifications :

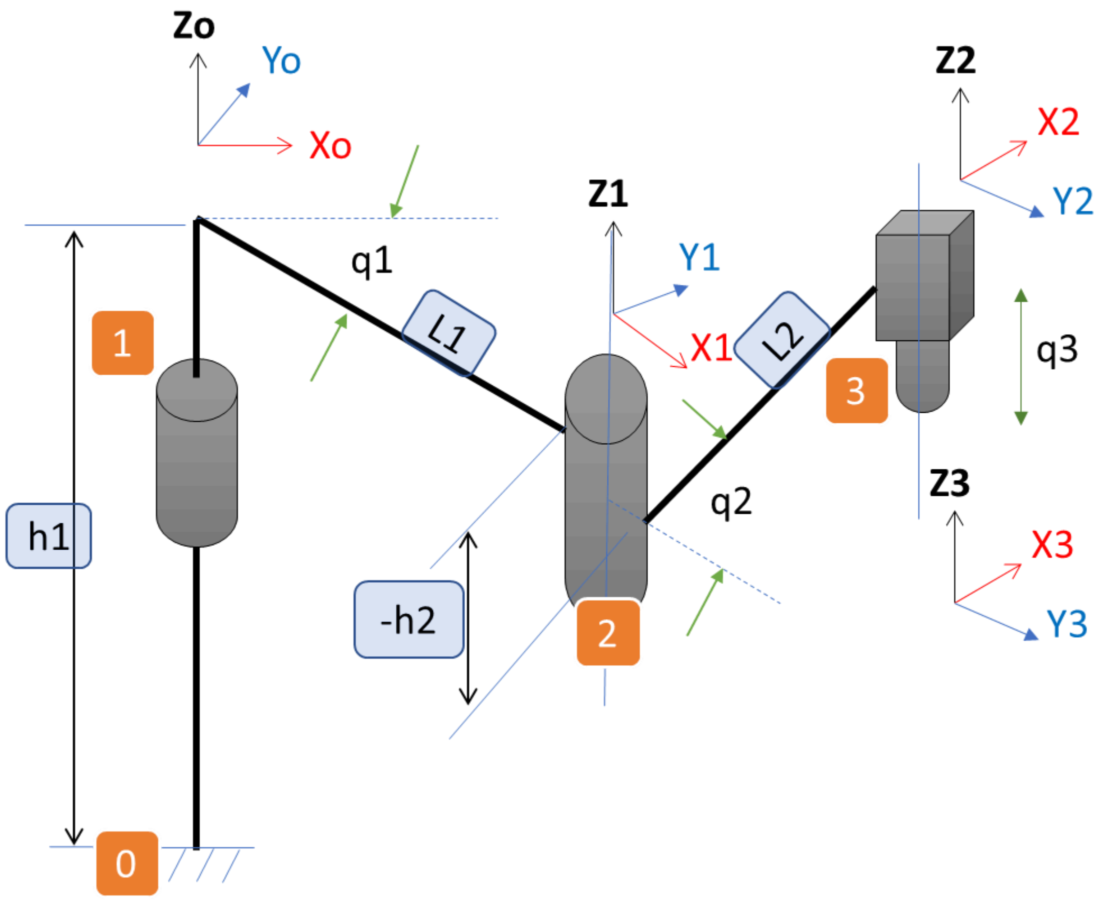




3. Kinematics analysis

2.1 Forward Kinematics

Forward Kinematic Calculation with DH Parameter arrived to define the relationship between end effector position to joint angles.



Denavit Hartenberg Parameters (D-H Parameters)

i	θ	d	b	α
1	Q1	h1	L1	0
2	Q2	-h2	L2	0

Transformation Matrix

$$A_1^0 = \begin{bmatrix} c1 & -s1 & 0 & c1L1 \\ s1 & c1 & 0 & s1L1 \\ 0 & 0 & 1 & \text{h1} \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad A_2^1 = \begin{bmatrix} c2 & -s2 & 0 & c2L2 \\ s2 & c2 & 0 & s2L2 \\ 0 & 0 & 1 & -h2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Transformation Matrix Base to End effector

$$A_2^0 = \begin{bmatrix} c1c2 - s1s2 & -c1s2 - s1c2 & 0 & c1c2L2 - s1s2L2 + c1L1 \\ s1c2 + c1s2 & -s1s2 + c1c2 & 0 & s1c2L2 + c1s2L2 + s1L1 \\ 0 & 0 & 1 & h1 - h2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

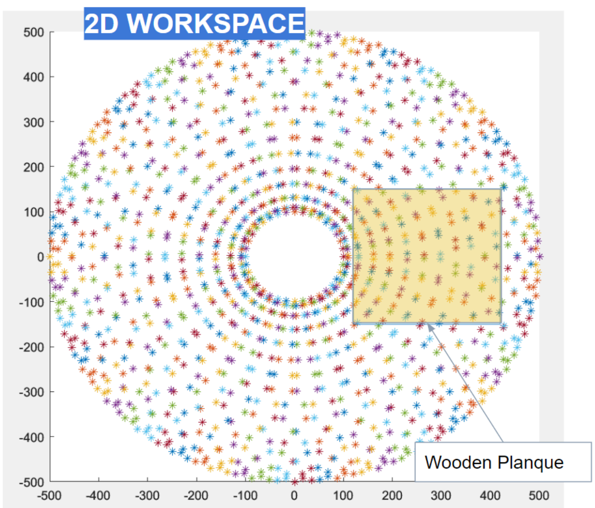
End effector position

$$P_x = L_1 C_1 + L_2 C_{12}$$

$$P_y = L_1 S_1 + L_2 S_{12}$$

$$P_Z = h_1 - h_2$$

2.2 Workspace Analysis



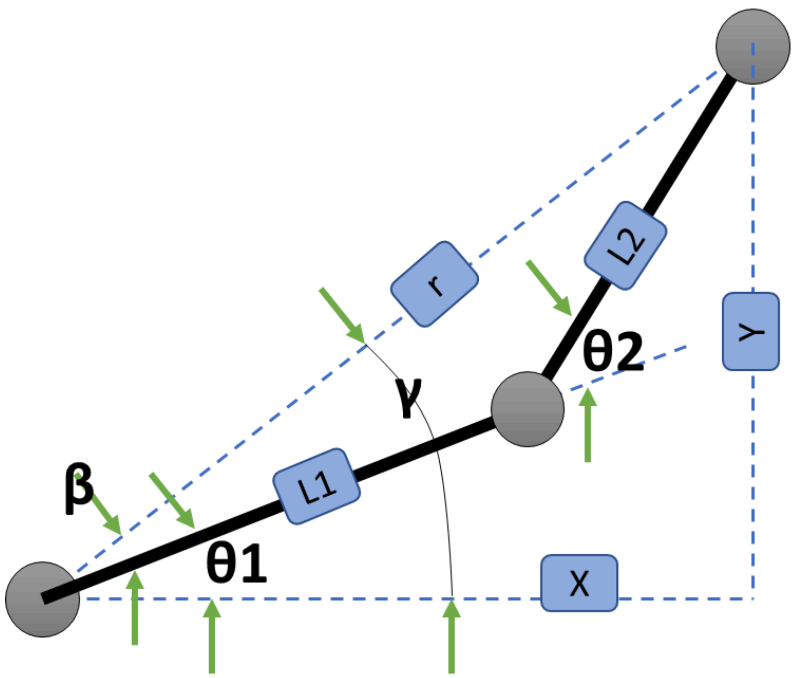
Matlab Code

```
clc
%Define length of the first link
Link1 = 300;
Link2 = 200;
```

```
%Define rotation possibilities of the both the links
%Q1 =linspace(0,360,200);
%Q2 =linspace(0,360,200);
for i = 0:10:360
   for j = 20:10:340
       x = (Link2*cosd(i)*cosd(j))-(Link2*sind(i)*sind(j))+(Link1*cosd(i));
       y = (Link2*sind(i)*cosd(j))+(Link2*cosd(i)*sind(j))+(Link1*sind(i));
       hold ON
       plot(x,y,'*')
   end
end
axis ([-500 500 -500 500]);
%Define wooden plank
x0 = 120
y0 = 0
line ([x0 x0+300],[y0-150 y0-150],'Linewidth',2)
line ([x0+300 x0+300],[y0-150 y0+150],'Linewidth',2)
line ([x0+300 x0],[y0+150 y0+150],'Linewidth',2)
line ([x0 x0],[y0+150 y0-150],'Linewidth',2)
hold off
```

2.3 Inverse Kinematics

With the desired X and Y values are set precisely according to required position, joint angles were calculated through Inverse Kinematics



$$\theta_1 = \tan^{-1}\left(\frac{Y}{X}\right) - \cos^{-1}((L_1 + L_2 \cos\theta_2)/r))$$

$$\theta_2 = (r^2 - (L_1^2 + L_2^2)/2L_1L_2)$$

Jacobian and Force Estimation on the End effector

$$J = \begin{bmatrix} -L_2S_{12} - L_1S_1 & -L_2S_{12} \\ L_1C_1 + L_2C_{12} & L_2C_{12} \end{bmatrix}$$

$$\hat{\tau} = [\,J\,].\widehat{F}$$

$$\widehat{F} = [\,J\,]^{-1}.\hat{\tau}$$

4. List of materials

#	Description	Quantity	Estimated cost	Remarks
1	Microcontroller	1	40 €	To program the entire system.
2	LED screen	1	20 €	To display the I/Os
3	Relay module 8 channel	1	19 €	To house all the inputs from buttons
4	Disc magnet	1	10 €	For the thumb cover
5	Push buttons	6	10 €	-include the cost of push buttons with LED
6	Thumb cover	1	10 €	To house magnet and cover thumb
7	Plastic housing	1	20 €	To house all the components
8	EMF Generator	1	20 €	To generate the EMF
9	Miscellaneous		20 €	
	Total		190 €	

5. Conclusion and outlook

In conclusion, a haptic control device has been designed with the aim of providing a more immersive and intuitive control experience. The device has been designed to actuate in three degrees of freedom and the end effector's workspace has been modeled to ensure that it is capable of reaching the intended positions. Inverse kinematics were derived to determine the angles of Link1 and Link2 that are required to reach the desired position. The haptic feedback has been realized through the use of a repulsive force proportional to the force sensor output of the end effector. This force is regulated by controlling the current to the electromagnetic generator. The device has also been designed with an ergonomic grip and is equipped with emergency stops to ensure user safety. The visual indications of the device are conveyed through translucent push buttons. The overall design of the haptic control device promises to bring new opportunities to interact with digital content and offers a more immersive experience.

Outlook:

In future, there is potential for further development of the haptic control device. One possibility could be to incorporate the permanent magnet directly into the controller itself. Currently, the magnet is kept in the thumb cover, but integrating it into the controller would simplify the design and increase the overall compactness of the device. Additionally, this could lead to further optimization of the haptic feedback and increase the device's overall functionality. These advancements would help to continue to enhance the user's experience and bring new opportunities for interaction with digital content.

References

Lenarcic, J., Bajd, T., & Stanišić, M. M. (2012). Robot mechanisms (Vol. 60). Springer Science & Business Media.

Hatzfeld, C., & Kern, T. A. (2016). Engineering Haptic Devices. Springer London Limited.

Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. (2007). Engineering Design: A Systematic Approach (K. Wallace & L. Blessing, Trans.). Springer Science and Business Media.

https://eu.robotshop.com/products/28-inch-touch-screen-for-uno-mega-development-board

https://www.amazon.de/RUNCCI-YUN-Momentanen-Druckschalter%EF%BC%8CMini-DruckTaster-Wasserdicht/dp/B087V5VKKY/ref=asc_df_B0825RCZJS/?tag=&linkCode=df0&hvadid=407418757836&hvpos=&hvnetw=g&hvrand=8789510963473781223&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9042616&hvtargid=pla-860495049330&th=1&ref=&adgrpid=87348359415

https://www.amazon.de/dp/B0046AMGW0?ref_=as_li_ss_tl&language=en_US&linkCode=gs2&linkId=72254cef471f87147f4816047575c866&tag=arkim07-21

https://eu.robotshop.com/products/8-channel-relay-module

https://www.amazon.com/Neodymium-Double-Sided-Adhesive-Permanent-Scientific/dp/B089D33ZL2/ref=sr_1_3?keywords=disc%2Bmagnets&qid=1675161918&sr=8-3&th=1

-https://mammothmemory.net/physics/magnets-and-electromagnetism/electromagnetism/which-end-of-an-electromagnet-is-north.html#:~:text=Turn%20the%20electromagnet%20so%20that,at%20is%20a%20north%20pole.

-https://www.youtube.com/watch?v=oEEYMhPY5tY