FYP'2023

Investigating CTEV (Clubfoot) Orthosis through Re-design, Automation and Alternative Mechanism

DURATION – 01TH AUG, 2022 TO 13TH MAY, 2023

Submitted By: **Group-P2**

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BACKGROUND UNDERSTANDING

INTRODUCTION TO CTEV

Congenital Talipes Equinovarus also known as Clubfoot, is a complex, congenital deformity in which the foot is twisted out of shape.

- Our objective is to develop a corrective orthosis for this disease which can be worn by the new-born child.
- The major requirements of this orthosis are that it should be of low cost and weight so that anyone can afford it and can be worn by the child comfortably
- Earlier for rectifying this kind of deformity into the new born baby we were using Ponseti Method.

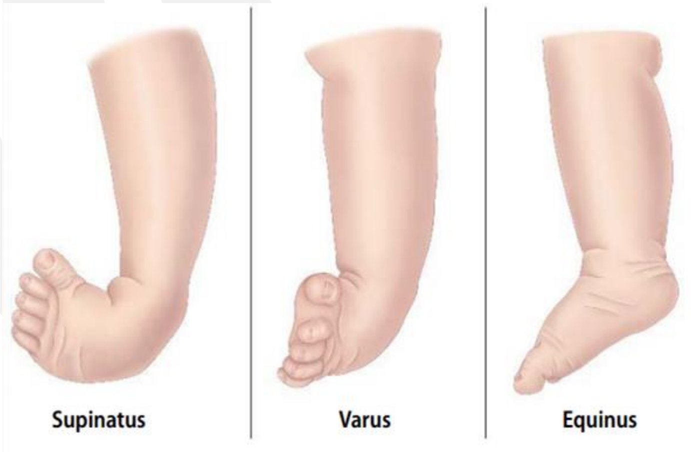


Fig.1 Deformities in Clubfoot

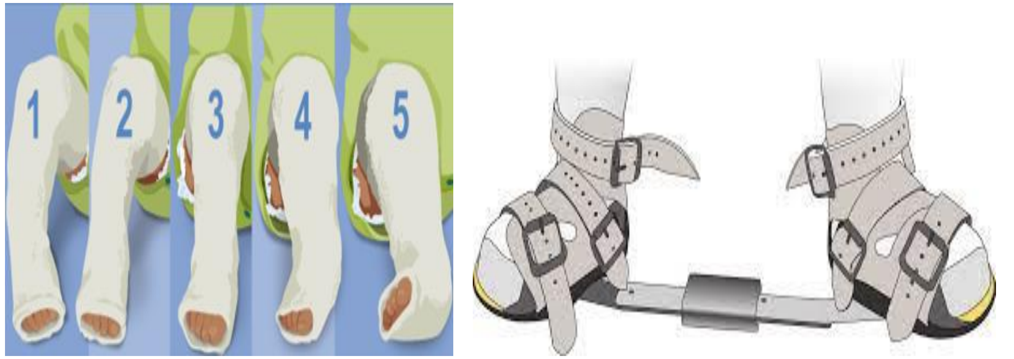


Fig.2 Ponseti Method

PRIOR EFFORTs

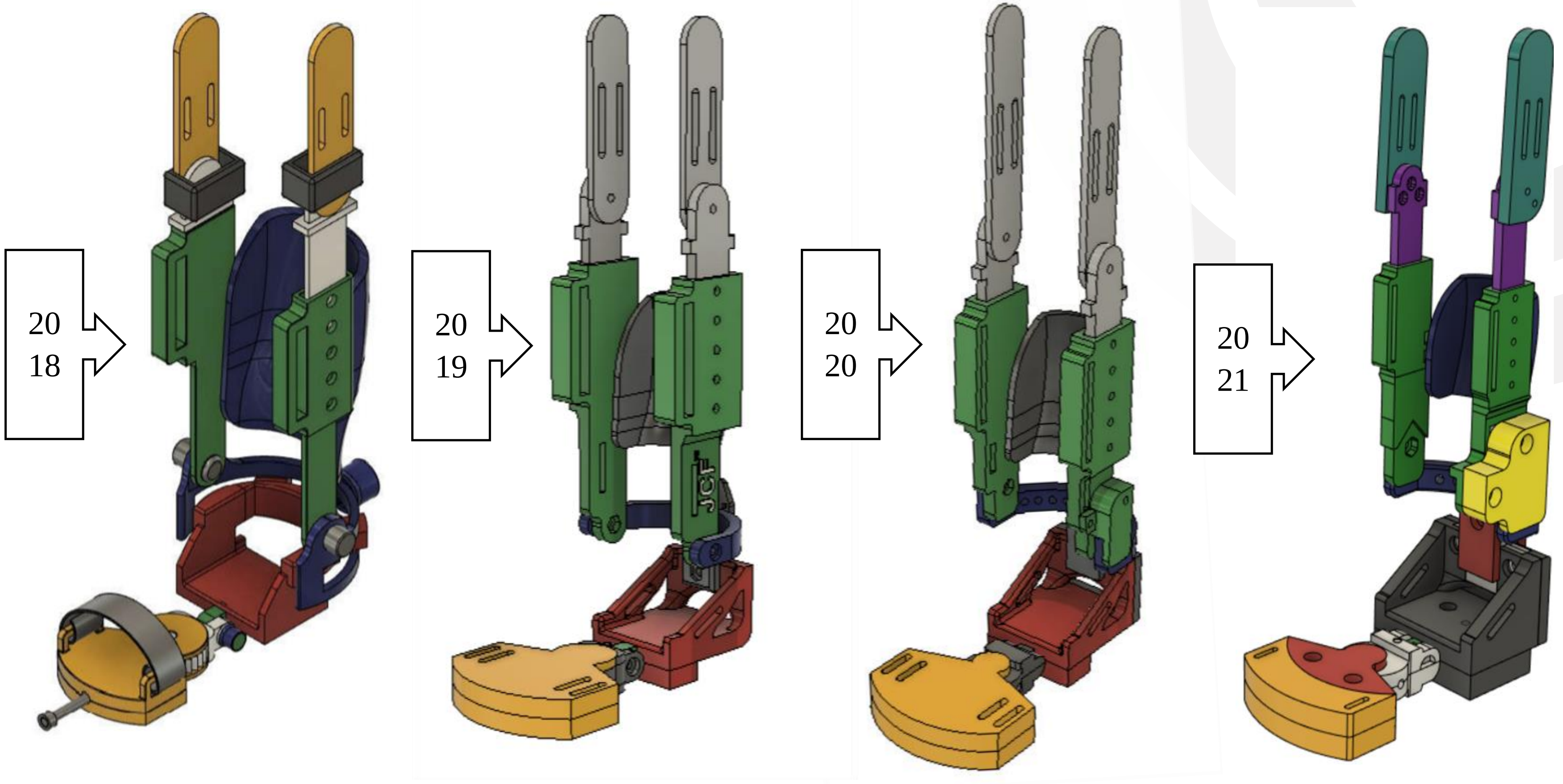
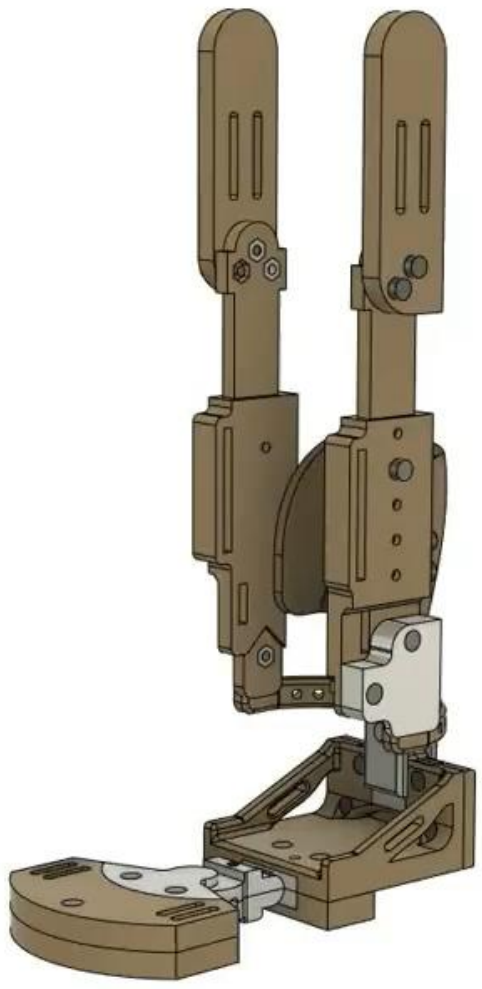


Fig. 1-9 (a) Interference Indexing Mechanism (b) Nut and Bolt indexing mechanism (c) Friction locking mechanism Worm-Gear (d) Friction locking mechanism with metallic seating for worm gear placement.

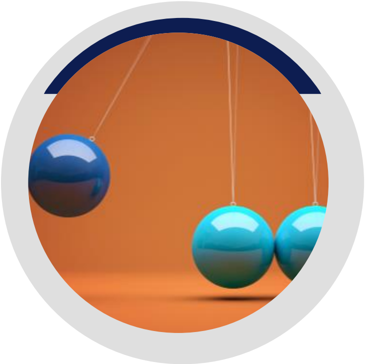
ASSEMBLY VIDEO: WORM & WORM GEAR MECHANISM



TECHNICAL ISSUES IDENTIFICATION IN CLUBFOOT ORTHOSIS

Manufacturing

- Too small parts
- Low precision



Actuation

- Shrinkage was high during investment casting

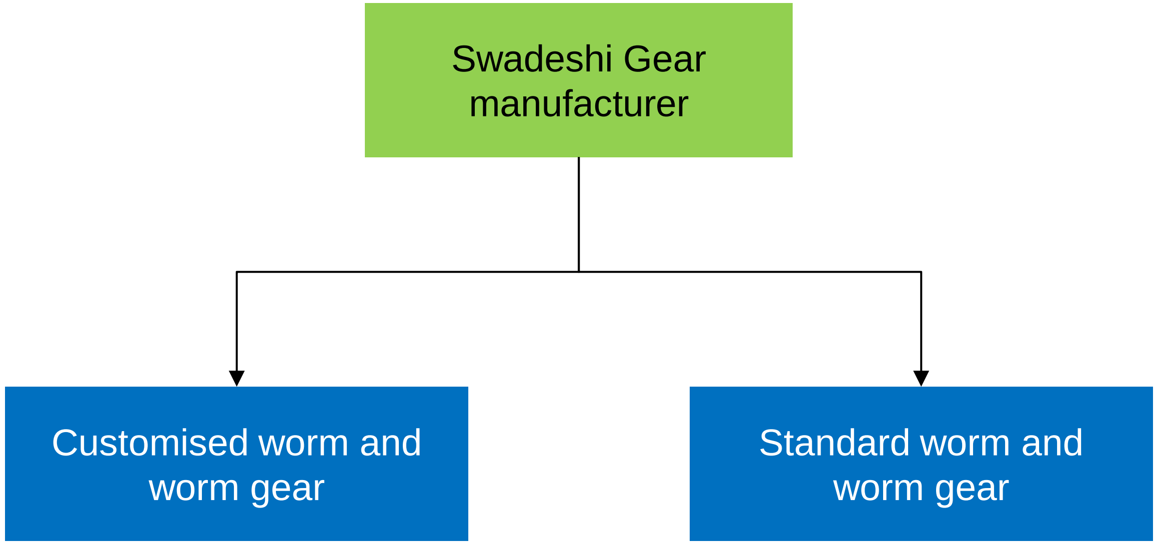
Cost & time

- Very costly and time consuming

OBJECTIVE

- Re-design the clubfoot orthosis to rectify the criticality into an actuation which actuated using worm and worm gear mechanism.
- Investigating the scope of automation in clubfoot using MATLAB.
- Re-design the clubfoot orthosis to incorporating alternate locking mechanism of motion.

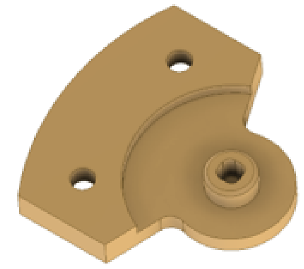
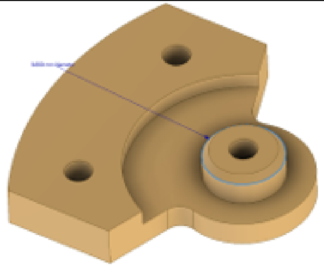
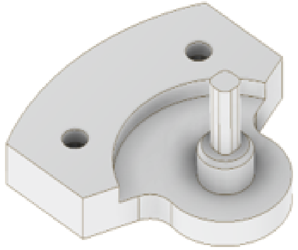
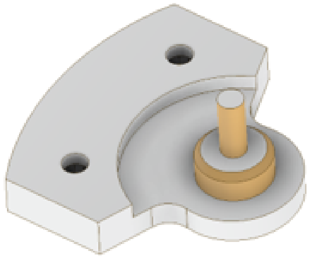
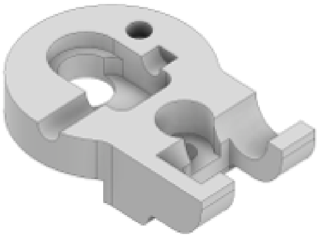
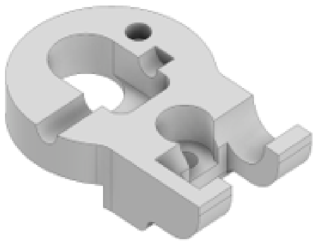
TECHNICAL ISSUES RECTIFICATION IN EXISTING CLUBFOOT ORTHOSIS



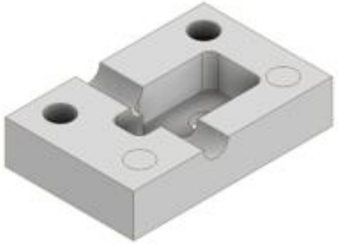
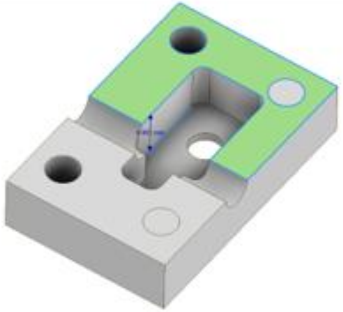
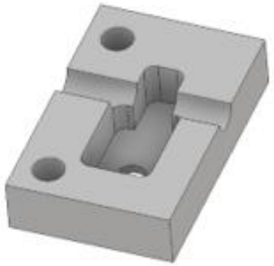
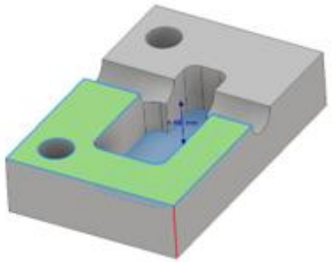
Made by investment casting

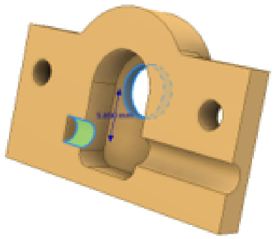
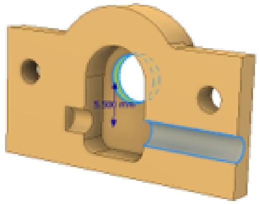
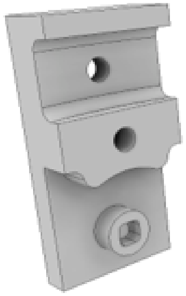
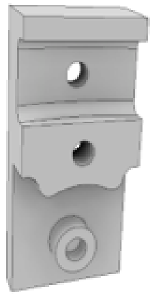
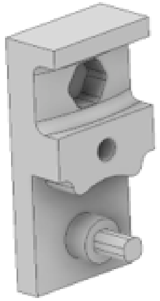
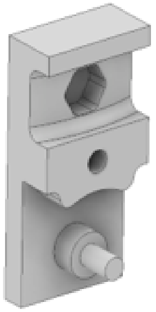
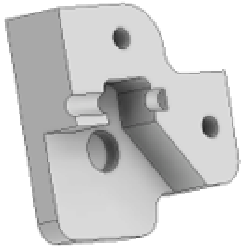
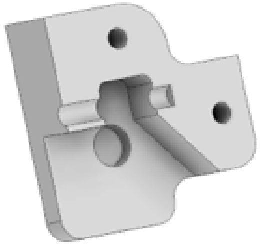
Made by CNC

Accepted   Rejected

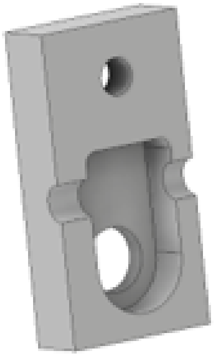
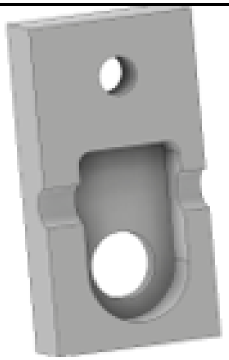
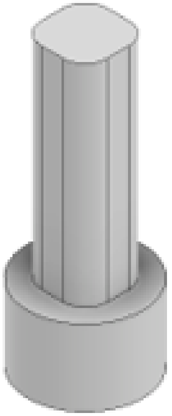
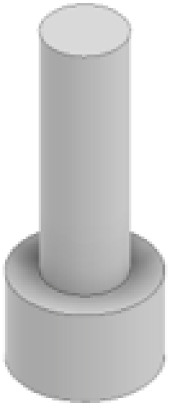
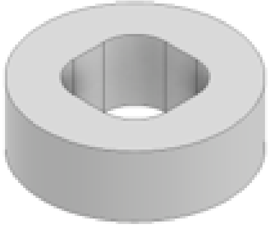
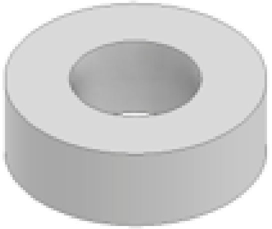
Sr	Description	Older Model	New Model
1.	**Metatarsal Top:** • The circular cavity was incorporated on the behalf of square cavity with dimension of 3mm. • External diameter of cylinder increases by 8.8 mm		
2.	Metatarsal Bottom: • External diameter of base of shaft increased to 8.8mm • Cylindrical shaft with the diameter of 3mm was incorporated on rectangular cross sectioned shaft.		
3.	Yaw Link Top: • The lateral distance of inner cavity where hub of the gear was placed, which increased to 8.8 mm and extra material was removed. • Shaft of worm gear was shifted by 0.35mm to get the 5.5mm of centre to centre distance		

TECHNICAL ISSUES RECTIFICATION IN EXISTING CLUBFOOT ORTHOSIS

6.	Coupling Shaft Cap: • Rectangular cavity was changed by circular.		
7.	Forefoot Roll Link: • Rectangular hub was removed. • Rectangular cavity was changed by circular.		
8.	Hindfoot Base Lower: • Circular cavity has been shifted by 0.35mm to set the centre to centre distance of 5.5mm • Cavity depth was increase to 4.4mm		
9.	Hindfoot Base Upper: • Circular cavity has been shifted by 0.35mm to set the centre to centre distance of 5.5mm • Cavity depth was increase to 4.4mm		

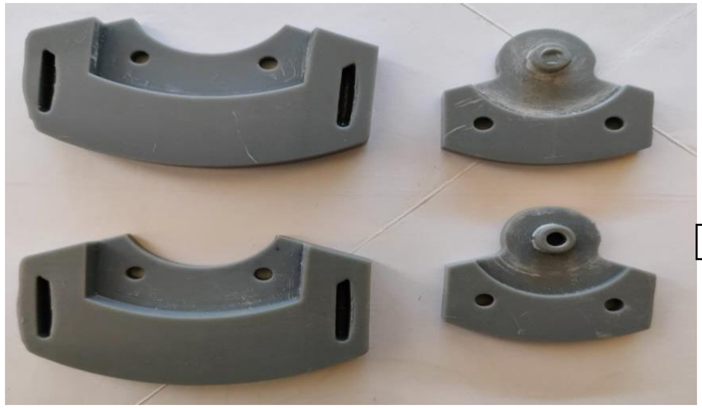
11.	Hindfoot Rolling Right: • Barrel was shifted by 0.35mm to set the centre to centre distance of 5.5mm • The lateral distance was modified by 8.8mm		
12.	Hindfoot Yaw Guide1: • Rectangular cavity was changed by circular.		
13.	Hindfoot Yaw Guide2: • Rectangular cross section of the shaft was modified in the by circular cross section.		
14.	Hindfoot Covering: • Barrel was shifted by 0.4mm to set the centre to centre distance of 5.5mm • The lateral distance was modified by 8.8mm from 9mm		

TECHNICAL ISSUES RECTIFICATION IN EXISTING CLUBFOOT ORTHOSIS

15.	Calf Support Left Metal: • Barrel was shifted by 0.35mm to set the centre to centre distance of 5.5mm with worm gear.		
16.	Hindfoot Pitch Pin: • Rectangular cross section of the shaft was modified in the by circular cross section.		
17.	Hindfoot Pitch Pin Cap: • Rectangular cavity of the cap modified by circular cross section.		

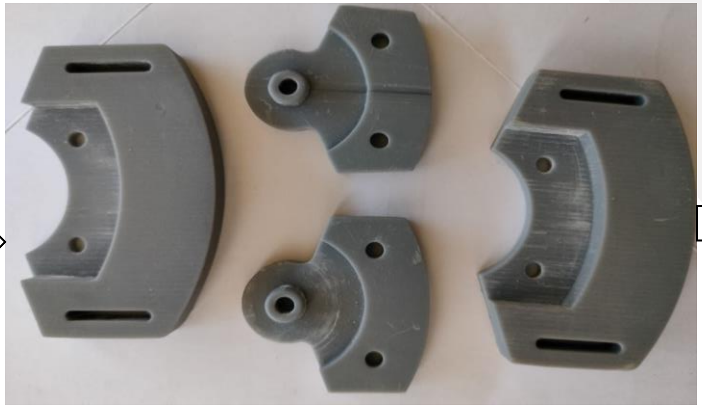
PROTOTYPE DEVELOPMENT OF FOREFOOT OF ORTHOSIS

Iteration-1



CAD Model with exact dimension

Iteration-2

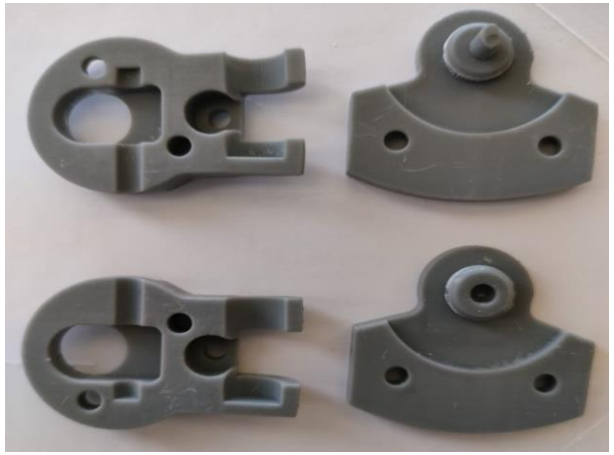


CAD Model with Shrinkage allowances

Iteration-3

Addition of Filling allowances

Iteration-4



encountering filling allowances with shrinkage allowances

Final Design

PROTOTYPE DEVELOPMENT OF HINDFOOT OF ORTHOSIS

Iteration-1

CAD Model with exact dimension







Iteration-2

Encountering filling allowances with shrinkage allowances

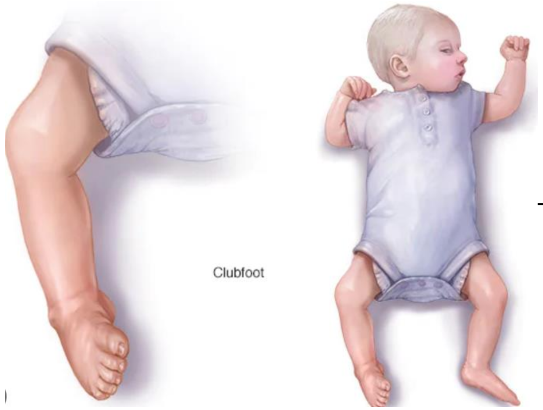


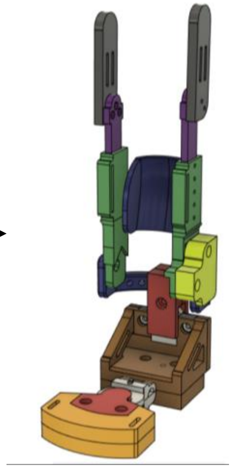




AUTOMATION IN EXISTING CLUBFOOT ORTHOSIS

AUTOMATION IN EXISTING CLUBFOOT ORTHOSIS





Children having Clubfoot problem

Wearing mechanical type orthosis

Go to the doctor for weekly check-up and monitoring the orthosis

Excessively laborious
Time-consuming

Next level

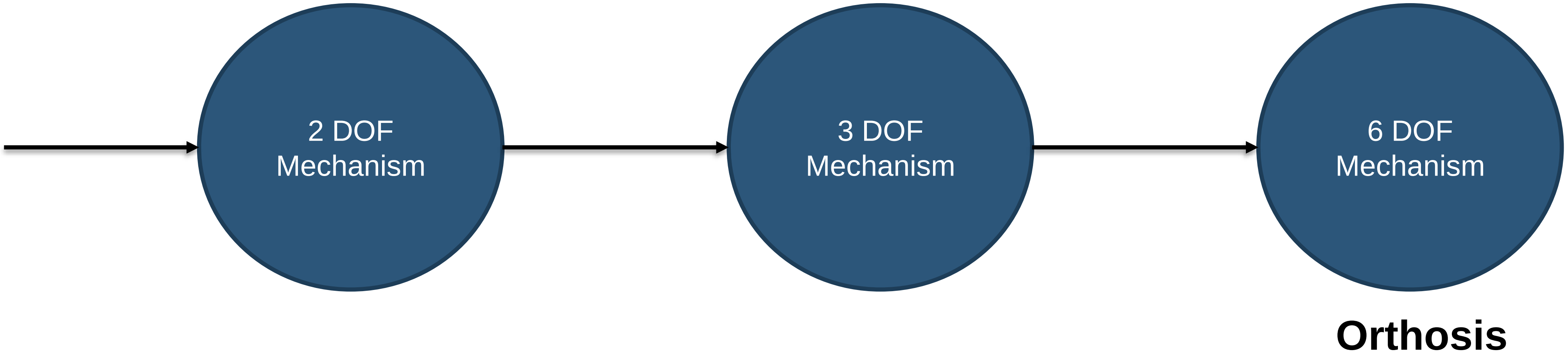
AUTOMATION

HARDWARE AND SOFTWARE REQUIREMENT

- **Software:**
  - MATLAB & Simulink
  - Inventor & OnShape: for building the assembly of clubfoot and integrate with MATLAB
- **Hardware:**
  - Stepper motors: getting installed on each pivot point of clubfoot
  - Arduino
  - Jumper wires
  - Battery
  - Breadboard

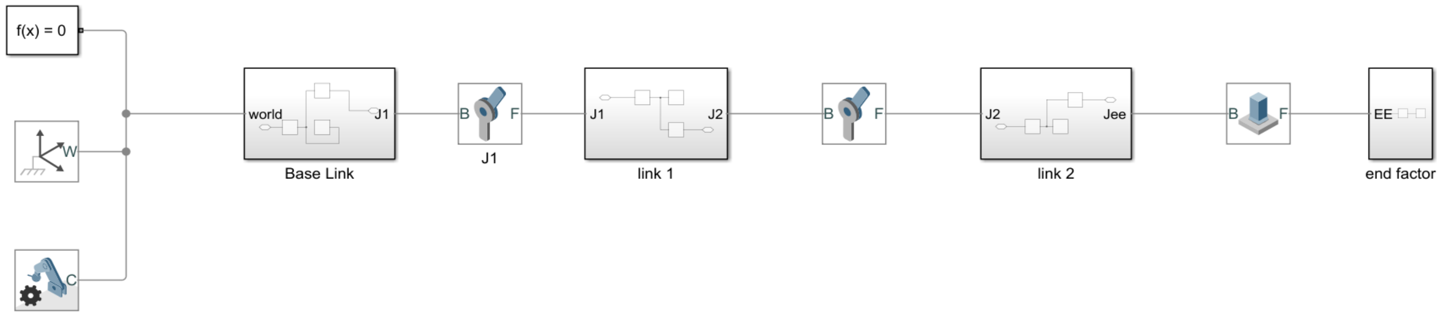
ROOT DEVELOPMENT OF EXISTING CLUBFFOT ORTHOSIS

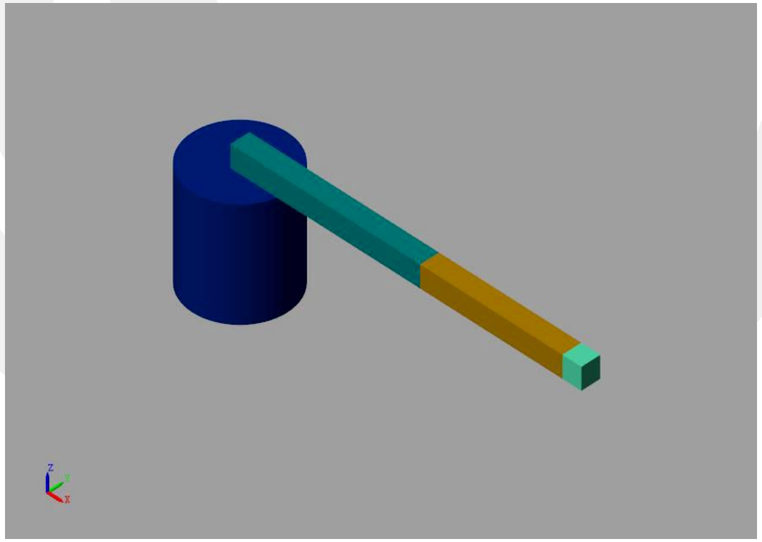
- In which we will integrating stepper motor at each pivot point which were previously actuated using a worm and worm gear mechanism.
- An automated orthosis would be able to make an accurate prediction of the trajectory along which the deformed foot would eventually revert to its original shape.
- To do this, we used MATLAB to plot out the predictable path or a trajectory that orthosis should follow.



LINKAGE MECHANISM: 2DOF

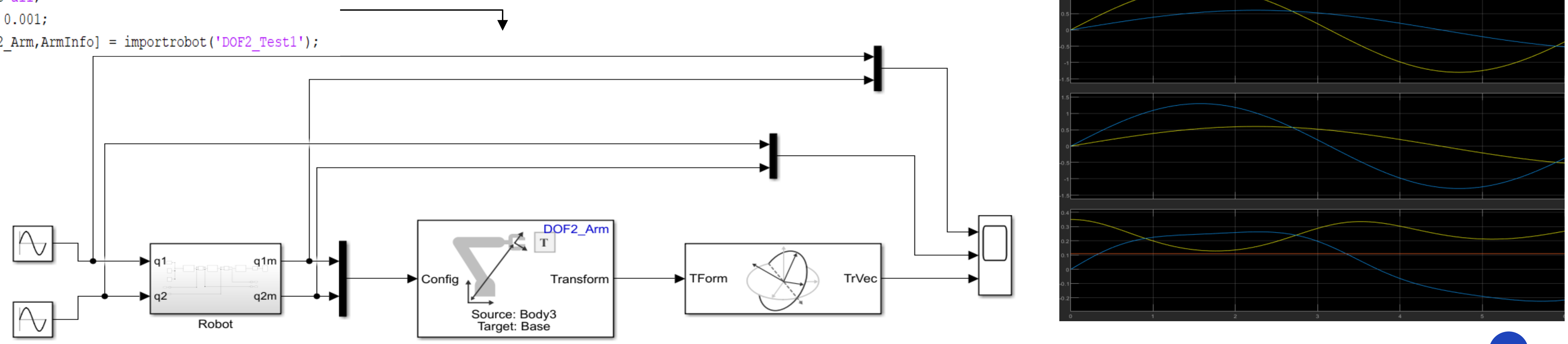
Assembly Creation





Forward Kinematics

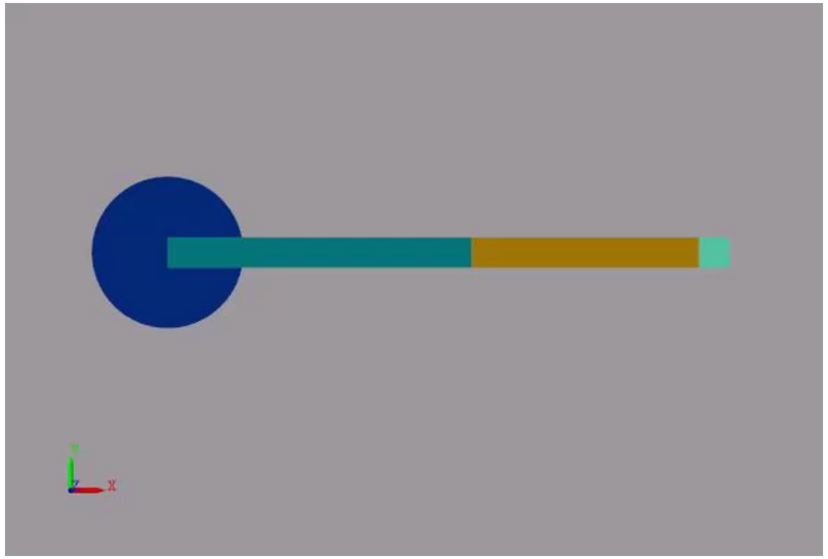
```
clear;
close all;
Ts = 0.001;
[DOF2_Arm,ArmInfo] = importrobot('DOF2_Test1');
```

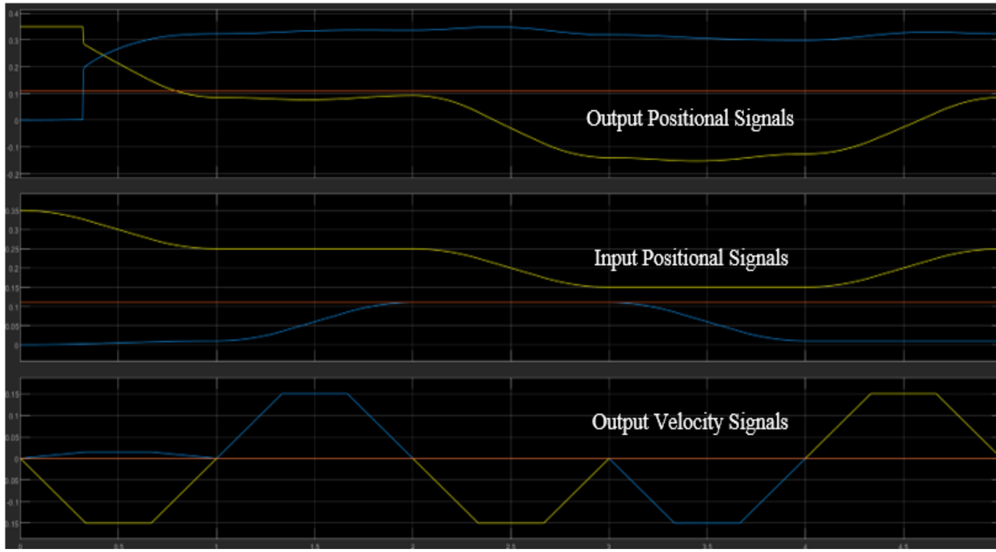


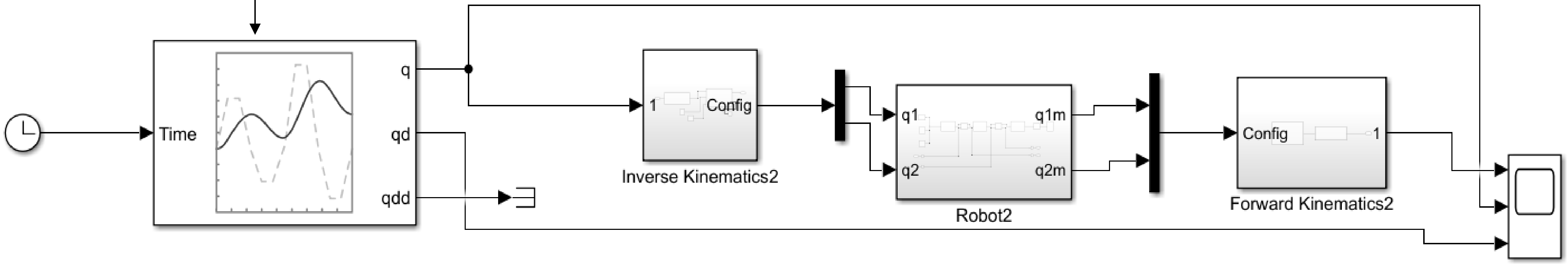
LINKAGE MECHANISM: 2DOF

Inverse Kinematics

```
clear;
close all;
Ts = 0.001;
[DOF2_Arm,ArmInfo] = importrobot('DOF2_Test1');
% wp = [0.35 0 0.11;0.25 0.01 0.11;0.25 0.11 0.11;
wp = [0.35 0.25 0.25 0.15 0.15 0.25; 0 0.01 0.11 0
tp = [0 0.5 1.5 2.5 3.5 4.5];
```

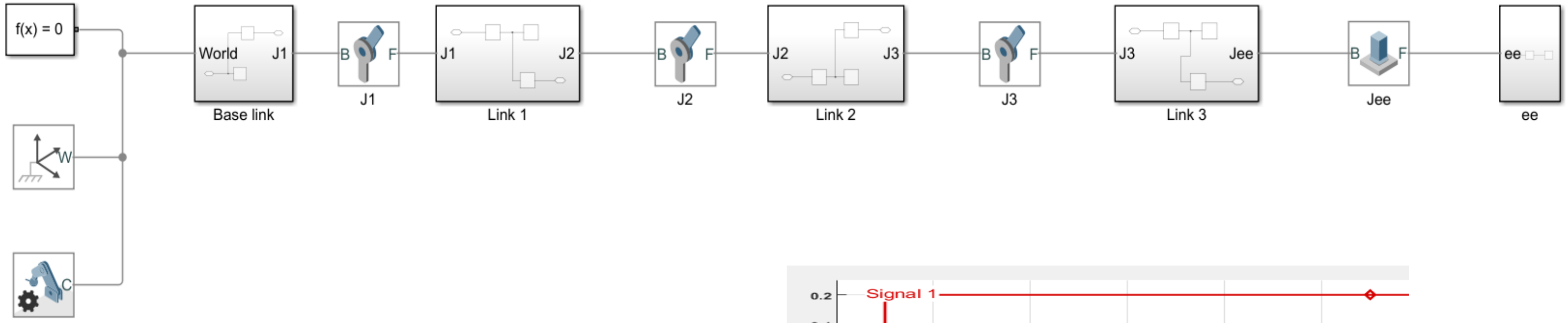


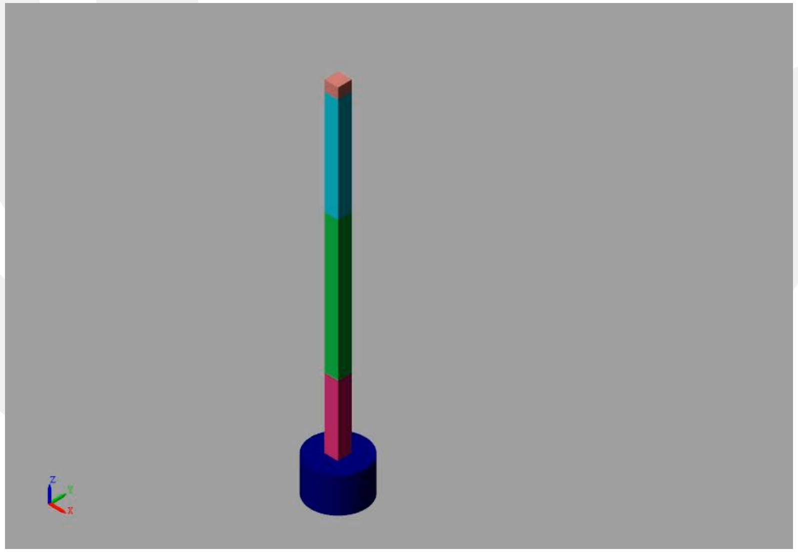




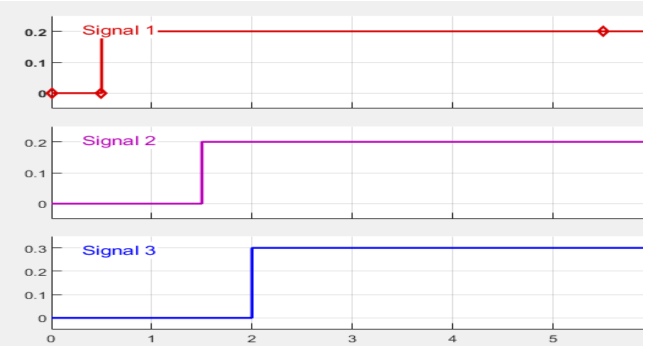
LINKAGE MECHANISM: 3DOF

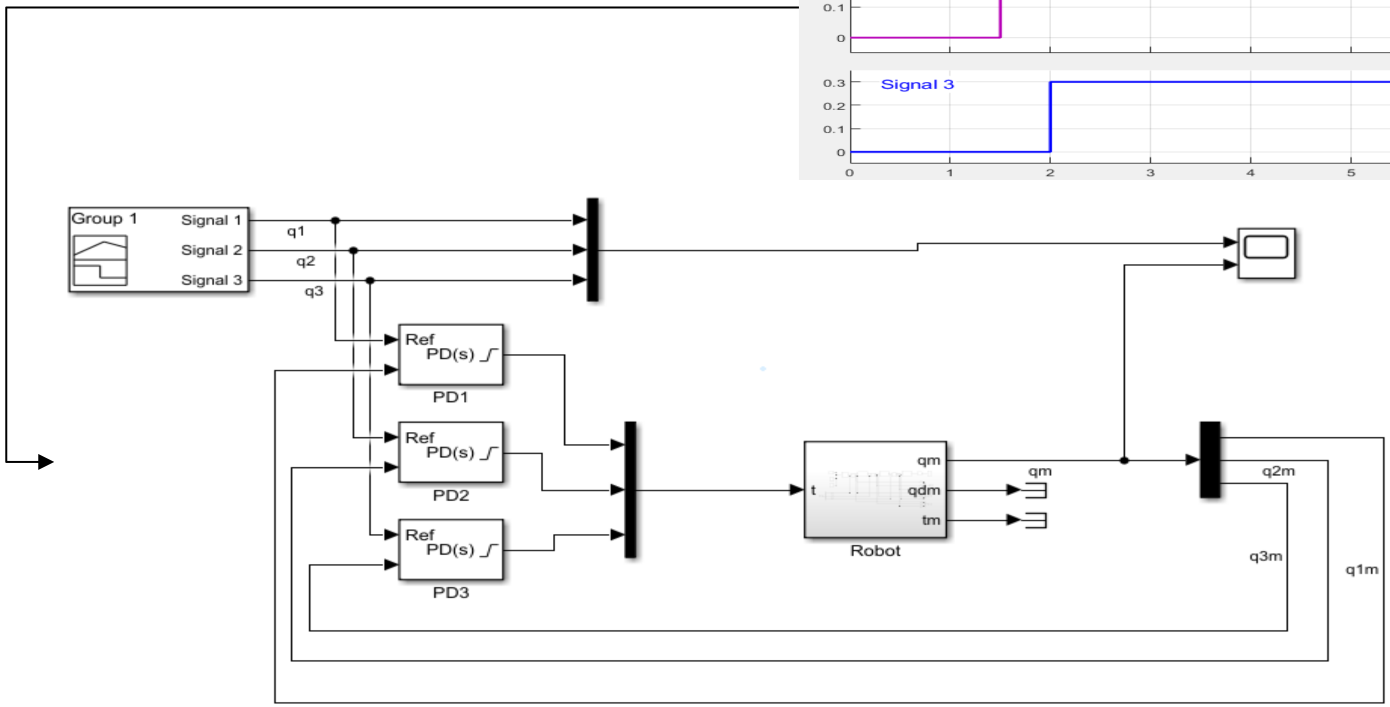
Assembly Creation

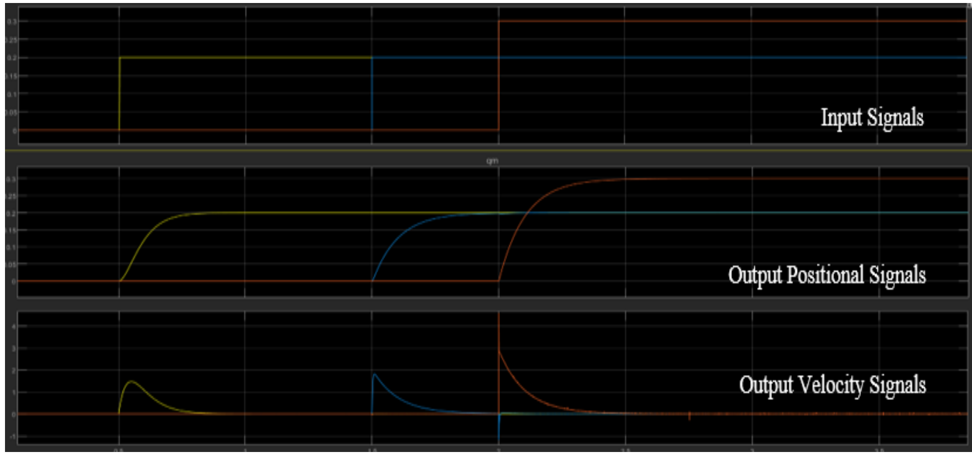




Forward Kinematics



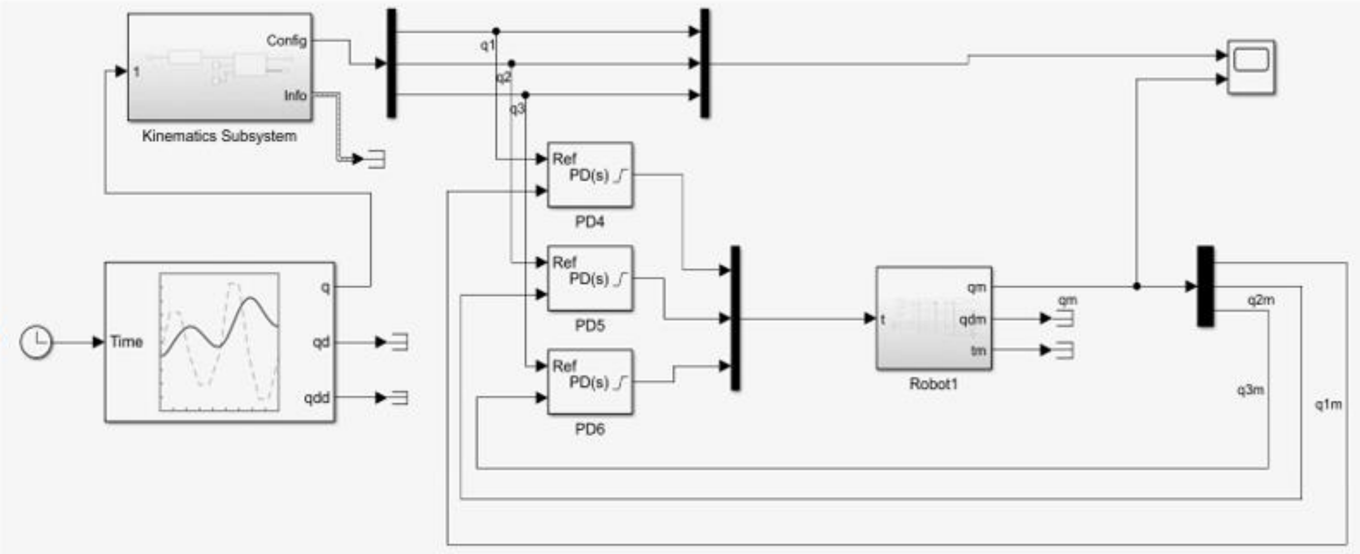


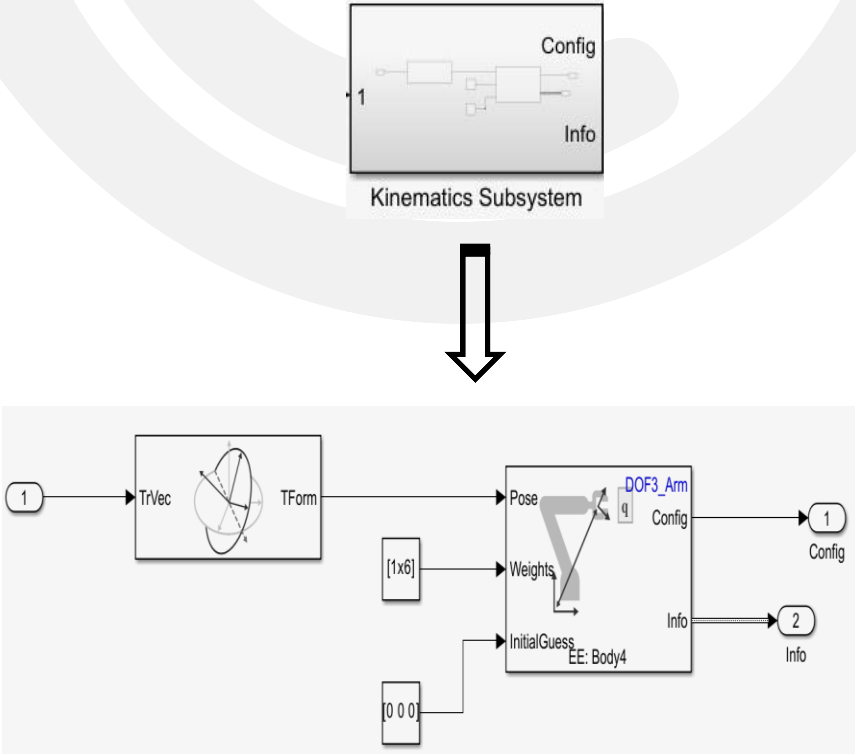


LINKAGE MECHANISM: 3DOF

Inverse Kinematics

```
clear;
close all;
Ts = 0.001;
[DOF3_Arm,ArmInfo3] = importrobot('DOF3_Test1');
% wp1 = [0.35 0.25 0.25 0.15 0.15 0.25; 0 0.01 0.11 0.11 0.01 0.01; 0.11 0.11 0.11 0.11 0.11 0.11];
wp1 = [0.35 0.0 0.25 0.15 0.5 0.25; 0 0.15 0.30 0.04 0.50 0.1; 0.0 0.3 0.45 0.0 0.25 0.1];
tp1 = [0 0.5 1.5 2.5 3.5 4.5];
```

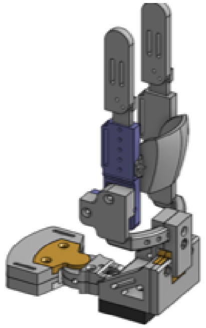




LINKAGE MECHANISM OF ORTHOSIS: 6DOF

Assembly Creation

onshape → Assembly Creation →

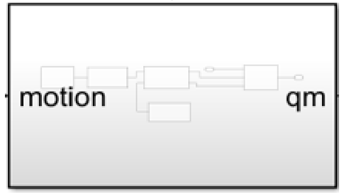


Copy the location of assembly file on cloud

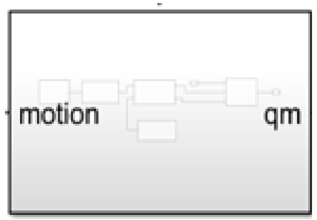
Open Command window of MATLAB

Command Window

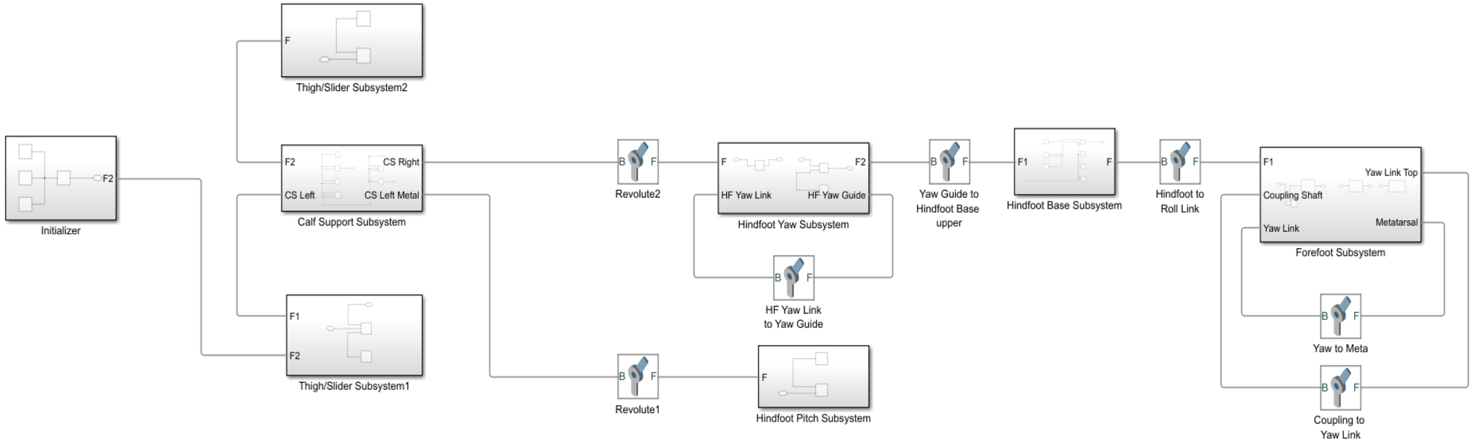
```
>> DOF3_Arm_Load
>> multibody_xml_file = smexportonshape(Cloud_Link)
>> model = smimport(multibody_xml_file)
```



Robot



Robot



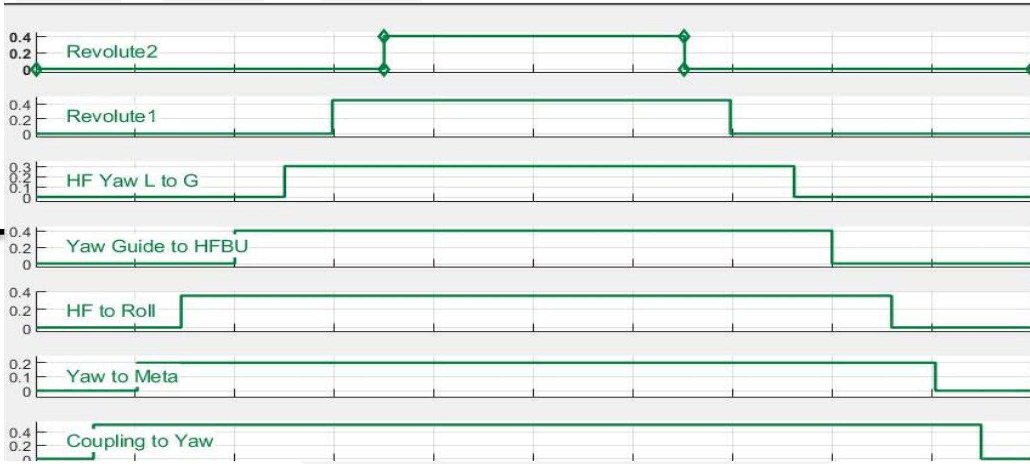
LINKAGE MECHANISM OF ORTHOSIS: 6DOF

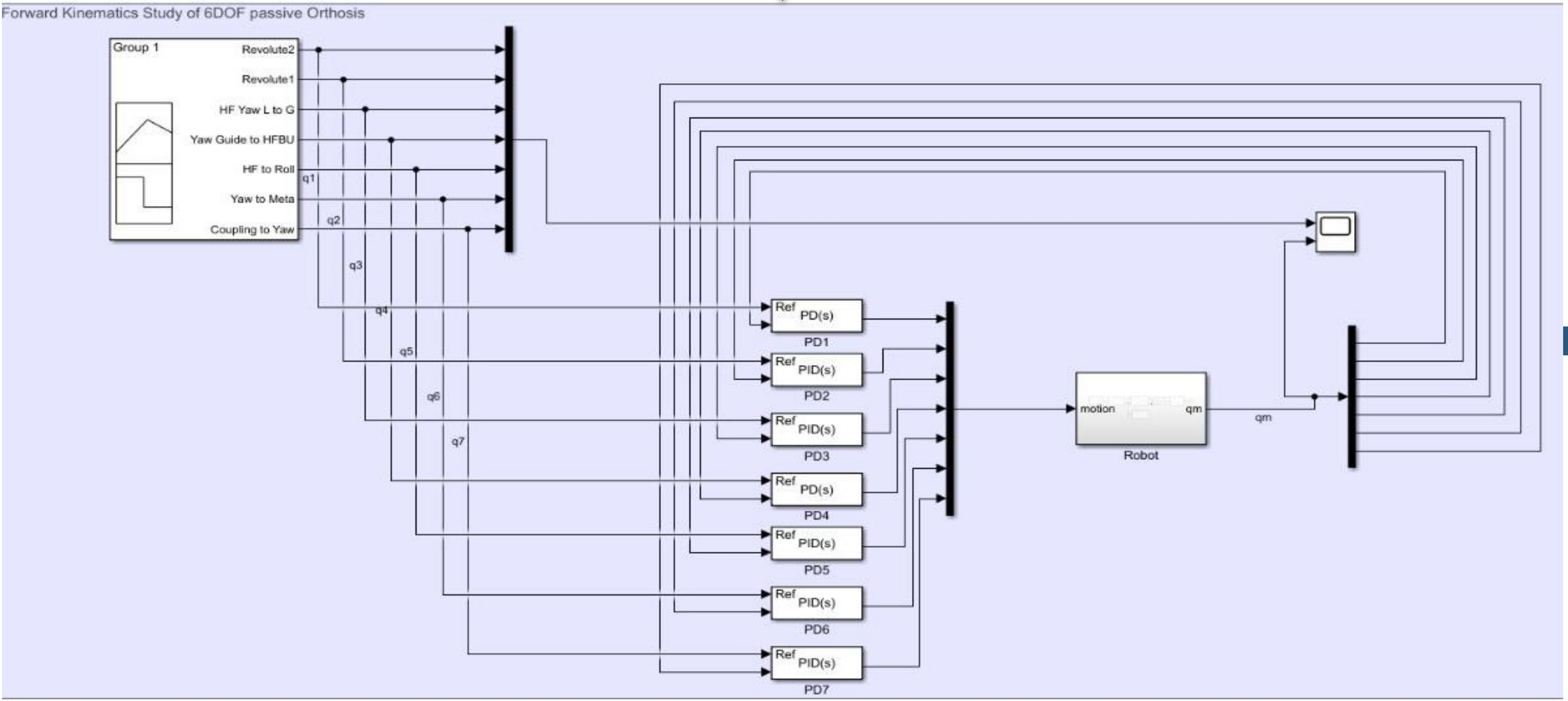
Forward Kinematics

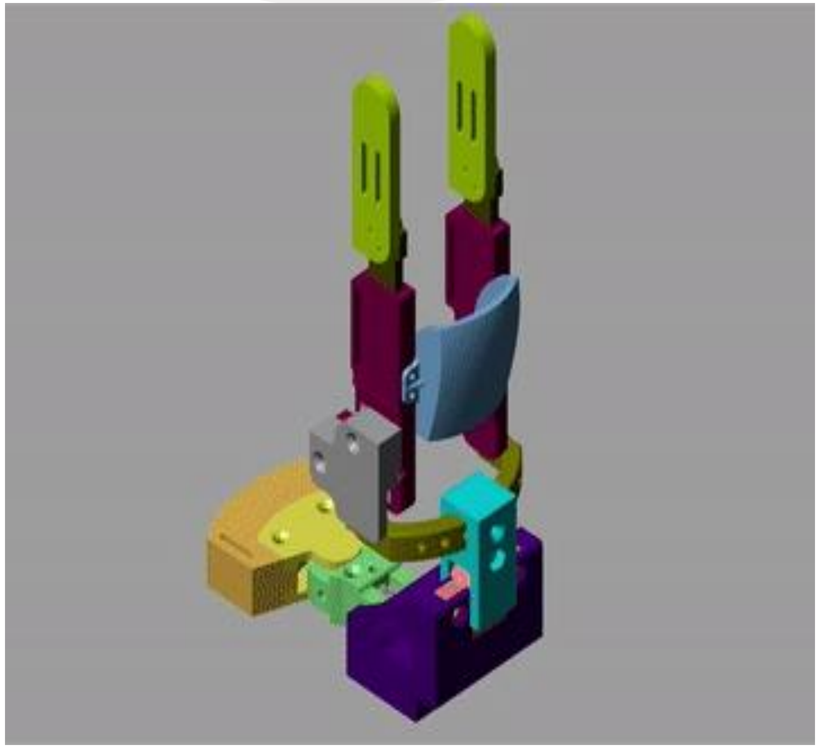
```
clear;
close all;
TunedBlocks = {'PD1', 'PD2', 'PD3','PD4', 'PD5', 'PD6', 'PD7'};
ST0 = slTuner('Six_DOF_assembly2', TunedBlocks);

addPoint(ST0, TunedBlocks);

addPoint(ST0, 'Robot/qm');

RefSignals = {'Six_DOF_assembly2/Signal Builder/q1', 'Six_DOF_assemb
addPoint(ST0, RefSignals);

Controls = TunedBlocks;
Measurements = 'Six_DOF_assembly2/Robot/qm';
options = looptuneOptions('RandomStart',80','UseParallel',false);
TR = TuningGoal.StepTracking(RefSignals, Measurements, 0.05,0);
ST1 = looptune(ST0, Controls, Measurements, TR, options);

writeBlockValue(ST1);
```

PD Controller Tuning

Input Signals

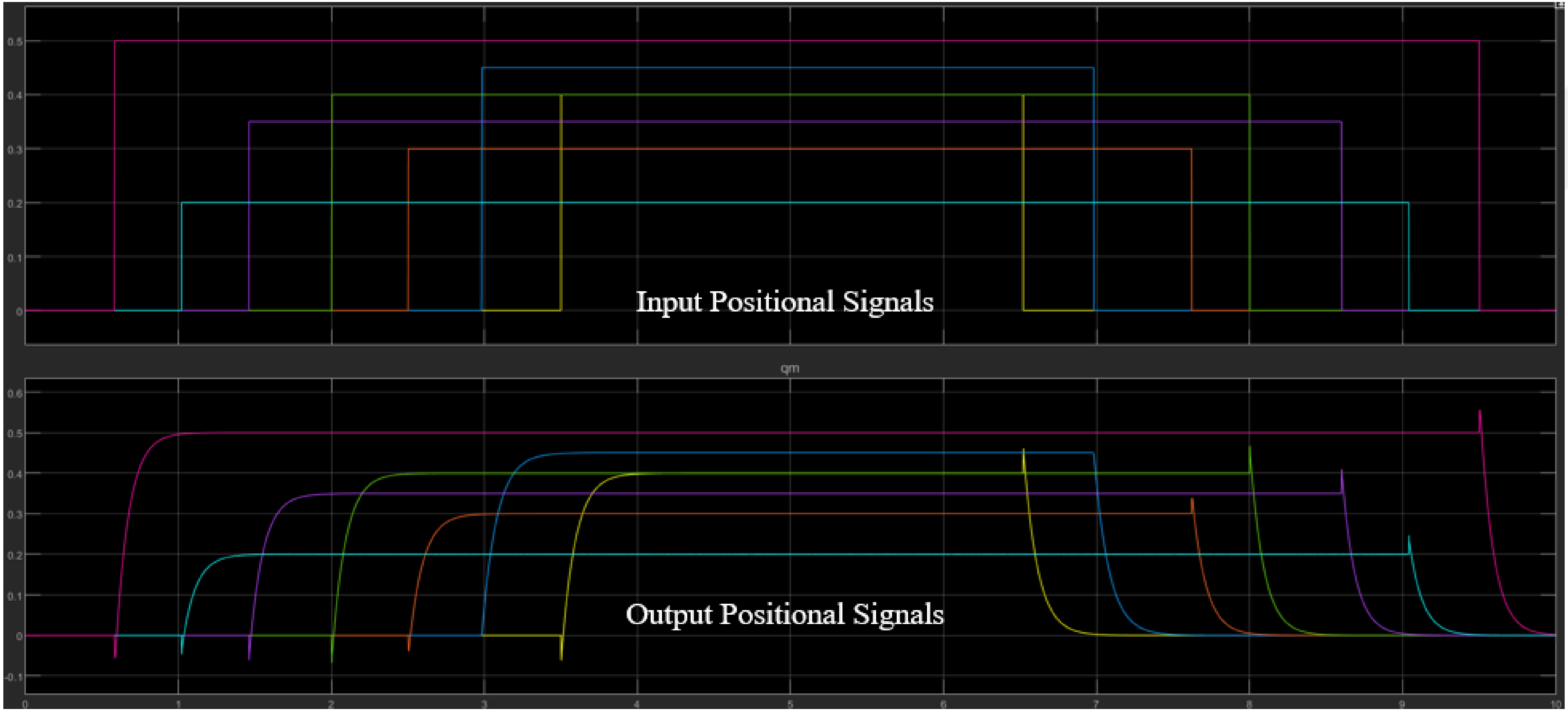






LINKAGE MECHANISM OF ORTHOSIS: 6DOF

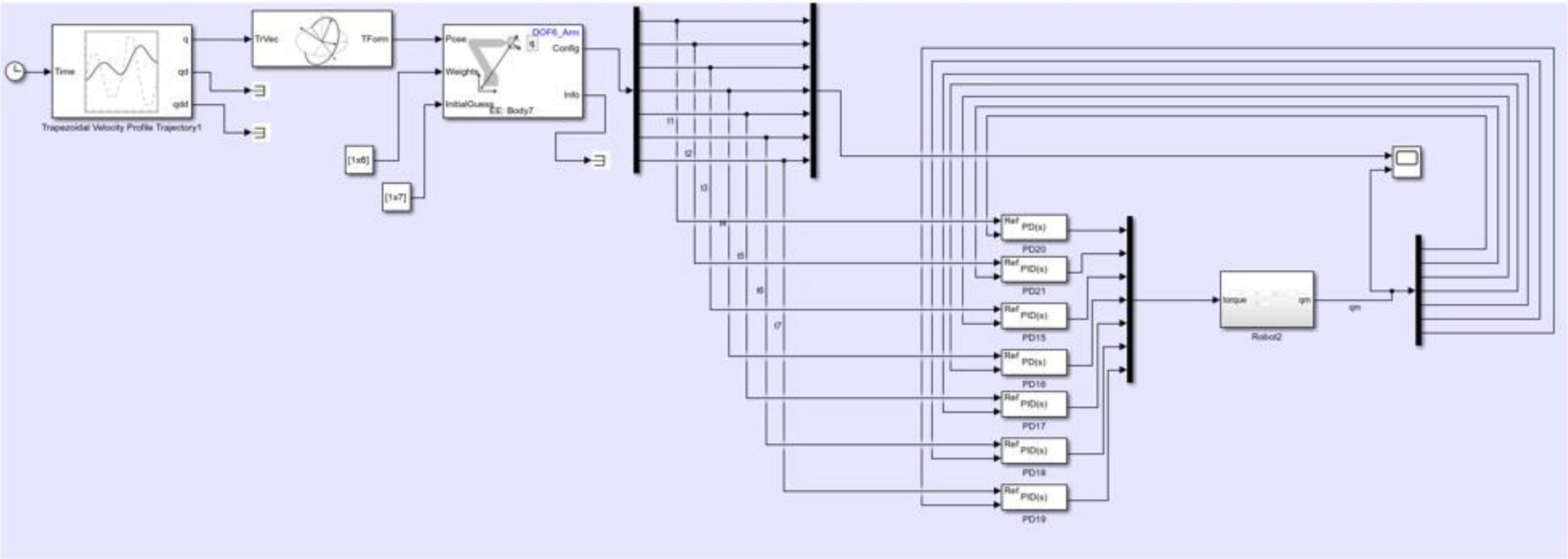
Forward Kinematics



LINKAGE MECHANISM OF ORTHOSIS: 6DOF

Inverse Kinematics

```
Ts = 0.001;
[DOF6_Arm,ArmInfo6] = importrobot('Assembly_file_6DOF');
% wp1 = [0.35 0.25 0.25 0.15 0.15 0.25; 0 0.01 0.11 0.11 0.01 0.01; 0.11 0.11 0.11 0.11 0.11 0.11];
wp1 = [-12 -16; 12 16; 12 16];
% wp1 = [-2 2 8; -10 4 8; -15 6 8; -20 8 8; -15 6 8; -10 4 8; -2 2 8];
tp1 = [0 0.5 1.5 2.5 3.5 5 6];
```

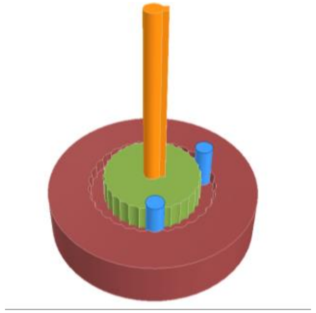
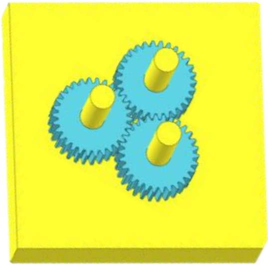
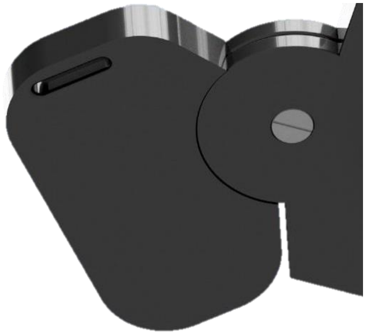


ALTERNATE LOCKING MECHANISM

ALTERNATE LOCKING MECHANISM

- The manufacturing of worm and gear is a very expensive process
- mainly due to its very small size and specialized manufacturing techniques and setups involved.
- Quality control process also add to this cost.
- This would make the orthosis unaffordable and out of reach for certain group of people.
- Thus, a need arises to look for different mechanism to lock the degrees of freedom of the orthosis.
- The aim is to look for mechanism which can be assembled easily while using standard off-the-shelf products or those which can be easily manufactured, without heavy setup.

MECHANISM SELECTION

Mechanism		Pros	Cons
2 Pin Mechanism		• Uses very simple components which are easily manufacturable.	• Low resolution • Cannot withstand high forces as contact area is small.
3 Gear Mechanism		• Has a very high resolution • Reliable and can withstand high forces.	• Complicated assembly. • Position of gears cannot be calculated.
Fastening Mechanism		• Very simple assembly • No specialized parts required. • Has infinite resolution	• Poor reliability • Position may gradually change due to jerks and impacts • Cannot withstand high forces.

THREE GEAR DESIGN AND CALCULATIONS

Pitch diameter (D)	6.6666 mm
Diametral pitch (P)	3.0002
Circular pitch (CP)	1.047 mm
Module (m)	0.3333 mm
Addendum (a)	0.1667 mm
Dedendum (b)	0.4166 mm
Working Depth (h)	0.7499 mm
Tooth Thickness (t)	0.5235 mm

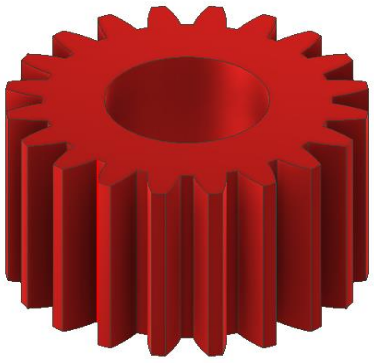
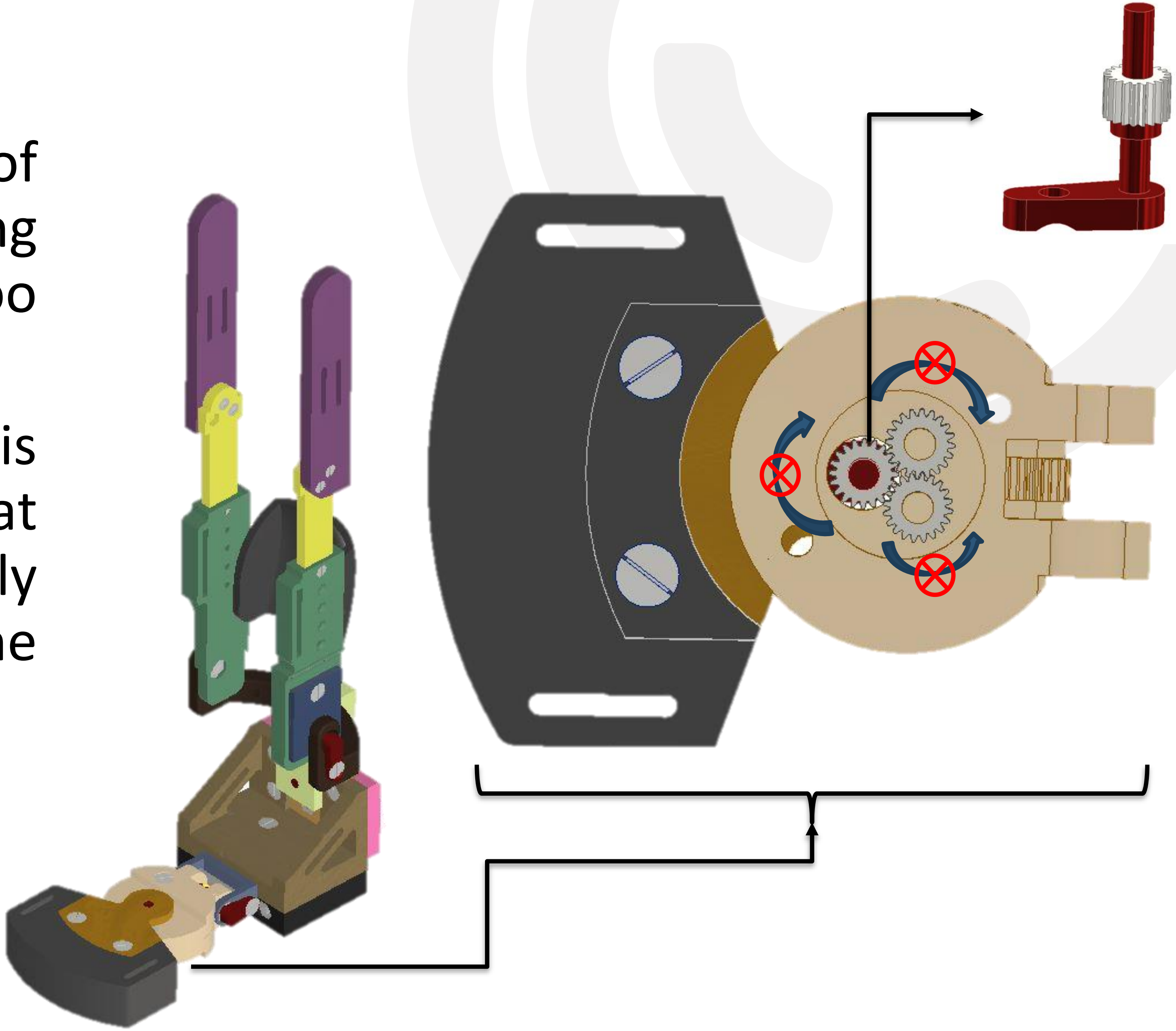


Fig. 4-4 Spur Gear with 3mm Hole

WORKING MECHANISM

- Since manufacturing of worm and worm gear along with automation is too costly.
- Thus to make the orthosis cheaper, we need to look at some other less costly mechanism to lock the rotation.



ASSEMBLY VIDEO

PROTOTYPE DEVELOPMENT

- First, a fixture was designed to test out if the proposed mechanism will work or not.
- The fixture is 3D printed along with the gears.
- Positive outcome of the fixture promoted us to design the complete orthosis assembly with the new ‘3 Gear’ mechanism.
- Since off-the-shelf

Fig. Prototype for Yawing motion

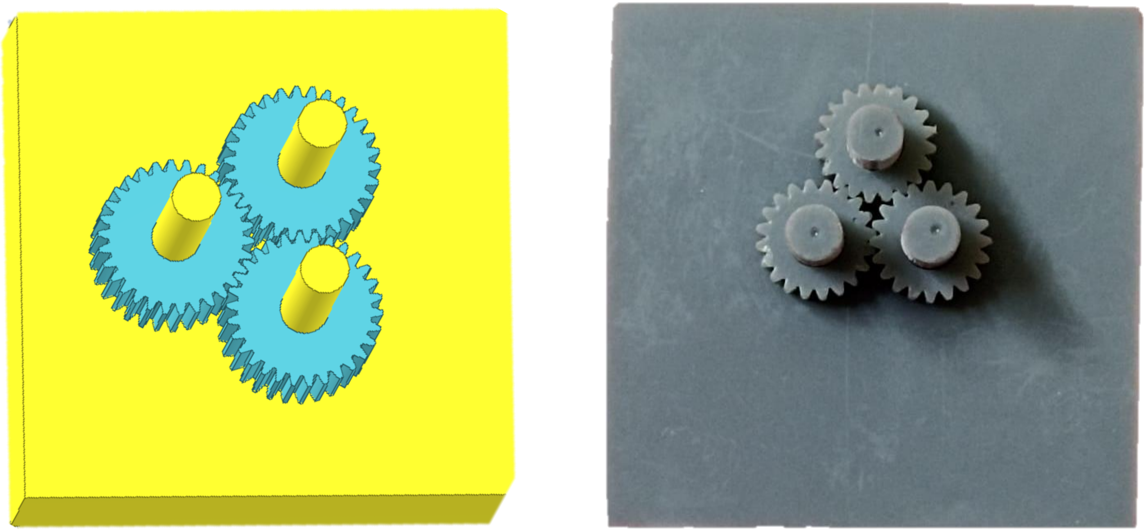


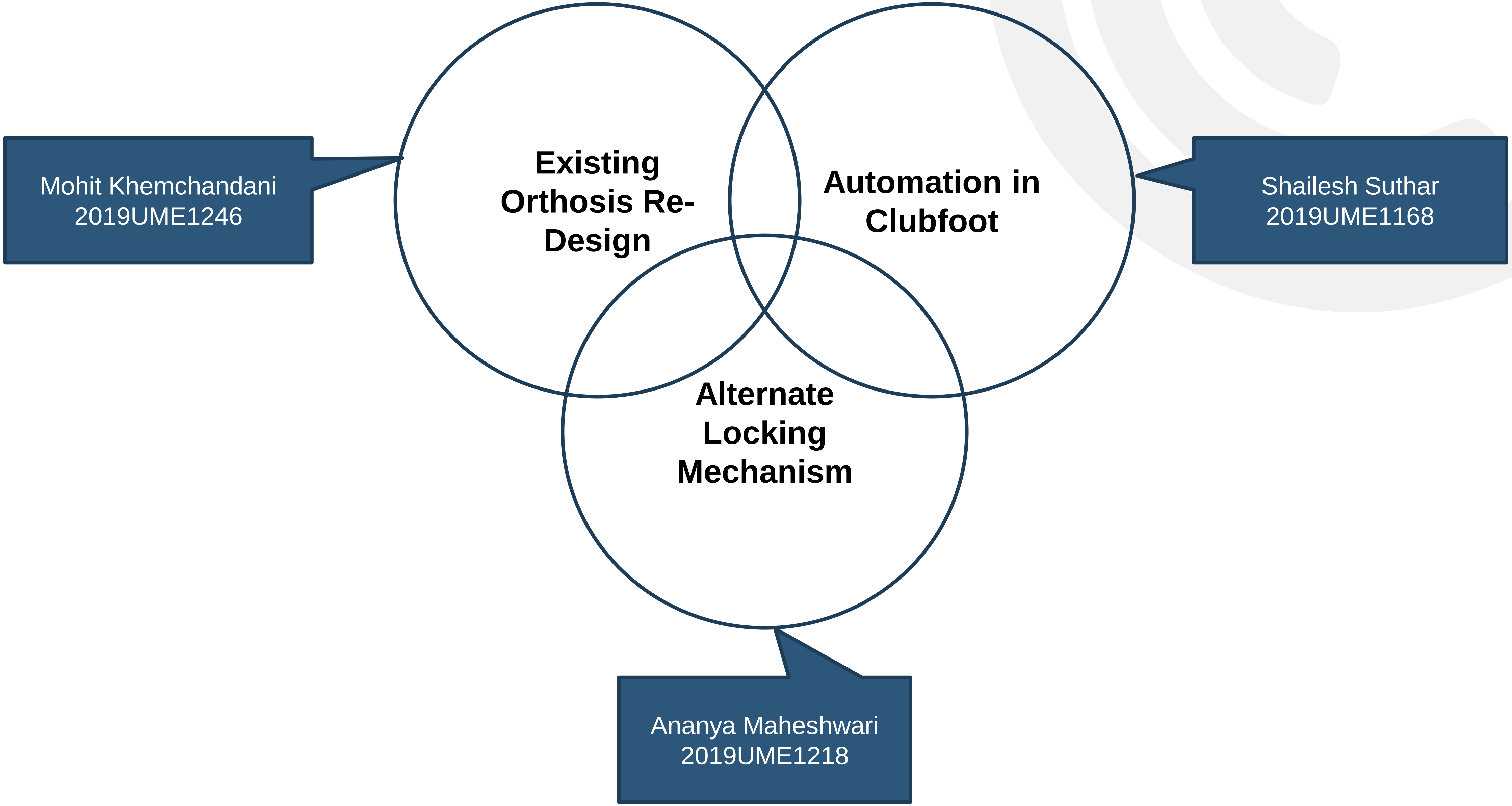
Fig. Fixture for stability of 3 gear mechanism (i) CAD design (ii) SLA Printed Fixture

CONCLUSION

CONCLUSION AND FUTURE SCOPE

- The primary objective of this final year project was to improve functionality of the existing orthosis and investigating the scope of implementing automation.
- Parallel to investigation of automation and development of the orthosis with alternate mechanisms was also done.
- The alternate mechanisms explored were such that their manufacturing, quality assurance, testing and assembly were much cheaper compared to the existing worm and gear assembly.
- Although efforts have been made to improve the orthosis by including automation and looking for alternate mechanisms, it is still not ready to be used, and has much room for improvement.
- The future work may include developing the orthosis prototype incorporating the hardware for orthosis automation, which includes procurement of items such as stepper motors, sensors, IDE, battery packs, etc, after which design changes may be done to incorporate these sensors and motors in the orthosis.
- Further, integration of work on MATLAB Simulink with the hardware is necessary.

CONTRIBUTION




Thank you!