भारतीय प्रौद्योगिकी संस्थान तिरुपति
TIRUPATI

Department of Mechanical Engineering
Indian Institute of Technology Tirupati

B. Tech Final Year Project Presentation

DESIGN AND FABRICATION OF EXPERIMENT FOR DYNAMIC ANALYSIS OF MECHANISMS

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2. A. Akhil (ME16B003)

Supervised by

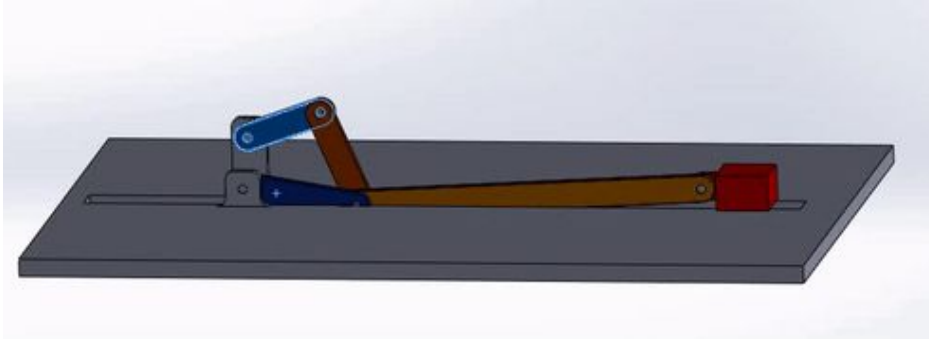
1. Dr. Sriram Sundar, Assistant Prof of ME

Date: 19-June-2020

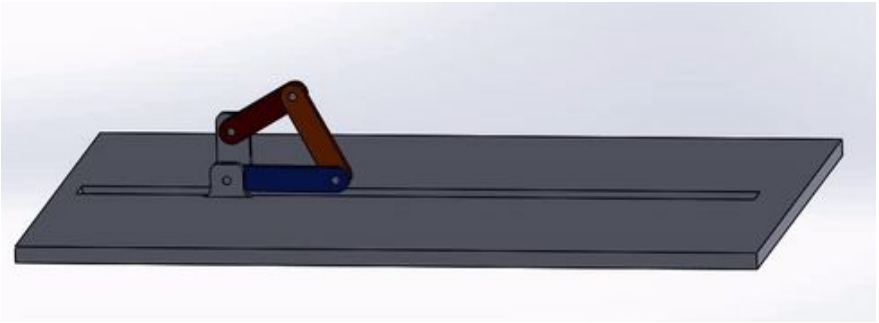
Objectives and Motivation

- **Introduction** - Design and fabrication of instrumented experimental setup for static, kinematic and dynamic analysis of mechanisms with retrofitted parts.

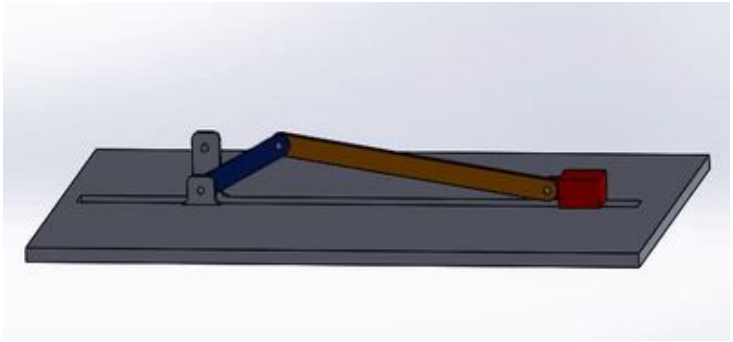
- **Motivation -** The experiment will supplement and reinforce the theoretical understanding of the undergraduate students taking the ME2206 (KDM) course.



Six bar mechanism



Four bar mechanism



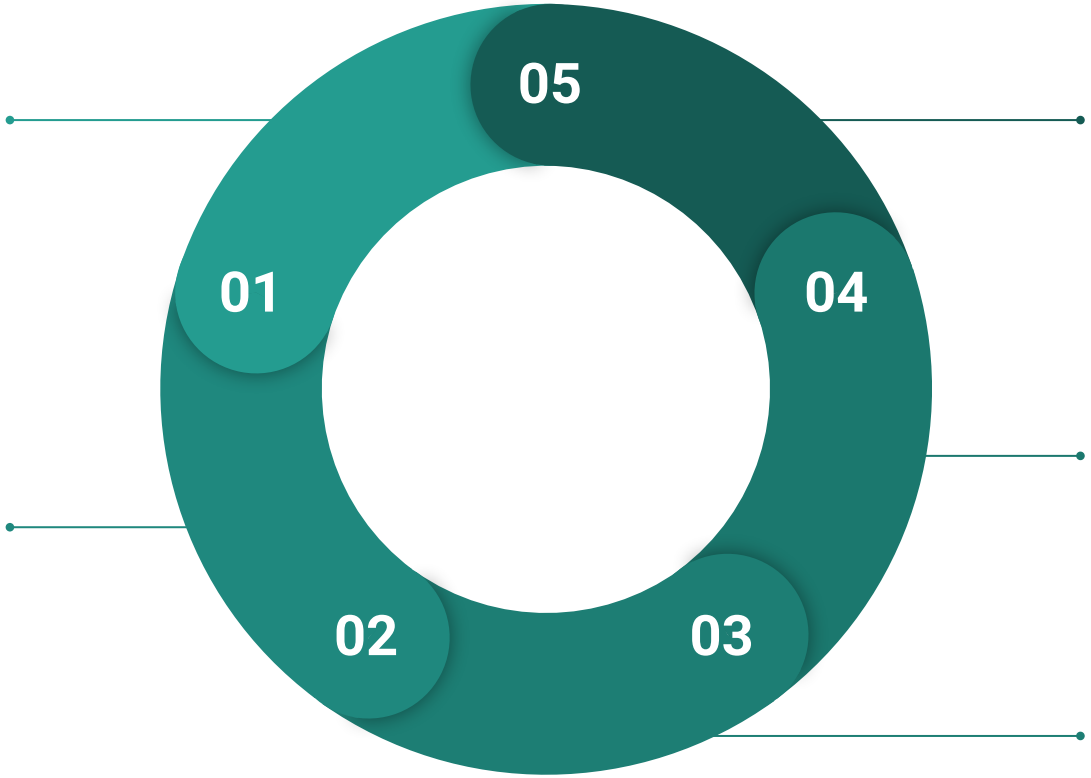
Slider crank mechanism

Workflow

Mathematical formulation

Kinematic analysis (GeoGebra, Python)

Dynamic analysis (MATLAB Simscape)



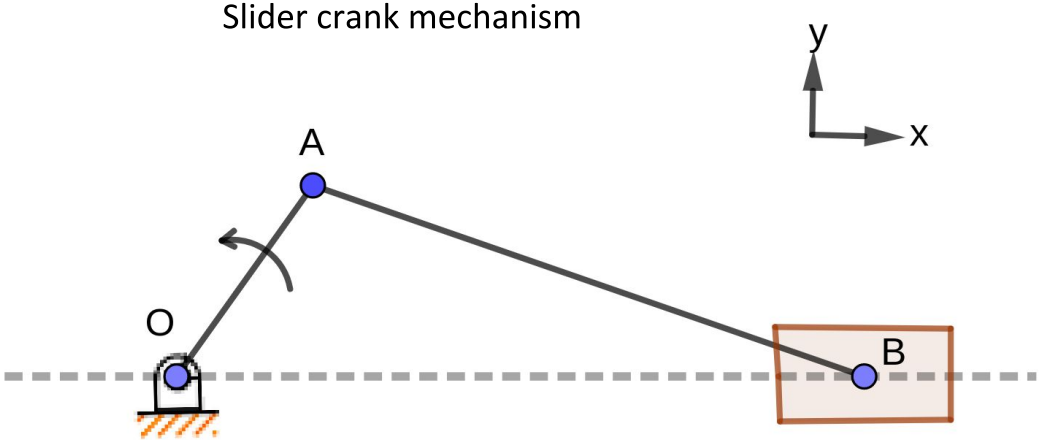
Instrumentation & GUI Software to get theoretical values

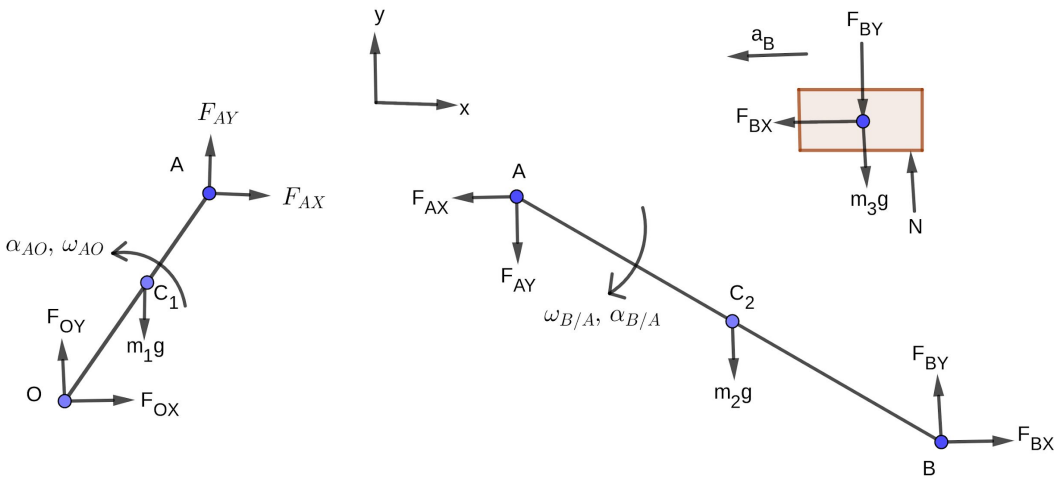
Fabrication of base frame and links

CAD modeling

Mathematical Formulation

Slider crank mechanism





Kinematics analysis

Finding angular velocity (AB) and slider velocity

$$\vec{V}_{B/A} = \vec{V}_B - \vec{V}_A \qquad \vec{V}_{B/A} = \vec{\omega}_{BA} \times \vec{r}_{B/A}$$

$$\vec{V}_{A/O} = \vec{\omega}_{AO} \times \vec{r}_{A/O} = \vec{V}_A \qquad \vec{\omega}_{BA} \times \vec{r}_{B/A} = \vec{V}_B - \vec{V}_A$$

Finding angular acceleration (AB) and slider acceleration

$$\vec{a}_{A/O} = \vec{a}_A = \vec{a}_A^t + \vec{a}_A^n \qquad \vec{a}_{B/A} = \vec{a}_{B/A}^t + \vec{a}_{B/A}^n = \vec{a}_B - \vec{a}_A$$

$$\vec{a}_A^t = \vec{\alpha}_{A/O} \times \vec{r}_{A/O} \qquad \vec{a}_A^n = \vec{\omega}_{AO} \times \vec{\omega}_{AO} \times \vec{r}_{A/O}$$

Dynamic analysis

Force and torque balance for link AB

$$F_{AX} = F_{BX}$$

$$F_{BY} = F_{AY} + m_2 g$$

$$I_{BA}\vec{\alpha}_{B/A} = \vec{r}_{C_2/A} \times m_2 g(-\hat{j}) + \vec{r}_{B/A} \times \vec{F}_B$$

Force balance for slider

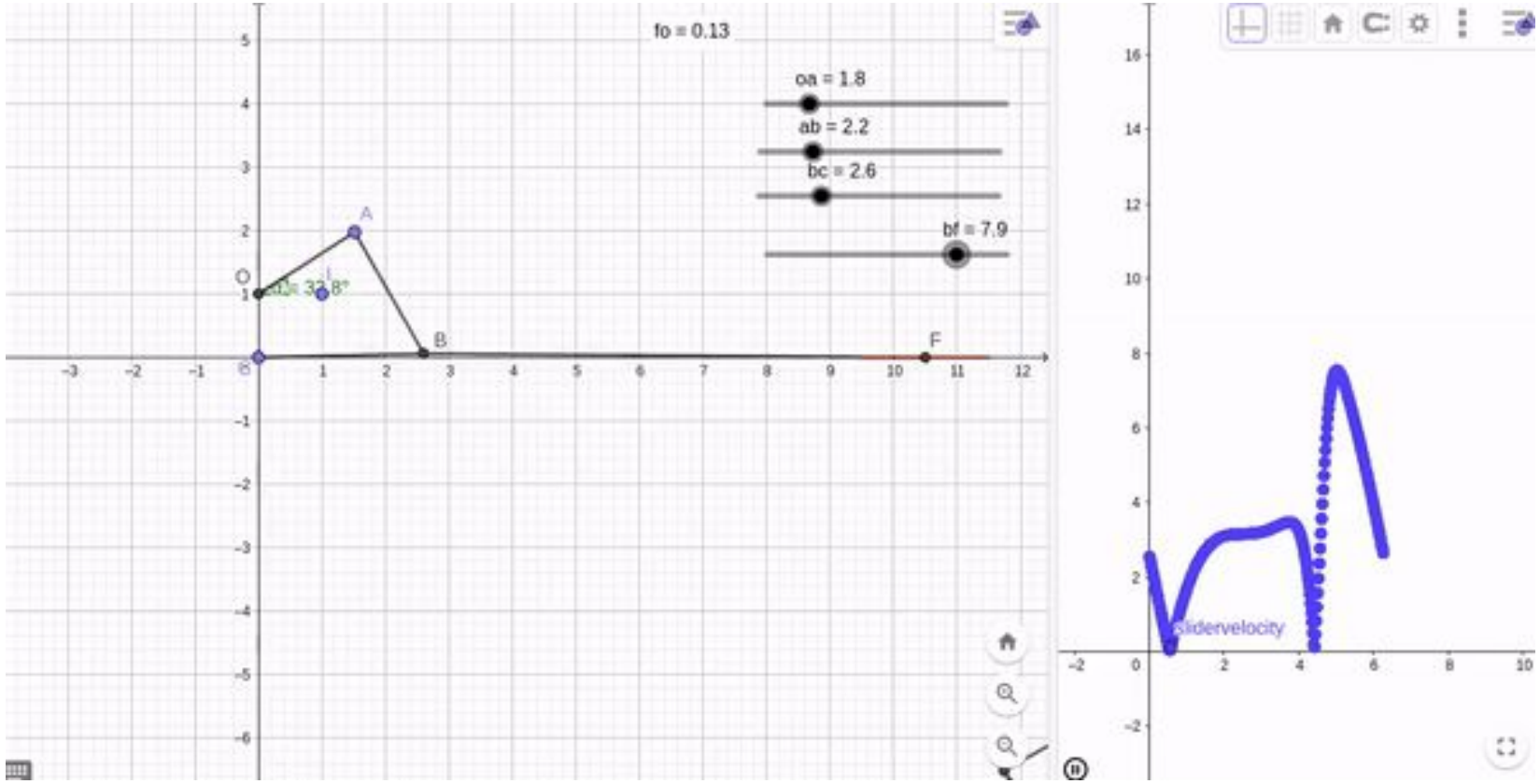
$$F_{BY} + m_3 g = N$$

$$m_3 a_B = F_{BX}$$

Note: there may be missing steps for the sake of brevity. Refer to report for completeness.

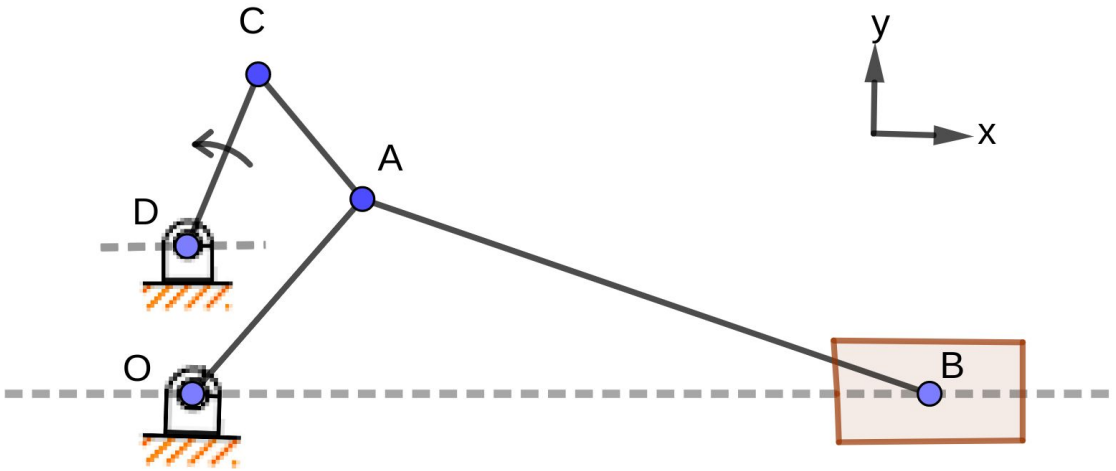
Kinematic analysis (Geogebra)

- By using Geogebra, we obtained preliminary link lengths and slider velocity profile.
- Analysed the velocity profile by changing link lengths.



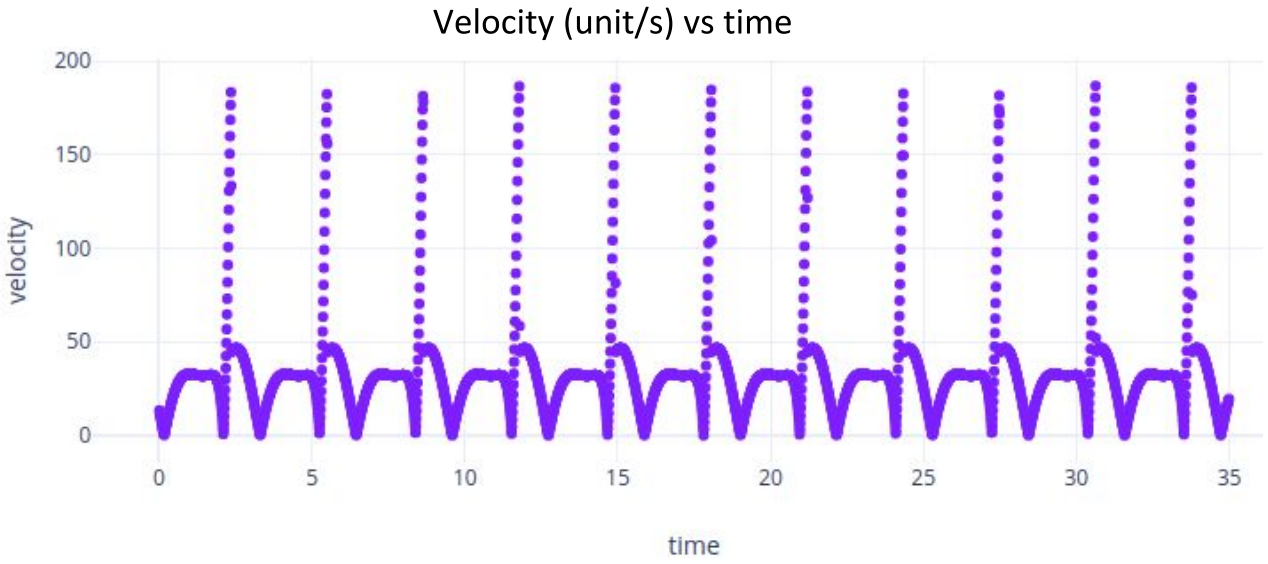
Design for constant velocity

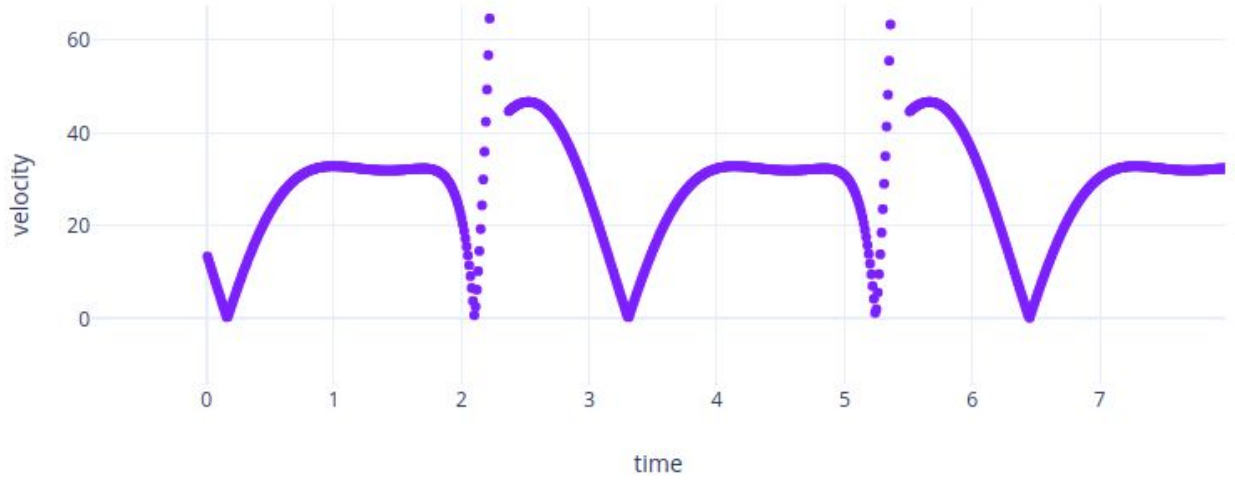
- Iteration over preliminary length ratios obtained from GeoGebra



Obtained length ratios for minimal velocity variation

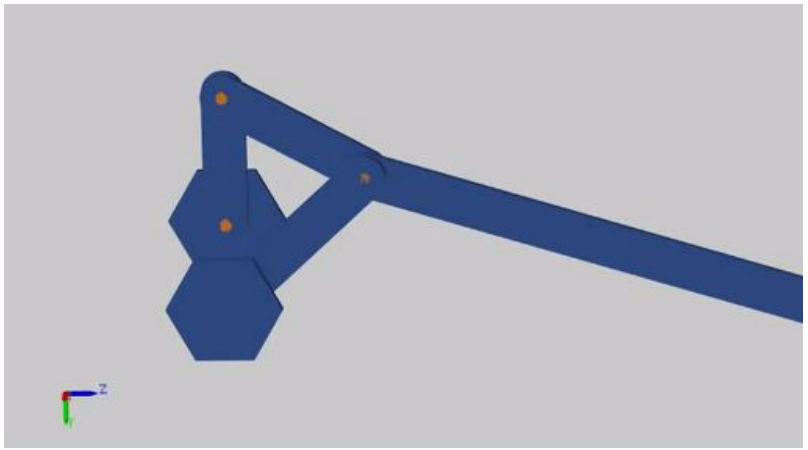
OA	AB	CD	AC
26	79	18	22

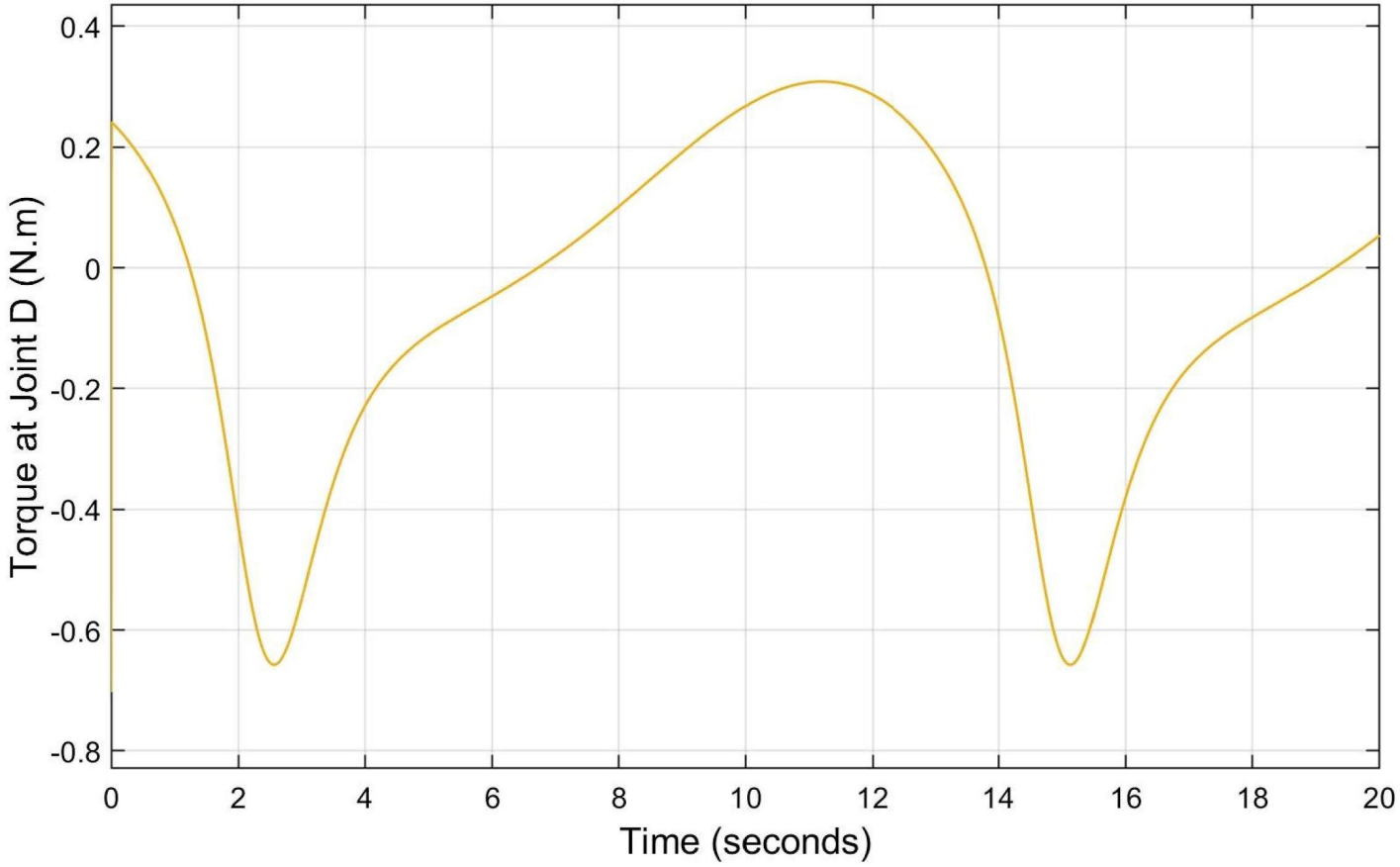




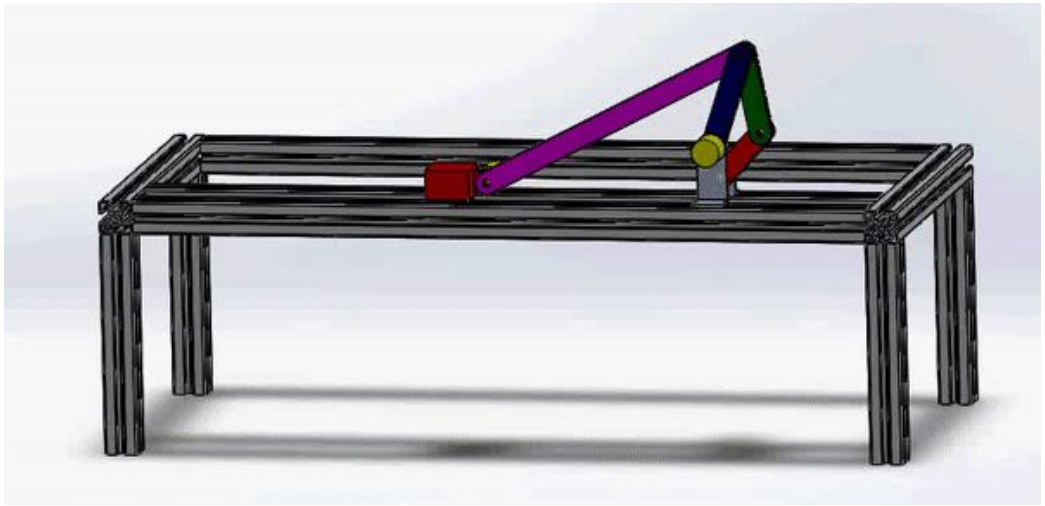
Dynamic Analysis

- By Dynamic analysis we calculated the range of torque and forces on the link which used to choose the actuator.

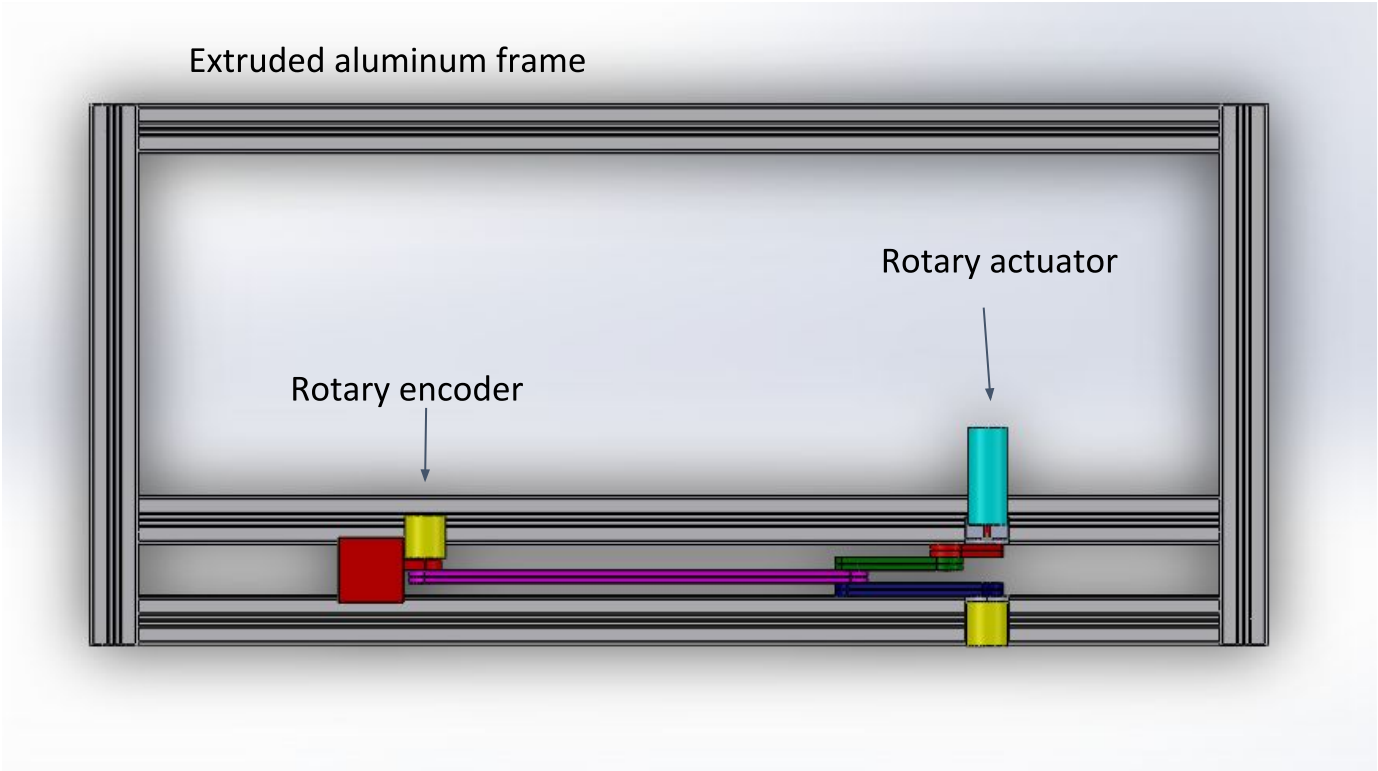




CAD Design of experimental setup



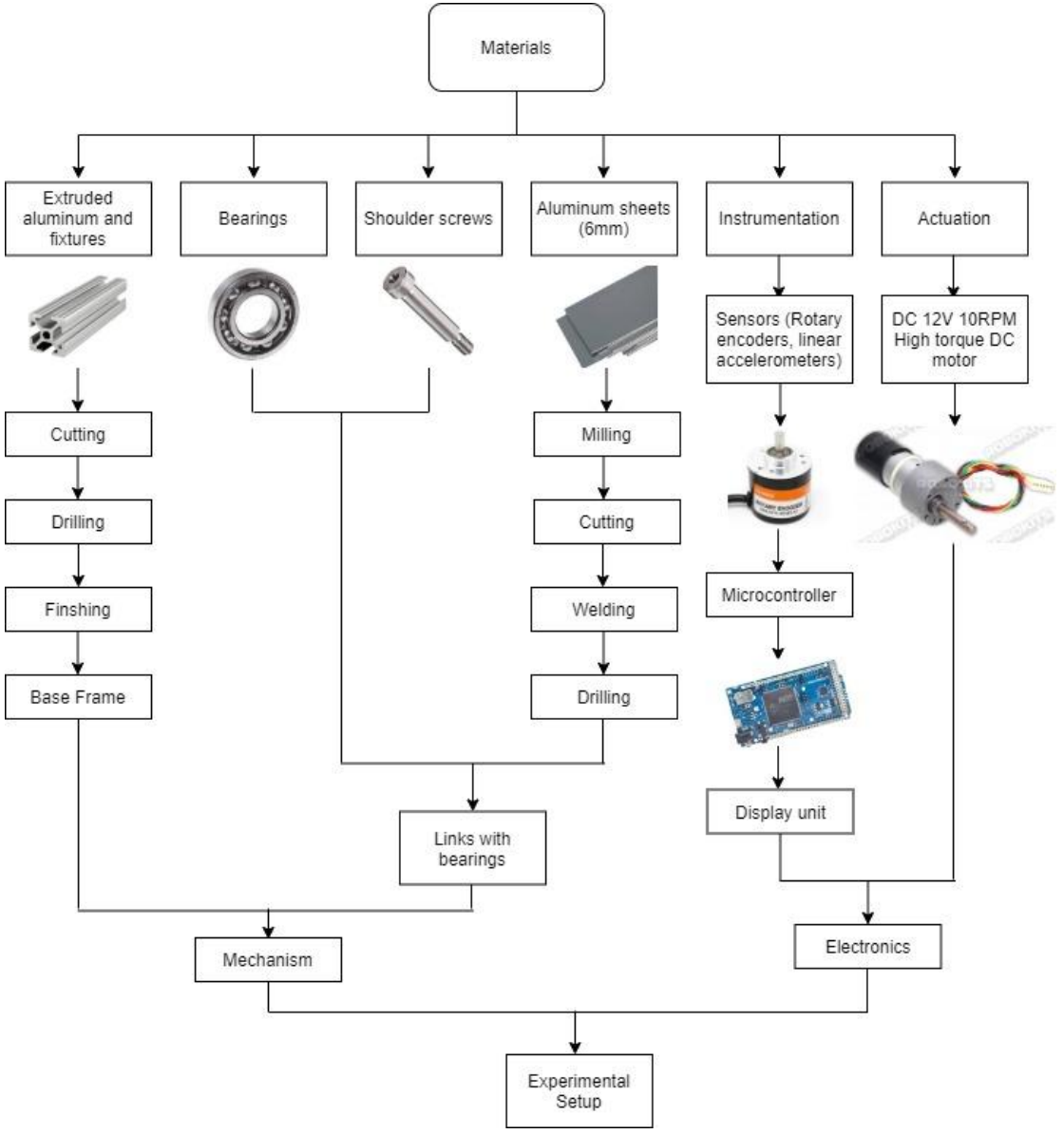
CAD: Motion Study



CAD: Top view

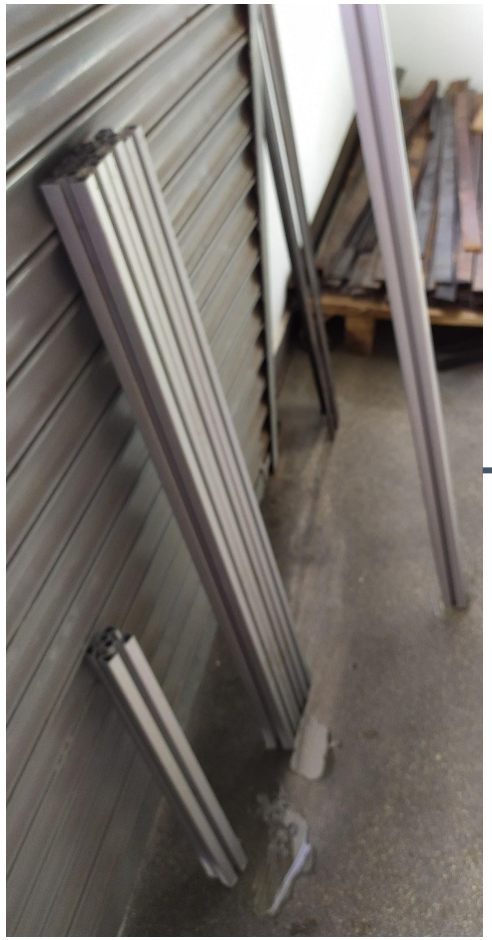
Model generated on Solidworks

Fabrication plan

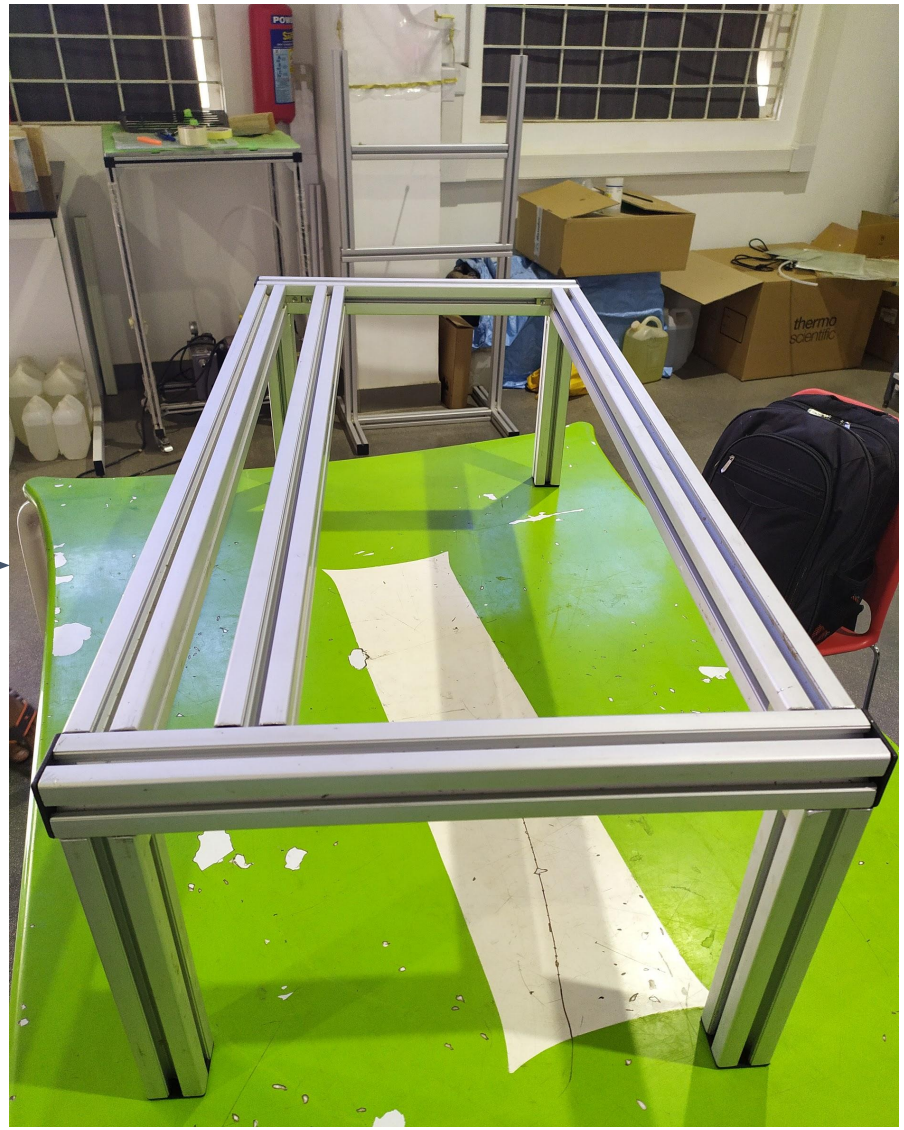


Sources: Bearing(SKF), Extruded Aluminum(indiamart.com), Shoulder screw(indiamart.com), AL sheets (indiamart.com)

Fabrication



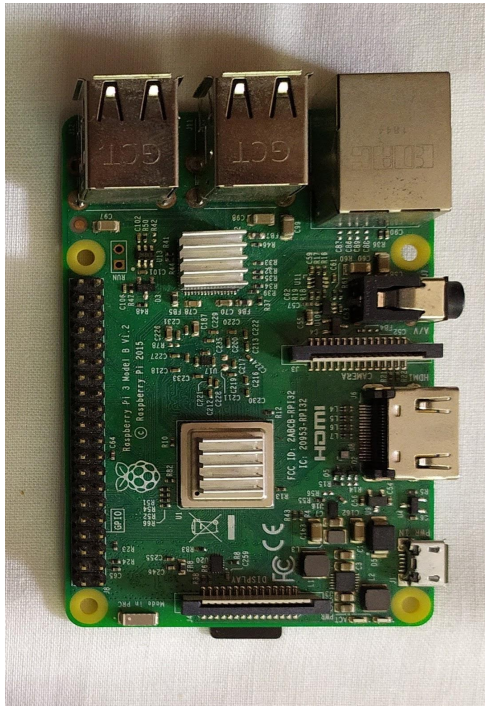
Extruded aluminium frame



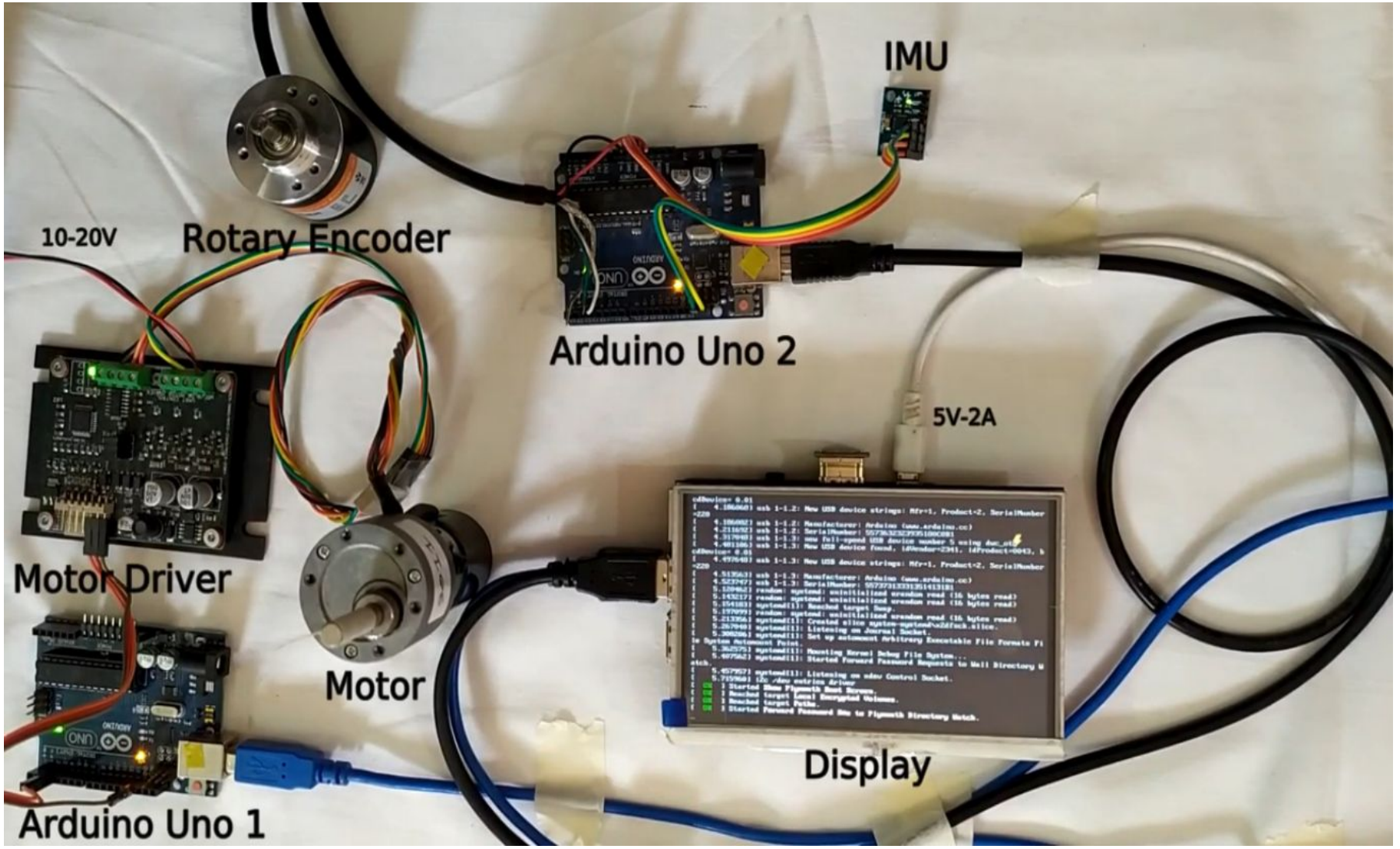
Assembled base

Links and L-joint

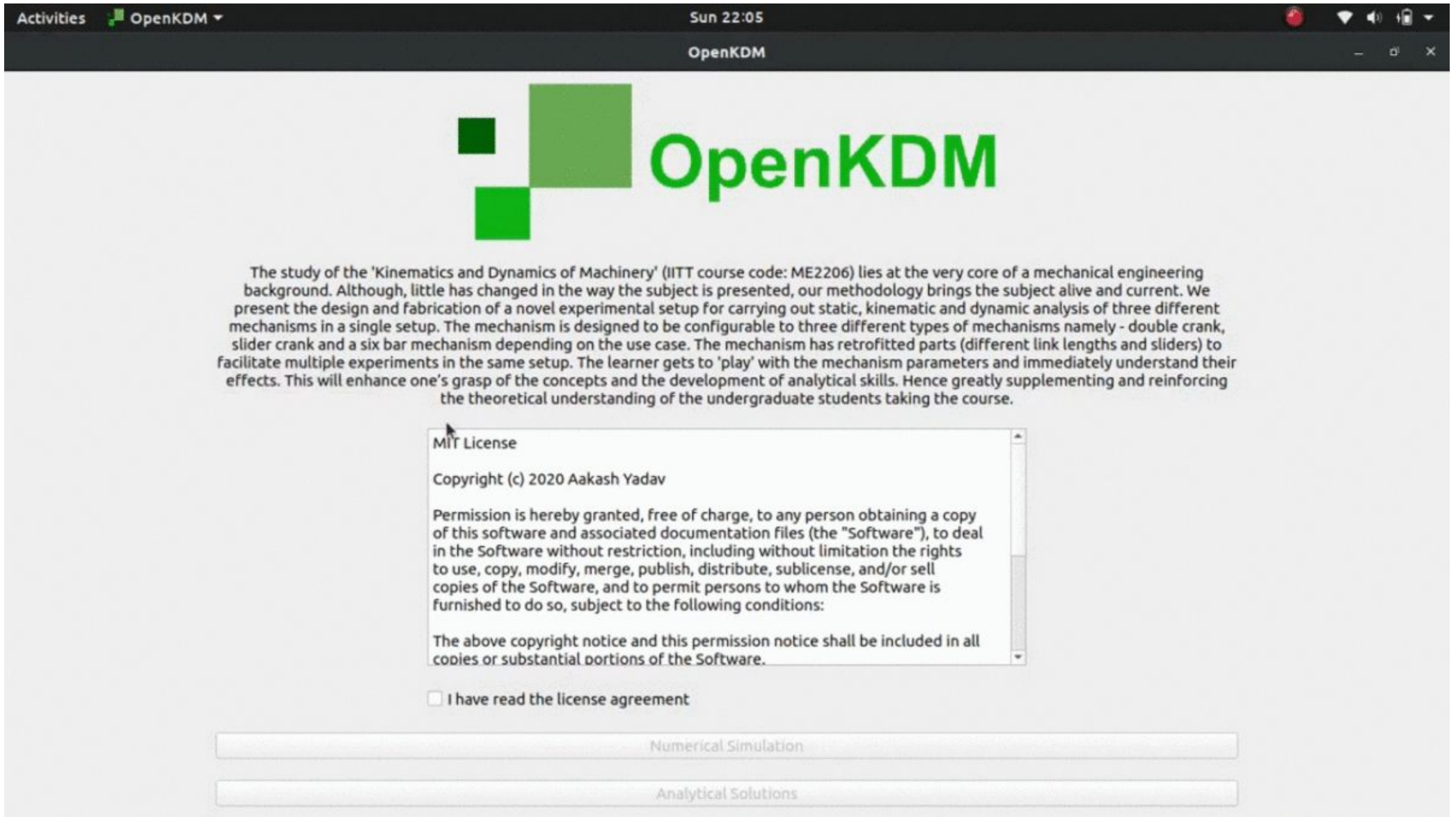
Instrumentation of setup



Raspberry Pi 3 B+



Software for analytical approach



YouTube: https://youtu.be/1nqF1lyesHM

Experiment plan

Aim:

1. To find the slider velocity and acceleration for six bar mechanism and slider crank mechanism
2. To find angular velocity and angular acceleration of all links in double crank mechanism.

Methodology and Results:

- This experimental setup will store the data of all parameters for each angular position.
- Students can select the angular position in the experimental setup to get the stored data display.
- Students need to solve theoretically for any particular angular position of mechanism.
- Students can compare theoretical results with practical results.

Conclusions

- Full fledged CAD model of the mechanism was created considering the fabrication constraints.
- All the required raw material were procured.
- The base frame has been assembled while manufacturing and assembly of the links is in process.
- Instrumentation of experimental setup has been completed.
- Software developed to get the link velocities, accelerations and forces by using analytical approach
- Designed the *lab manual* for the experiment.

References

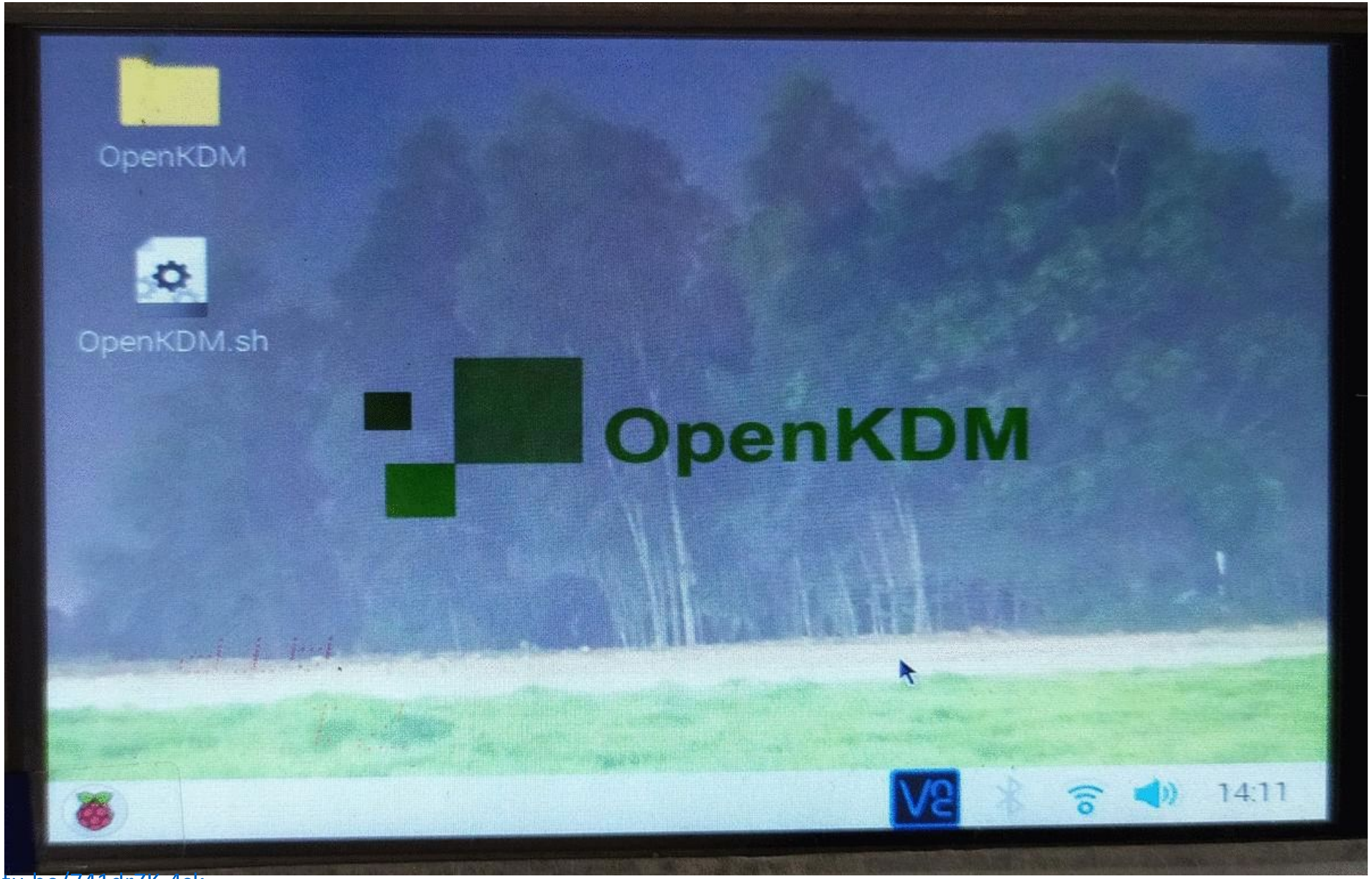
1. A. Ghosh and A. K. Mallik, Theory of mechanisms and machines. Affiliated East-West Press Private Limited, 2002.

2. R. L. Norton, Kinematics and dynamics of machinery. McGraw-Hill Higher Education, 2011.

3. J. J. Uicker, G. R. Pennock, J. E. Shigley, et al., Theory of machines and mechanisms, volume 1. Oxford University Press New York, NY, 2011.

END

Instrumentation of setup

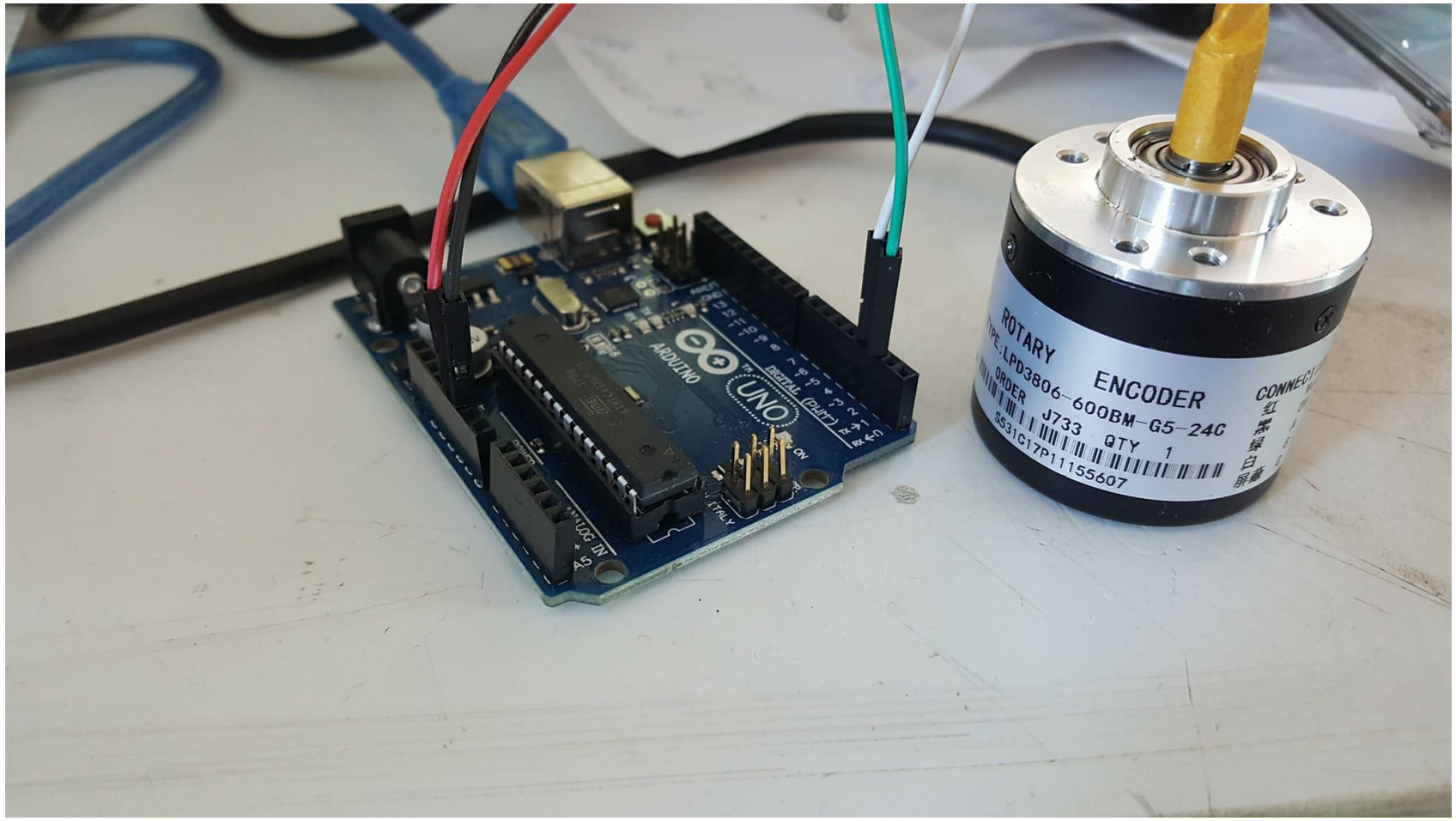


YouTube: https://youtu.be/741drZK-4sk

Workflow

- Mathematical formulation
- Kinematic analysis (GeoGebra, Python)
- Dynamic analysis (MATLAB Simscape)
- CAD modeling
- Fabrication of base frame and links
- Instrumentation with its interface
- Software to get theoretical values
- Lab manual

Testing of Rotary Encoder



- 600 PPR Rotary encoder was selected and purchased
- In-house Arduino program was used to test the encoder for measuring rotation angles.

Actuator selection

DC 12V 10 rpm high torque quad encoder motor

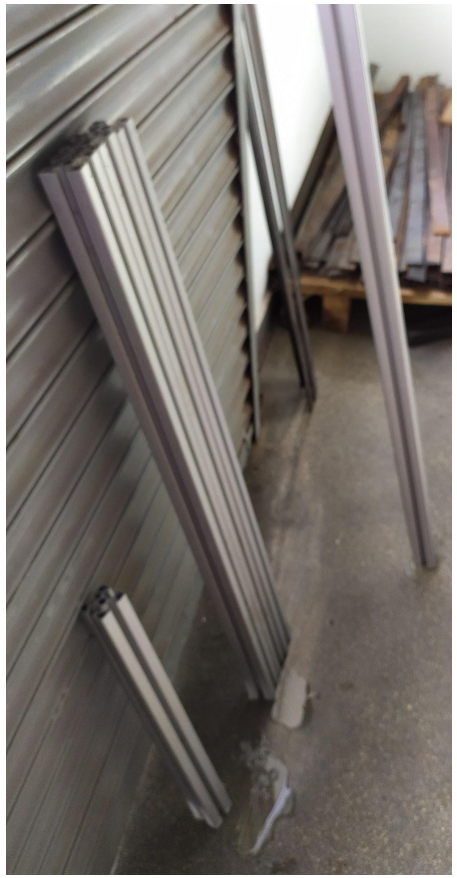
DC servo driver

Image source: Robokits India

Raw materials

Aluminium flat

Bearings



Extruded aluminium frame

Future Work

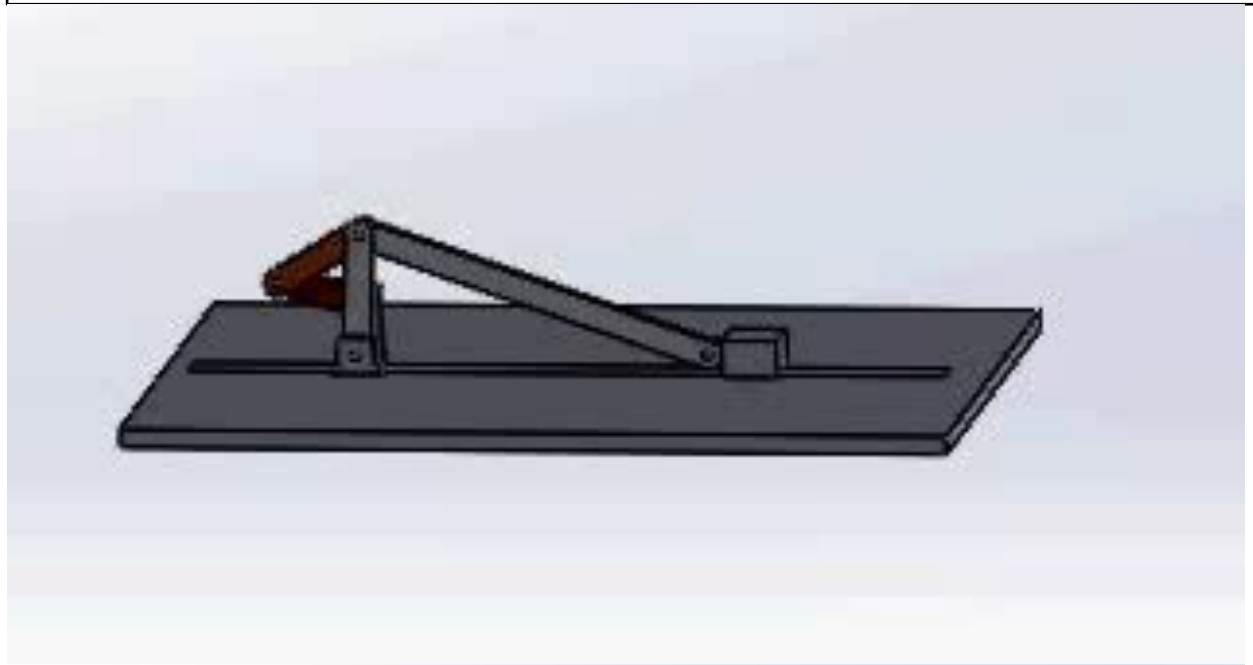
Fabrication (31st March) → Testing (10th April) → Documentation

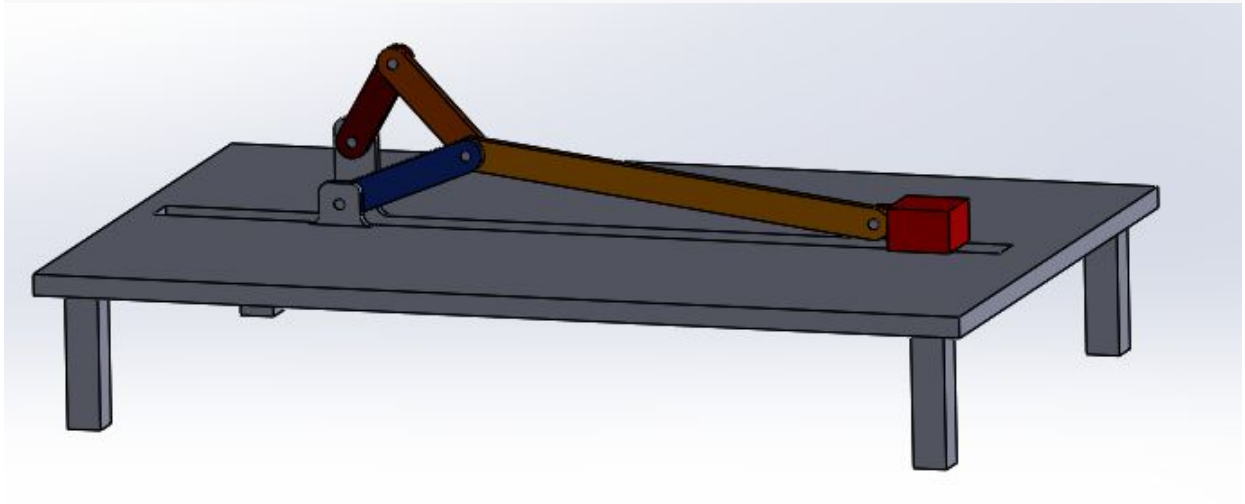
- Fabrication and assembly of links.
- Integration of encoders and other electronics

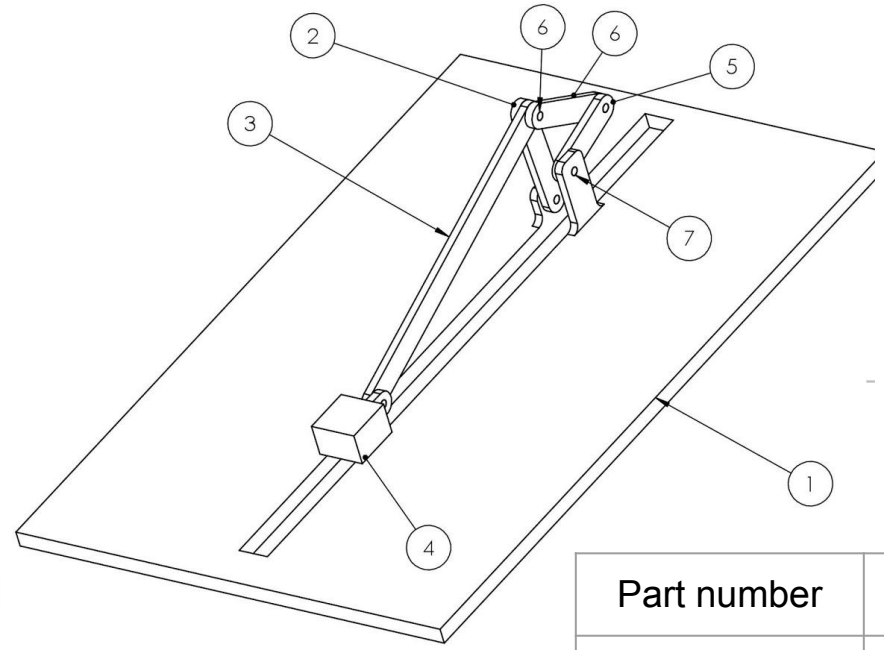
- Experimentation, testing and validation.
- Design changes if required

- Creation of experiment manual and documentation.

3D Model







Part number	Part Name
1	Ground
2	Link OA
3	Link AB
4	Slider
5	Link CD
6	Link AC

The above models were rendered using SolidWorks

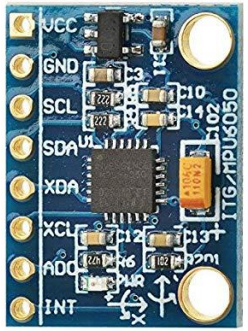
Sensor selection

Based on the results obtained from kinematic and dynamic analysis using MathWorks Simscape, we selected the required sensors.

- 2-Phase Incremental Optical Rotary Encoder to detect angular velocity and angular acceleration of links

Source: robu.in

- 3-Axis Accelerometer is to detect linear acceleration and linear velocity of slider.



Source: amazon.in

Cost Analysis

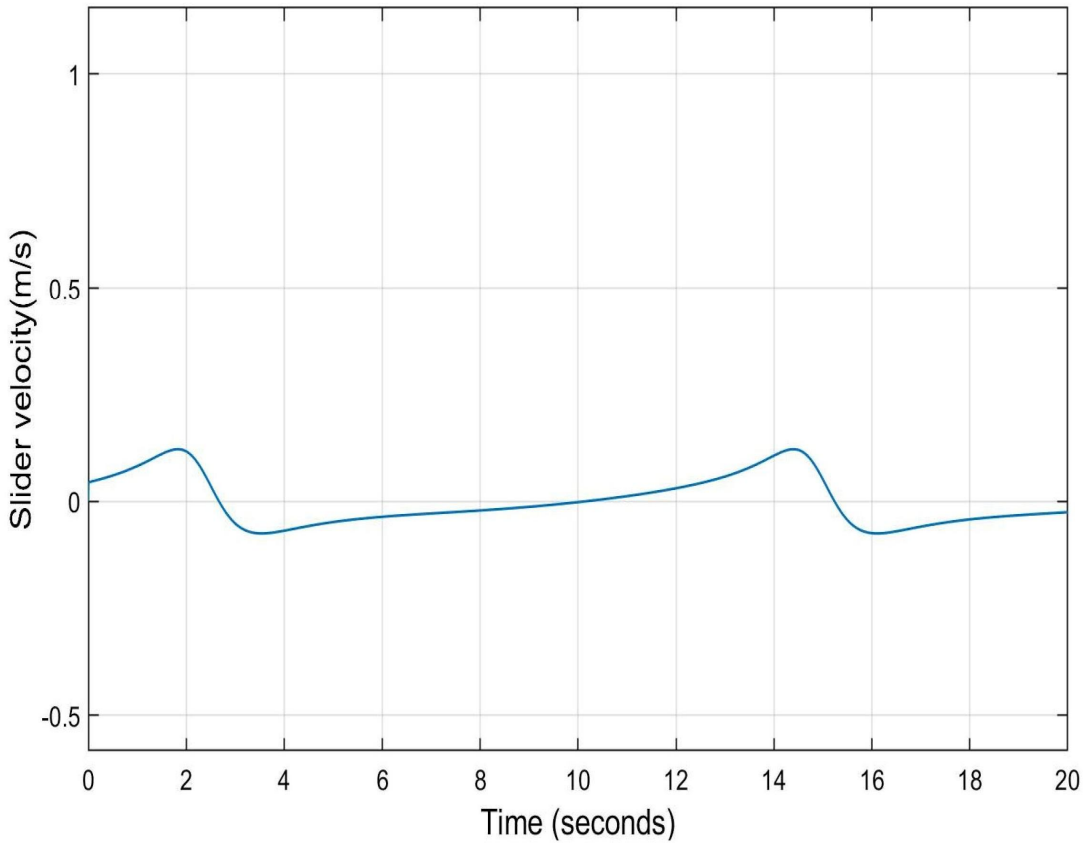
No	Name	Unit cost in INR	Quantity	Cost in INR
1	Bearing	50	20	1000
2	Shoulder screw	20	6	120
3	Aluminum (for links and slider)	200 per kg	15kg	3000
4	Extruded Aluminum	400 per m	5	2000
5	Actuator	-	-	-
6	Rotary Encoder	2000	3	6000
7	Linear Accelerometer (8kHz)	200	1	200
8	Display	1000	1	1000
9	Other Electronics and miscellaneous			5000
10	Slotted weights, pulley	2000	1	2000
	Grand Total			20,320/-

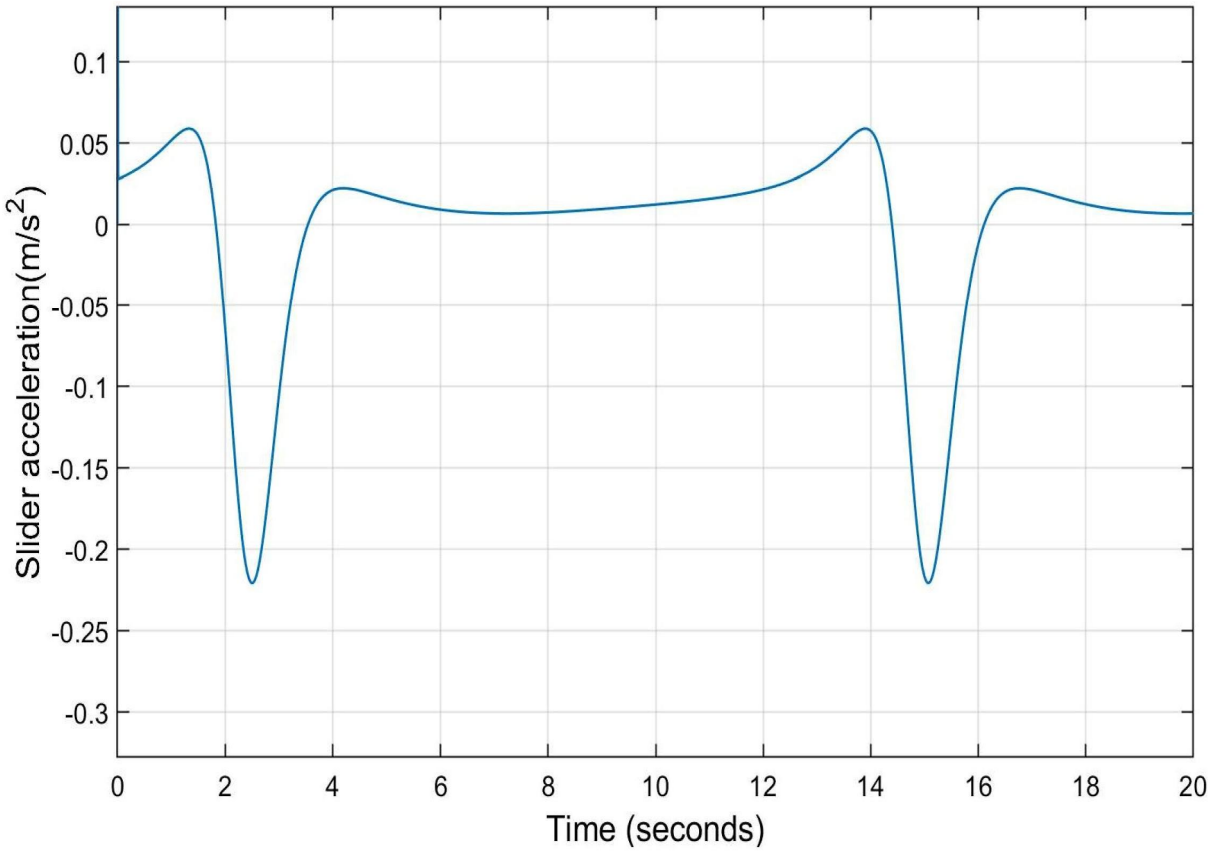
Note: tentative, minor changes may occur

Conclusions

- The complete analysis of the mechanism(s) was performed using applicable method and software.
- 3D CAD model of the mechanism was created to facilitate better visualisation.
- Various design considerations were addressed and manufacturing workflow and plan were accomplished as a prerequisite to manufacturing.
- BoM was prepared and materials acquisition from the vendor is in process.

Results


Slider velocity(m/s)
1
0.5
0
-0.5
0
2
4
6
8
10
12
14
16
18
20
Time (seconds)


Slider acceleration(m/s^2)
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
0
2
4
6
8
10
12
14
16
18
20
Time (seconds)

Future Work

Actuator selection → Final Design → Fabrication

- Need to find the best actuator with its control system.
- Final prototype model consisting of links, bearings, motors, sensors, etc.
- Fabrication and assembling of links.
- Experimentation, testing and validation.

References

1. MATLAB version 9.3.0.713579 (R2017b). The Mathworks, Inc., Natick, Massachusetts, 2017.
2. A. Ghosh and A. K. Mallik, Theory of mechanisms and machines. Affiliated East-West Press Private Limited, 2002.
3. M. Hohenwarter, M. Borcherds, G. Ancsin, B. Bencze, M. Blossier, A. Delobelle, C. Denizet, J. Éliás, A. Fekete, L. Gál, Z. Konecný ˇ , Z. Kovács, S. Lizelfelner, B. Parisse, and G. Sturr (2013). GeoGebra 4.4. http://www.geogebra.org.
4. R. L. Norton, Kinematics and dynamics of machinery. McGraw-Hill Higher Education, 2011.
5. Python Core Team (2018). Python: A dynamic, open source programming language. Python Software Foundation. URL https://www.python.org/.
6. J. J. Uicker, G. R. Pennock, J. E. Shigley, et al., Theory of machines and mechanisms, volume 1. Oxford University Press New York, NY, 2011.

Acknowledgements

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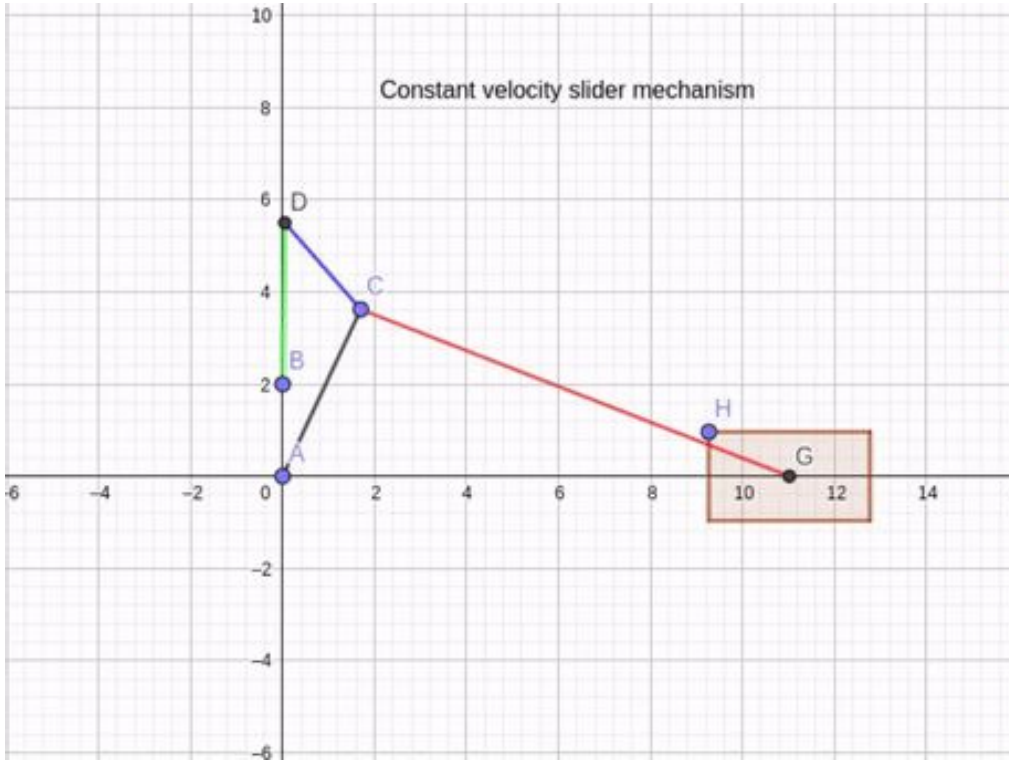
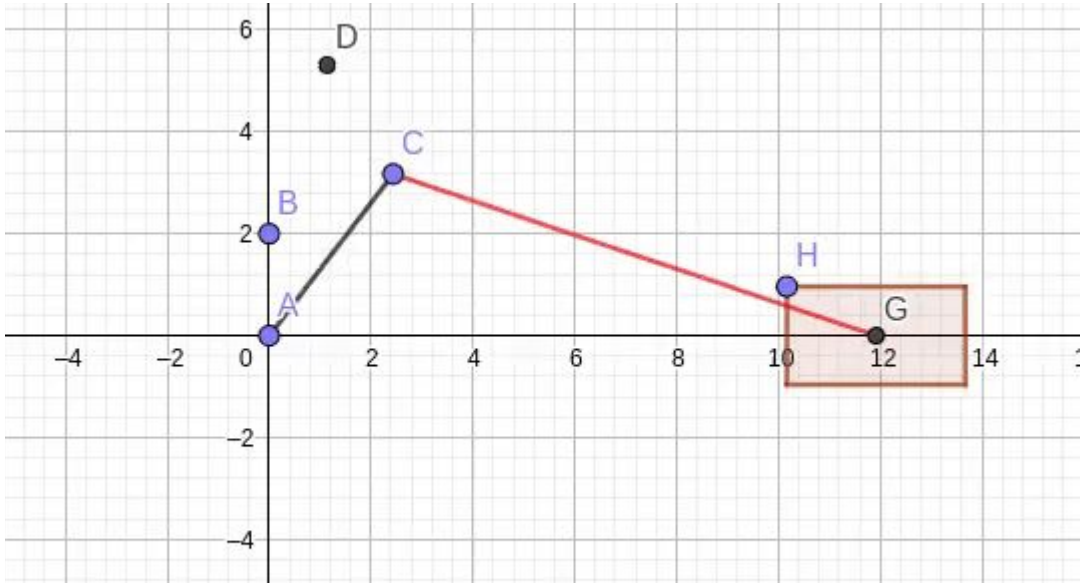
To our families, thank you for encouraging us in all of our pursuits and inspiring us to follow our dreams. We are especially grateful to our parents, who supported us emotionally and financially.

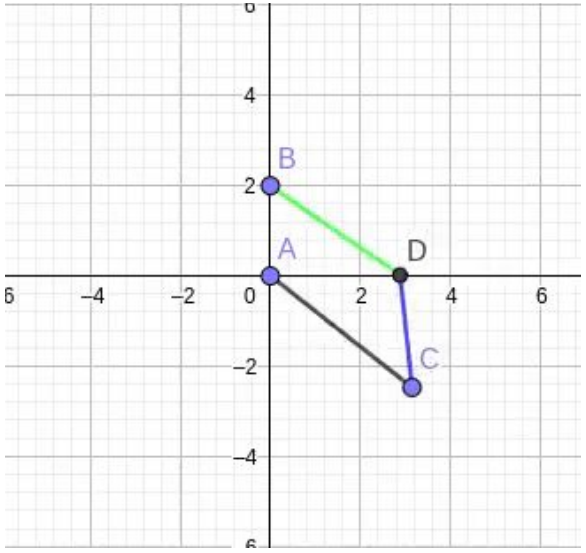
END

Supplementary material

Mechanism

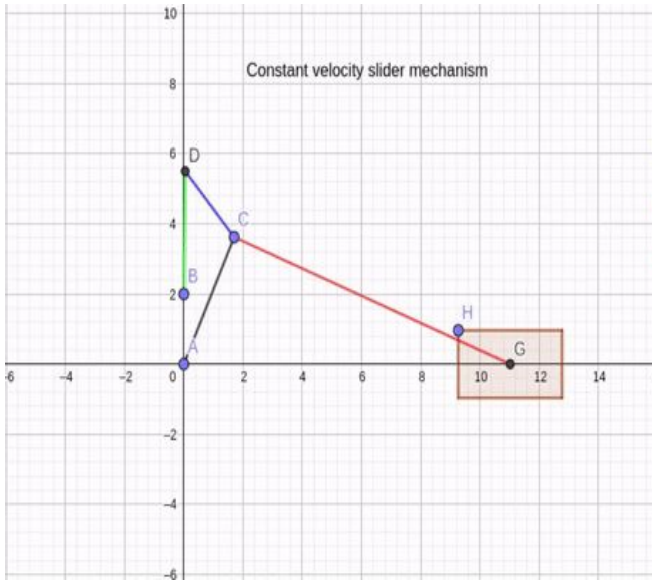


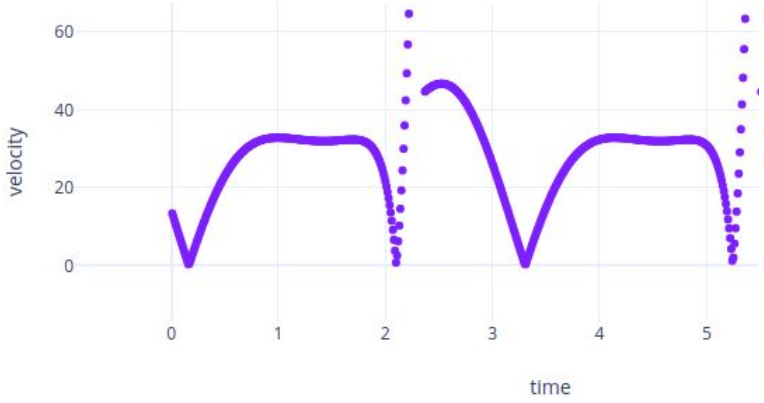




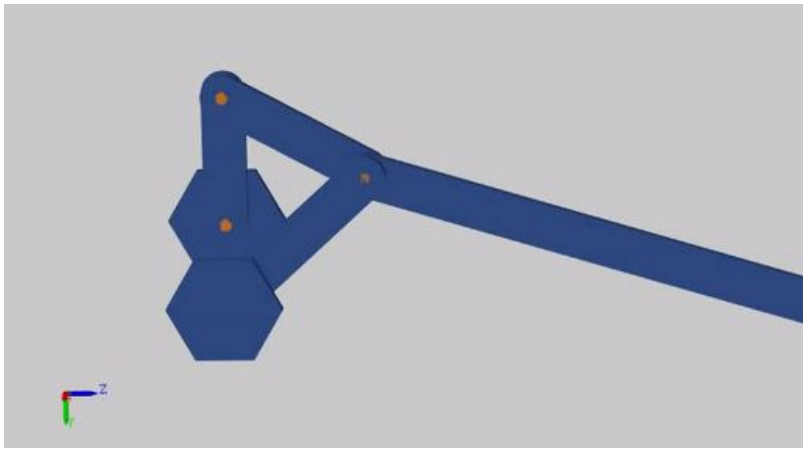
Updates

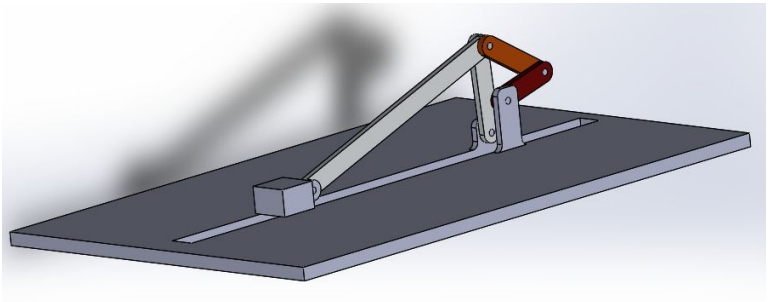
GeoGebra | Python | Simscape | Sensors selection





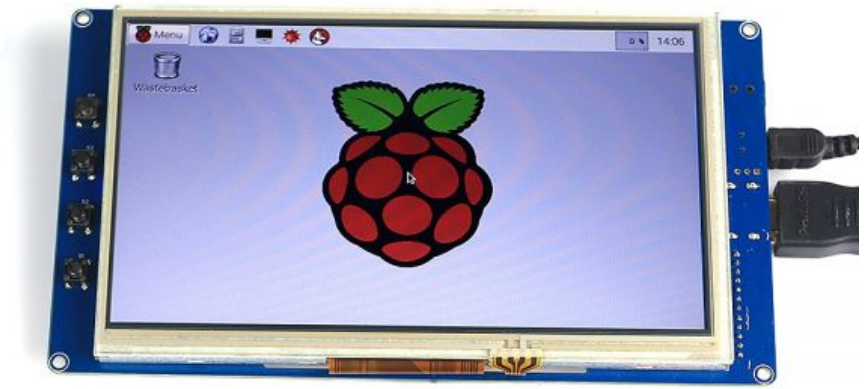
Velocity (unit/s) vs time



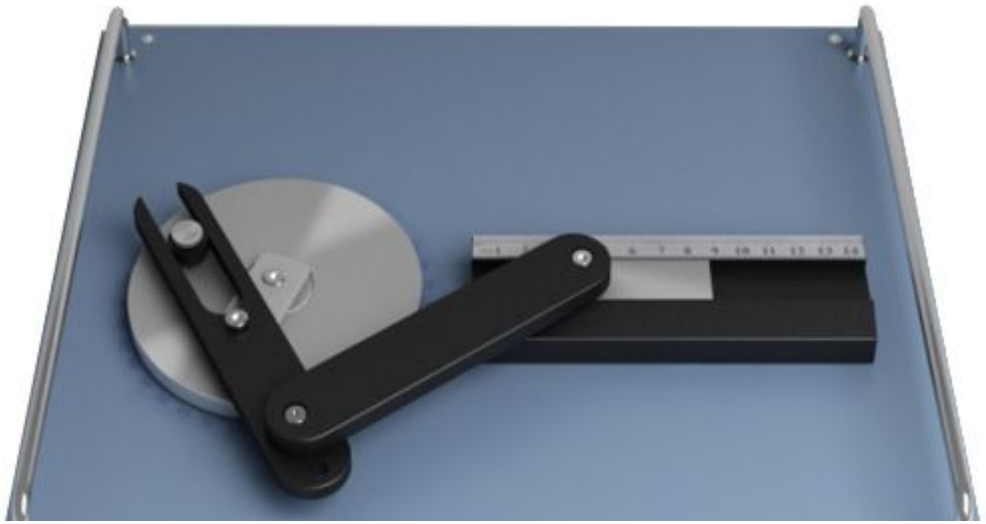


Introduction and Objectives

- To design and fabricate an experimental setup for static, kinematic and dynamic analysis of mechanism.
- The setup will have retrofitted parts in order to let the student carry out multiple experiments in the same setup.
- The experiment will supplement and reinforce the theoretical understanding of the undergraduate students taking the ME2206(KDM) by providing them the opportunity to match the analytical results with the actual experimental results.

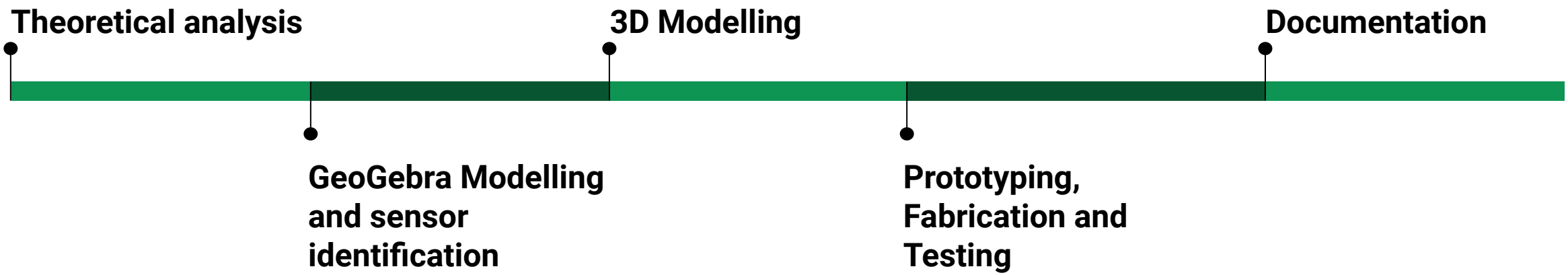


source: ardubotics.com



source: sun labtech

Plan

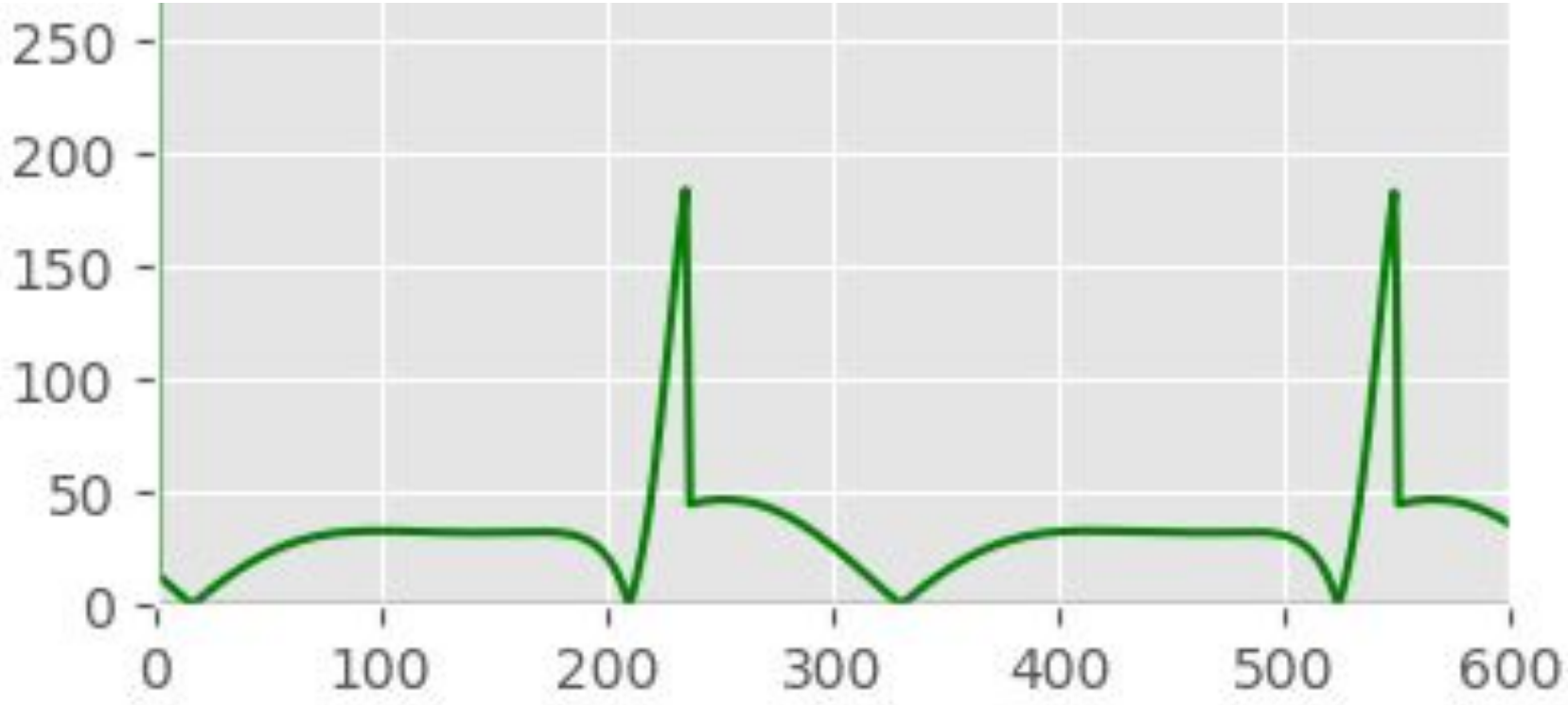


Estimated budget : INR 25,000.00 - 30,000.00

Probable sensors for instrumentation: Rotary encoders, Ultrasonic range sensors, linear accelerometers, strain gauges

Literature Review

- Kinematics and Dynamics of Machinery, Robert L. Norton
- Theory of Mechanisms and Machines, Ghosh and Mallik
- Theory of Machines and Mechanisms, Uicker, Pennock and Shigley



Mathematical Formulation

Slider crank mechanism

Force and torque balance for link OA

$$F_{OX} + F_{AX} = 0$$

$$F_{OY} + F_{AY} = m_1 g$$

$$I_{AO}\vec{\alpha}_{AO} = \vec{r}_{C_1 O} \times m_1 g(-\hat{j}) + \vec{r}_{A/O} \times \vec{F}_A$$

Note: there may be missing steps and common notations for the sake of brevity. Refer to report for completeness