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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Supervised by

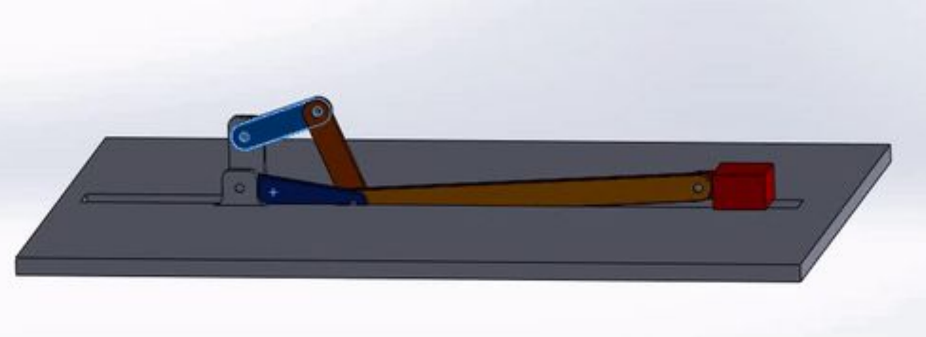
1. Dr. Sriram Sundar, Assistant Prof of ME

Date: 11-Mar-2020

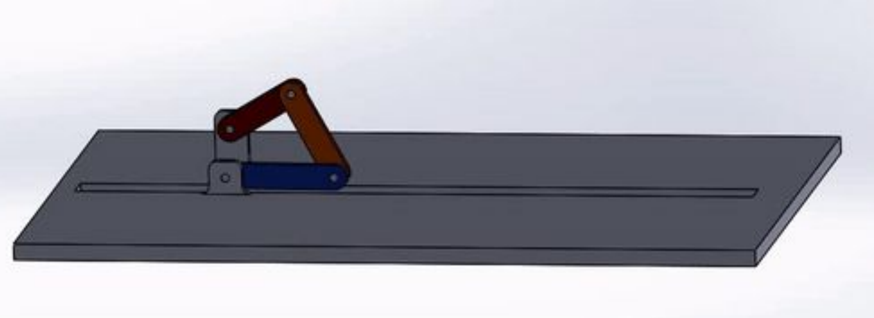
Objectives and Motivation

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

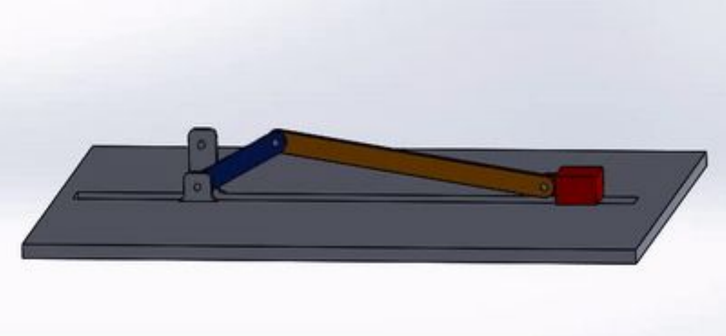
- **Motivation -** The experiment will supplement and reinforce the theoretical understanding of the undergraduate students taking the ME2206 (KDM) course.



Six bar mechanism



Four bar mechanism



Slider crank mechanism

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.

Manufacturing plan

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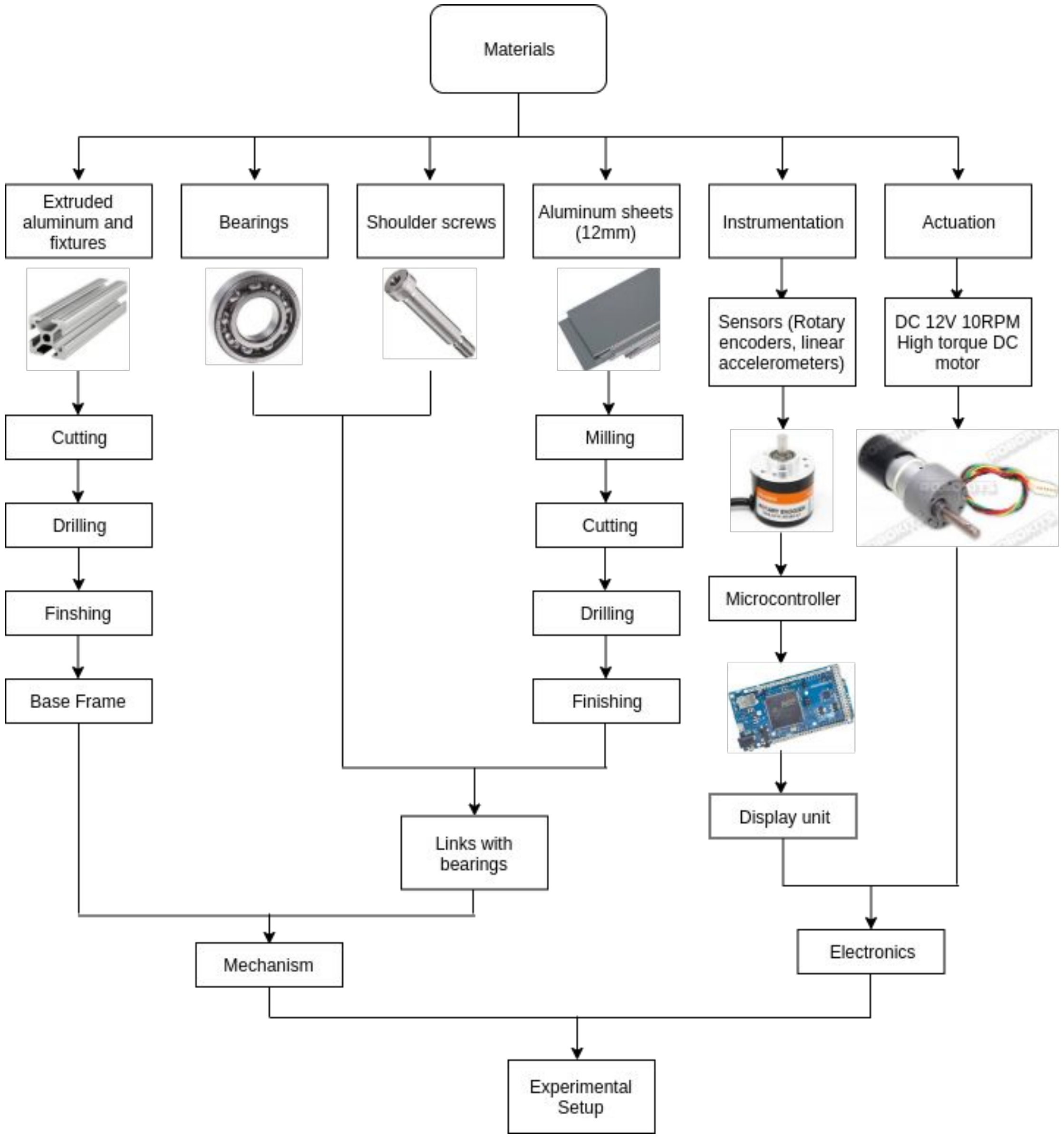
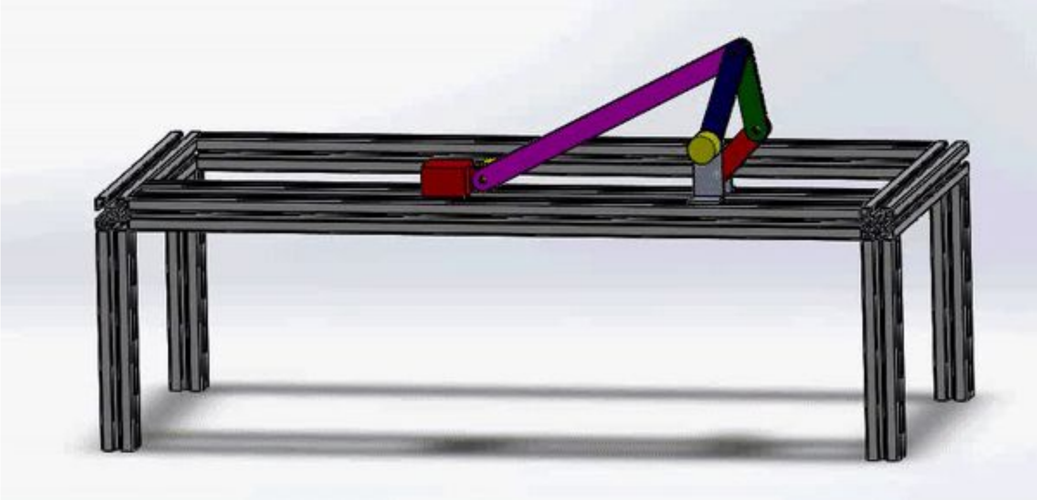
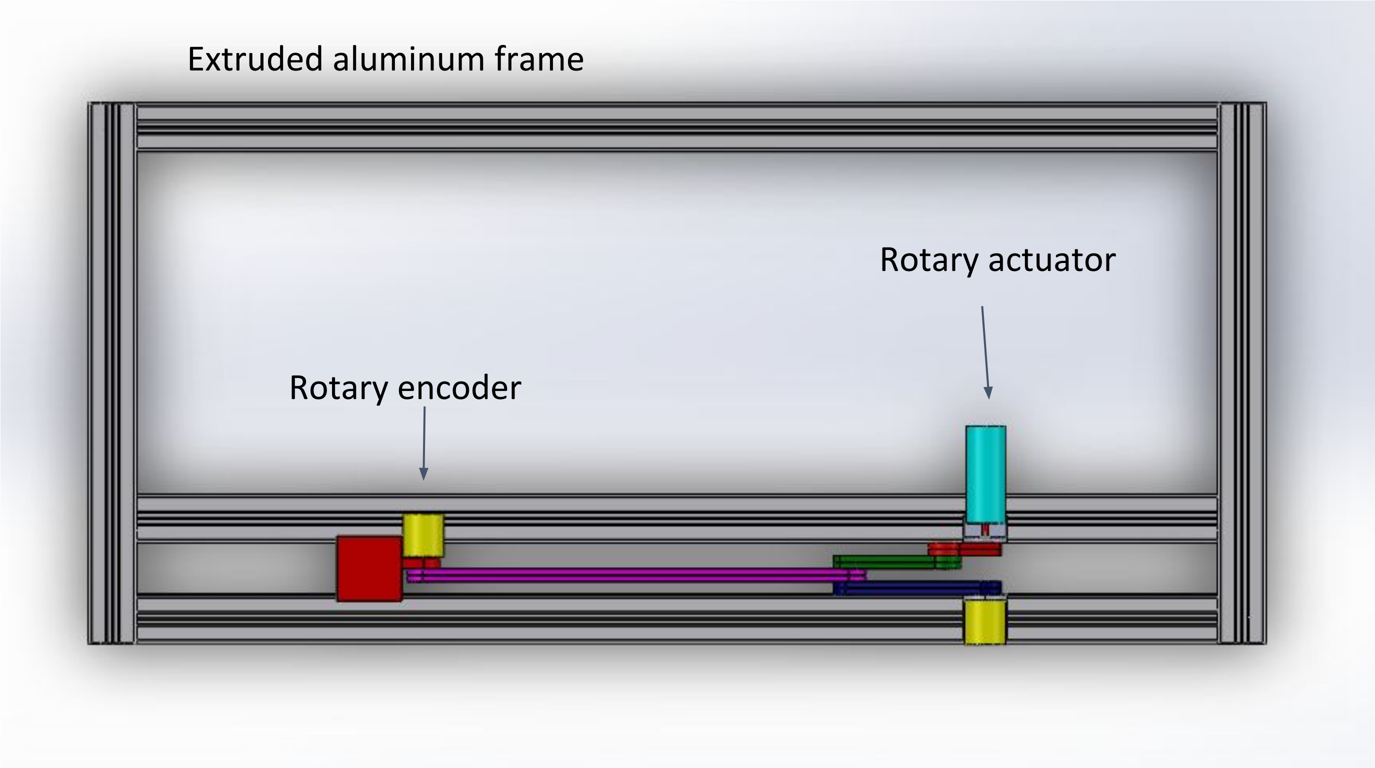


Sources: Bearing(SKF), Extruded Aluminum(indiamart.com), Shoulder screw(indiamart.com), AL sheets (indiamart.com)

Updated CAD Design



CAD: Motion Study



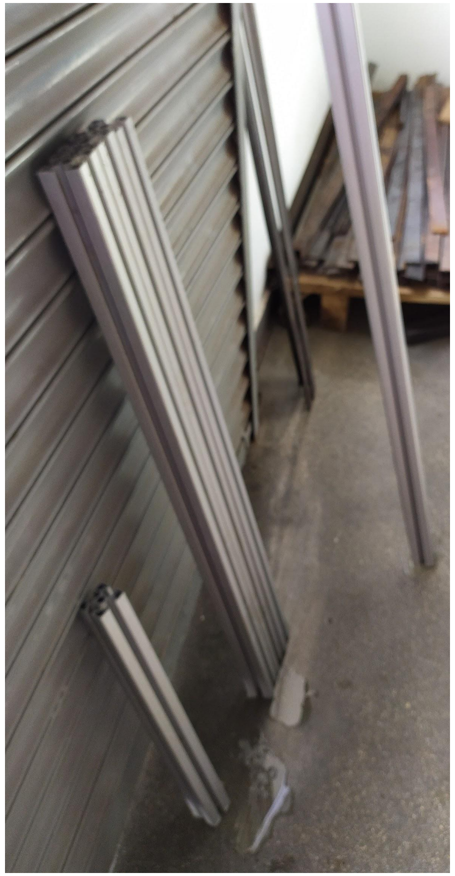
CAD: Top view

Model generated on Solidworks

Raw materials

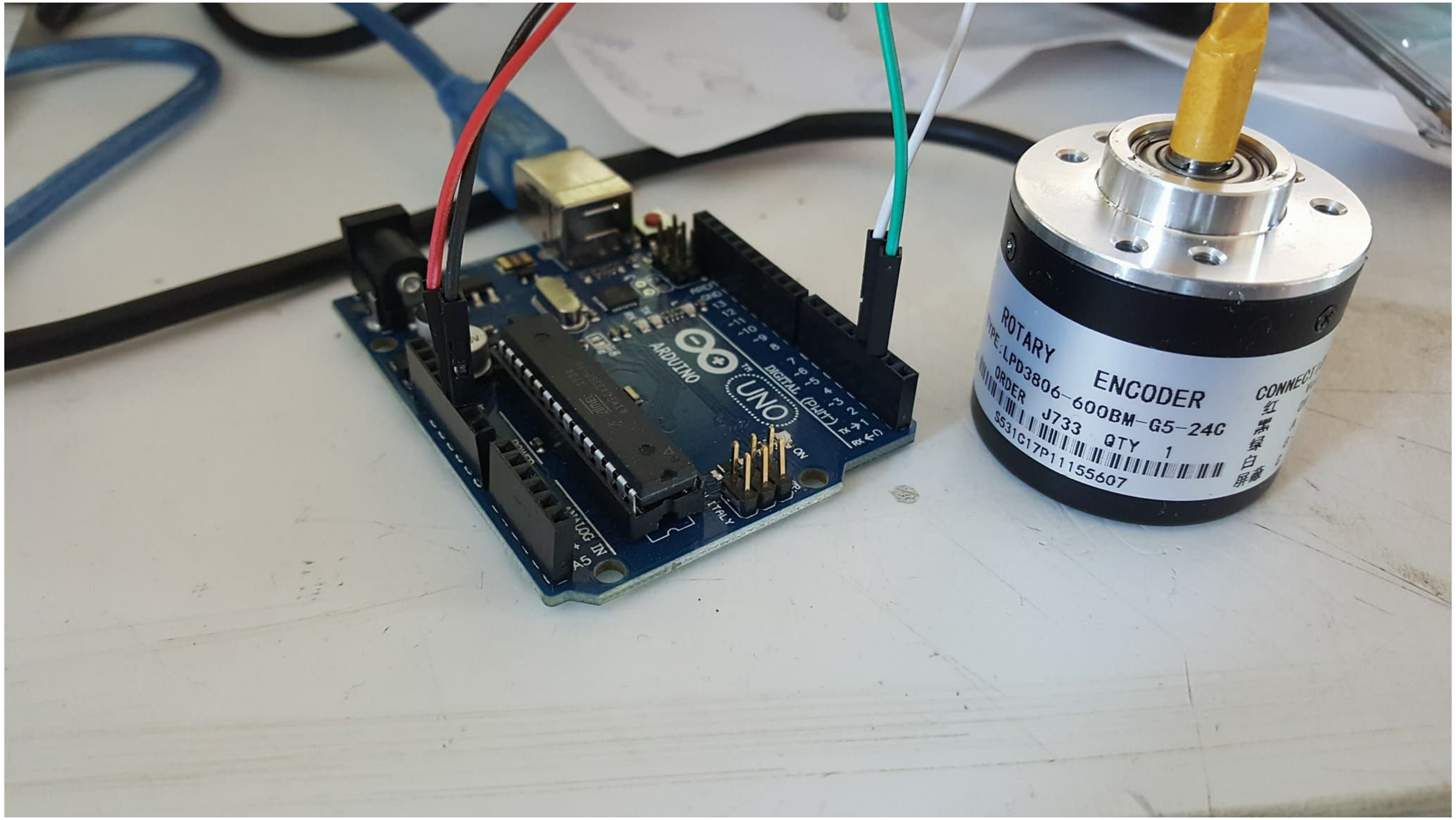
Aluminium flat

Bearings



Extruded aluminium frame

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.

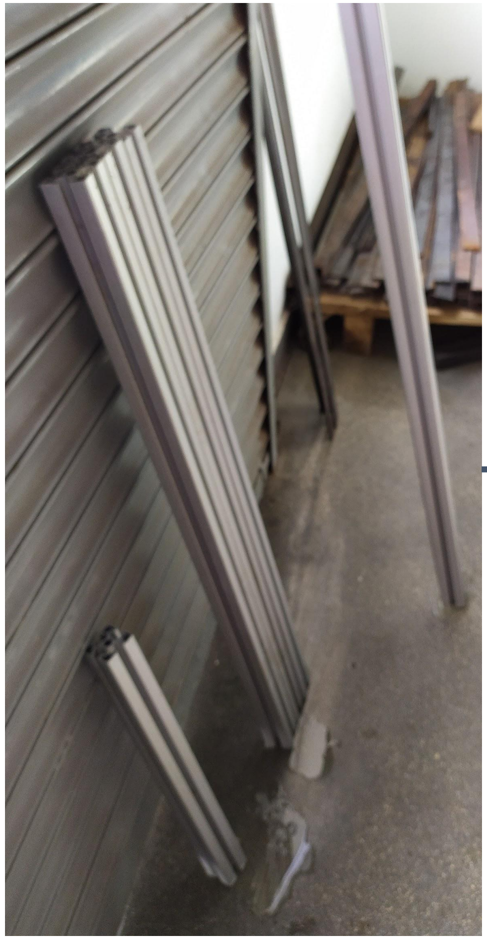
Actuator selection

DC 12V 10 rpm high torque quad encoder motor

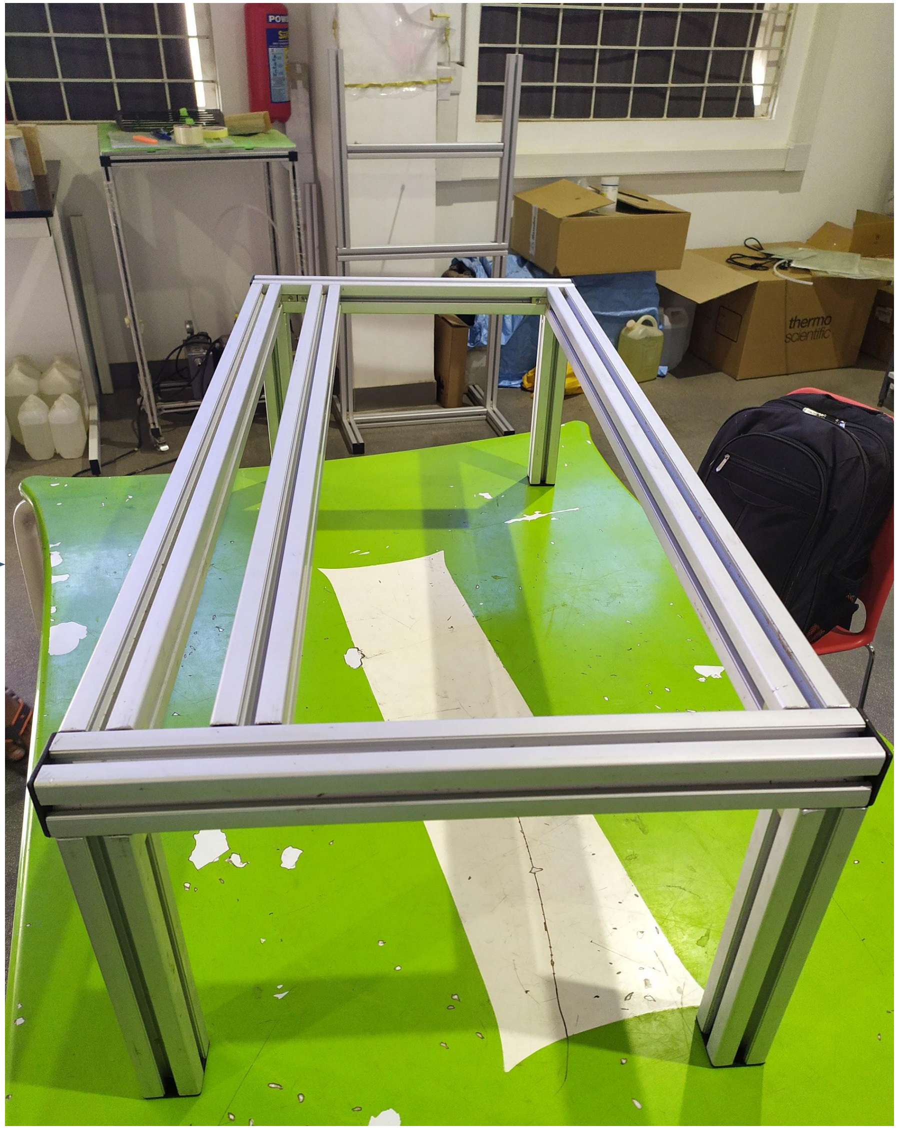
DC servo driver

Image source: Robokits India

Fabrication



Extruded aluminium frame



Assembled base

Links and L-joint

Conclusions

- Full fledged CAD model of the mechanism was created considering all the manufacturing challenges (Design for manufacturing).
- All the required raw material were procured
- Rotary encoders were tested for angle measurement using Arduino.
- The base frame has been assembled while manufacturing and assembly of the links is in process.

Future Work

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

Fabrication (31st March)

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

Testing (10th April)

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

Documentation

- Creation of experiment manual and documentation.

References

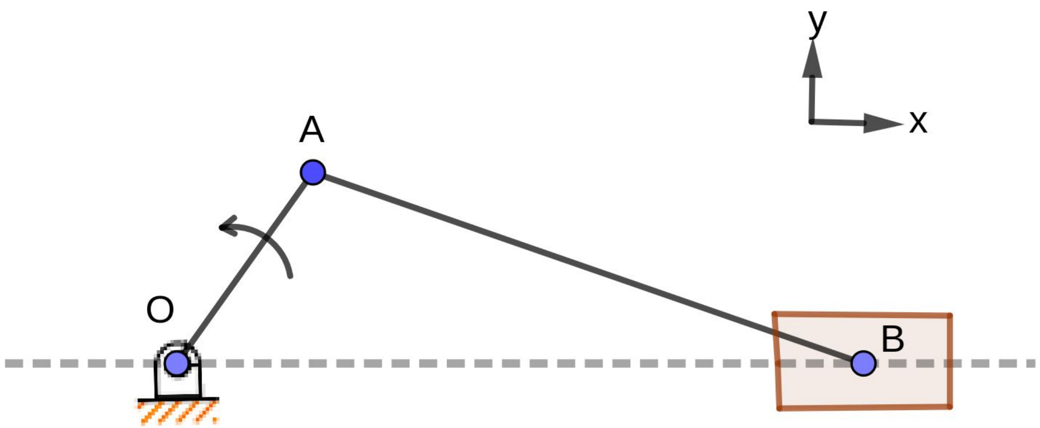
1. A. Ghosh and A. K. Mallik, Theory of mechanisms and machines. Affiliated East-West Press Private Limited, 2002.

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

Mathematical Formulation



Slider crank mechanism

Kinematics analysis

Finding angular velocity (AB) and slider velocity

$$\vec{V}_{B/A} = \vec{V}_B - \vec{V}_A$$

$$\vec{V}_{A/O} = \vec{\omega}_{AO} \times \vec{r}_{A/O} = \vec{V}_A$$

$$\vec{V}_{A/O} = \vec{V}_A - \vec{V}_O = \vec{V}_A$$

$$\vec{V}_{B/A} = \vec{\omega}_{BA} \times \vec{r}_{B/A}$$

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

Finding angular acceleration (AB) and slider acceleration

$$\vec{a}_{A/O} = \vec{a}_A = \vec{a}^t_A + \vec{a}^n_A$$

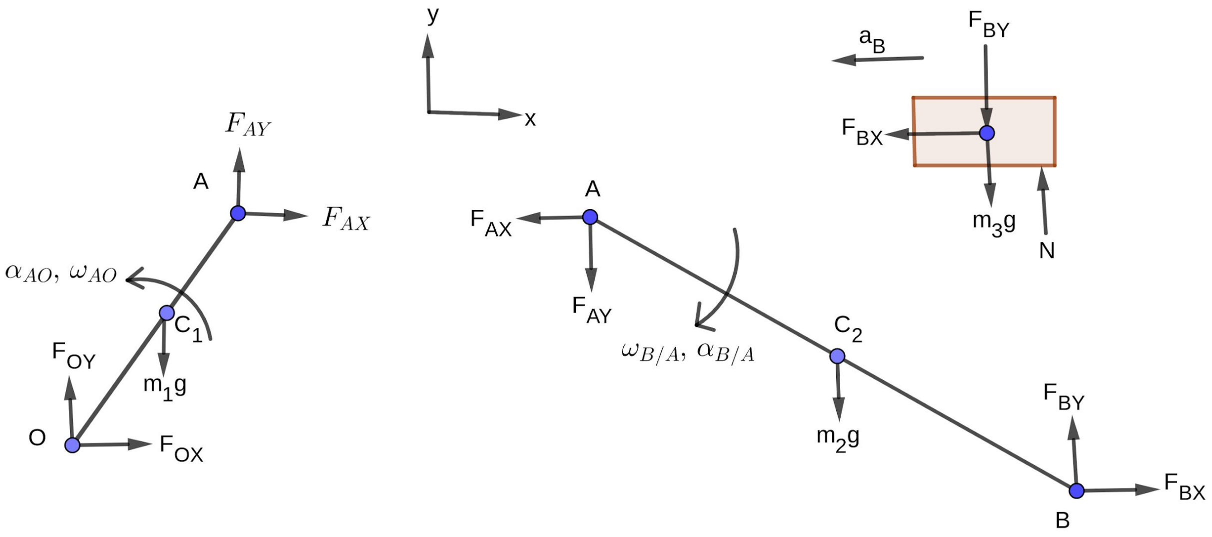
$$\vec{a}^t_A = \vec{\alpha_{A/O}} \times \vec{r_{A/O}}$$

$$\vec{a}^n_A = \vec{\omega_{AO}} \times \vec{\omega_{AO}} \times \vec{r_{A/O}}$$

$$\vec{a}_{B/A} = \vec{a}^t_{B/A} + \vec{a}^n_{B/A} = \vec{a}_B - \vec{a}_A$$

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

Mathematical Formulation



Dynamic analysis

Force and torque balance for link OA

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

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

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

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

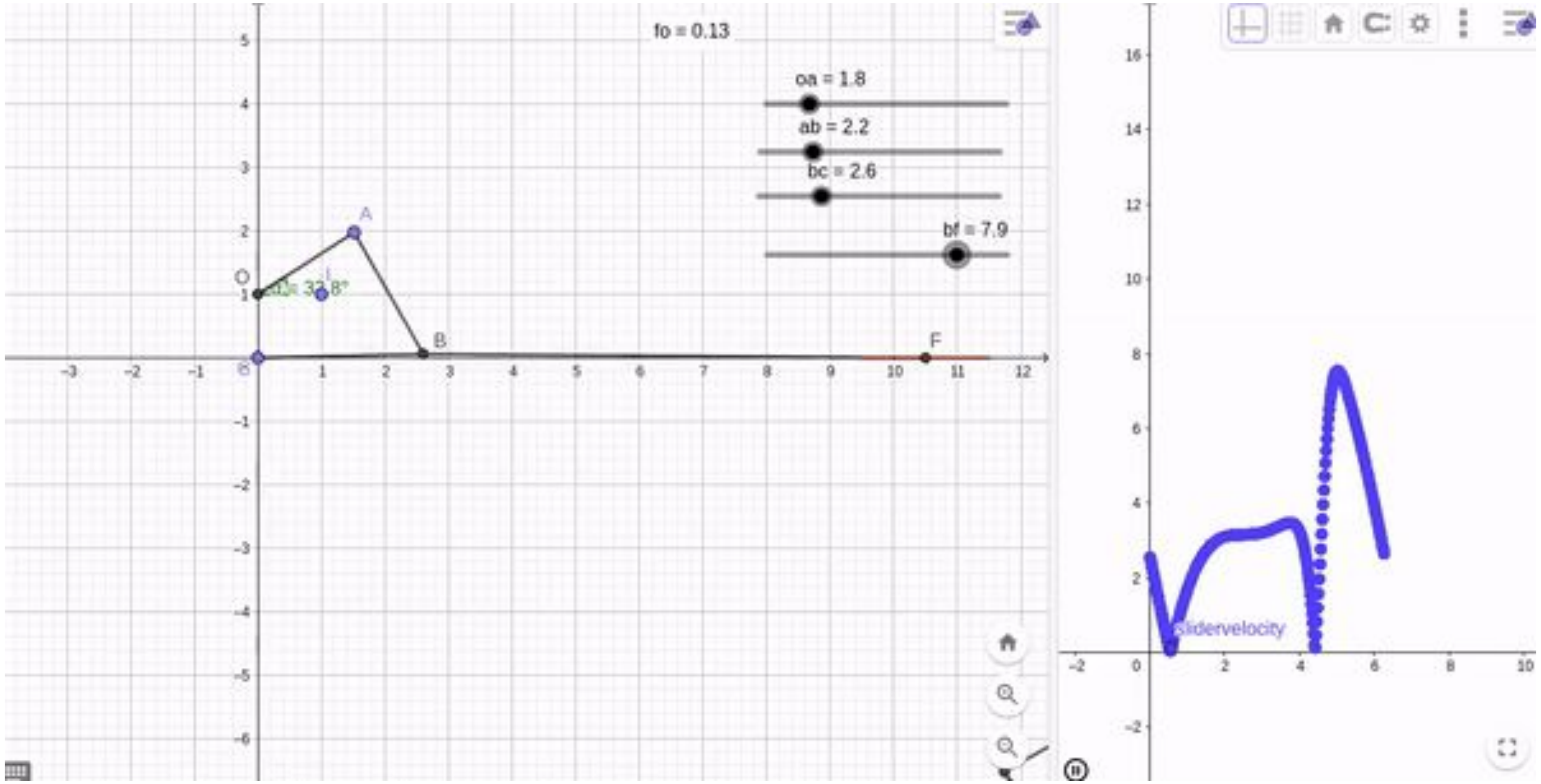
$$F_{BY} + m_3 g = N$$

$$m_3 a_B = F_{BX}$$

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

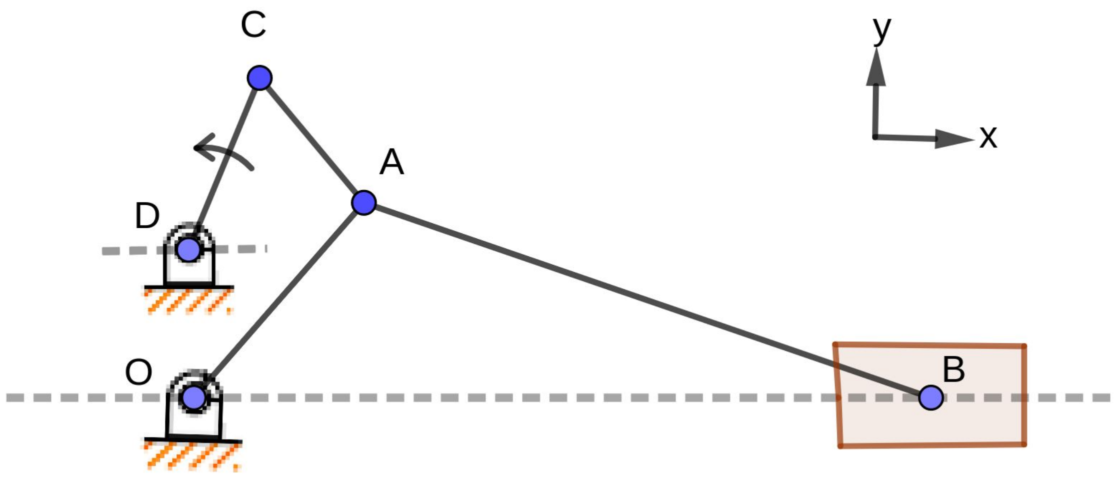
Kinematic Analysis

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



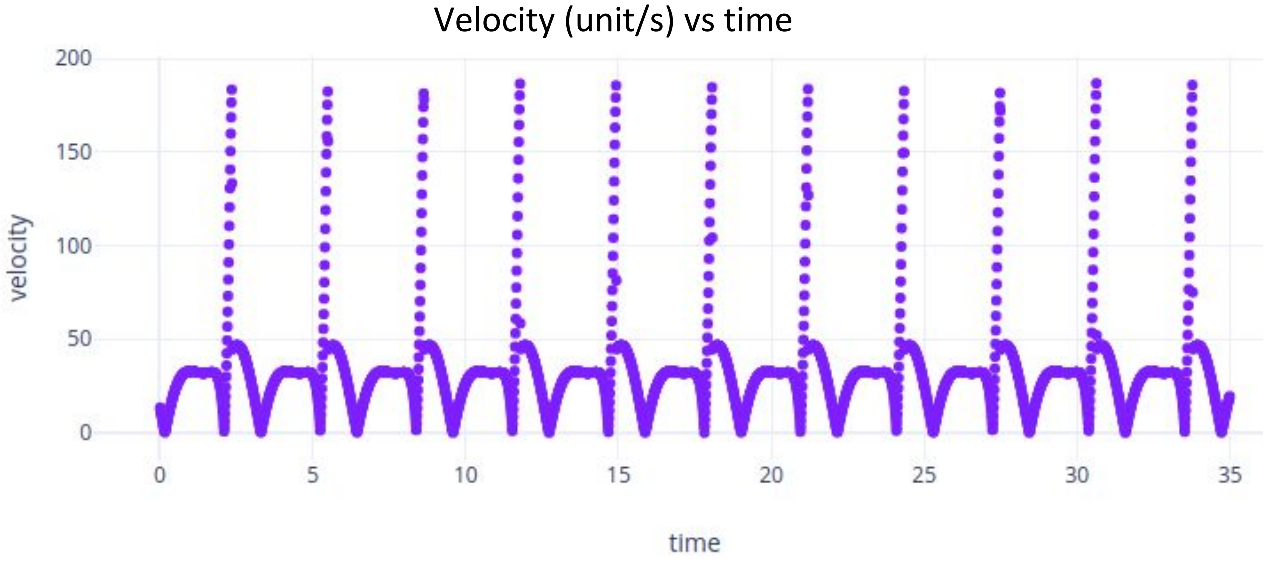
Design for constant velocity

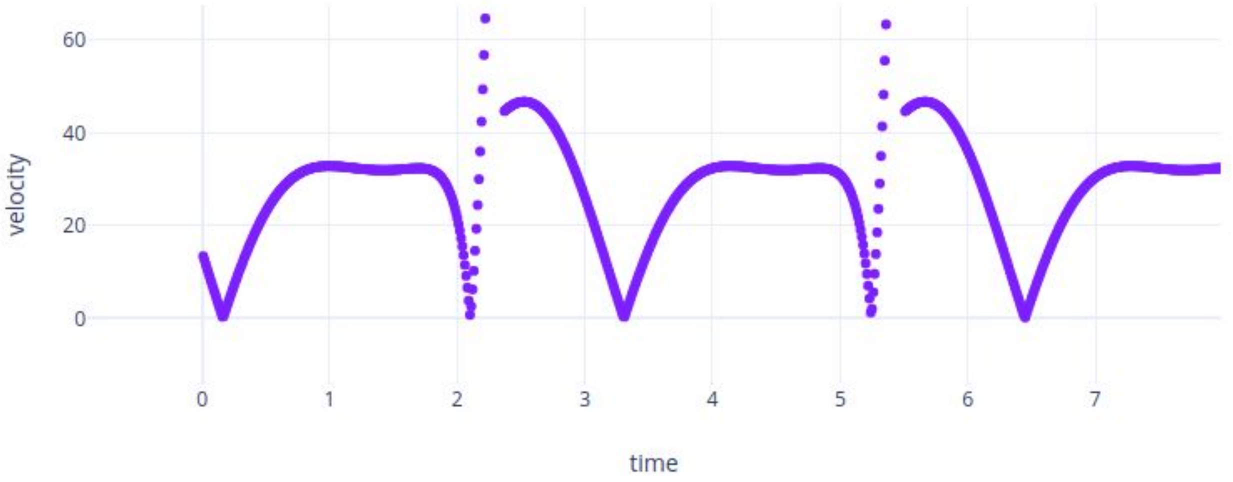
- Iteration over preliminary length ratios obtained from GeoGebra



Obtained length ratios for minimal velocity variation

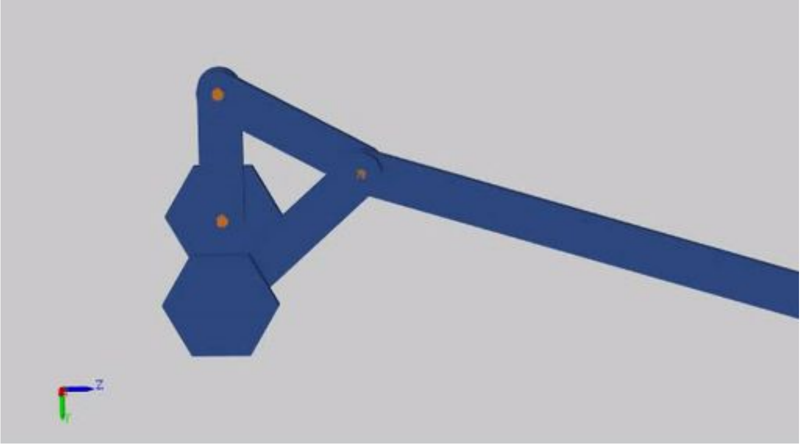
OA	AB	CD	AC
26	79	18	22

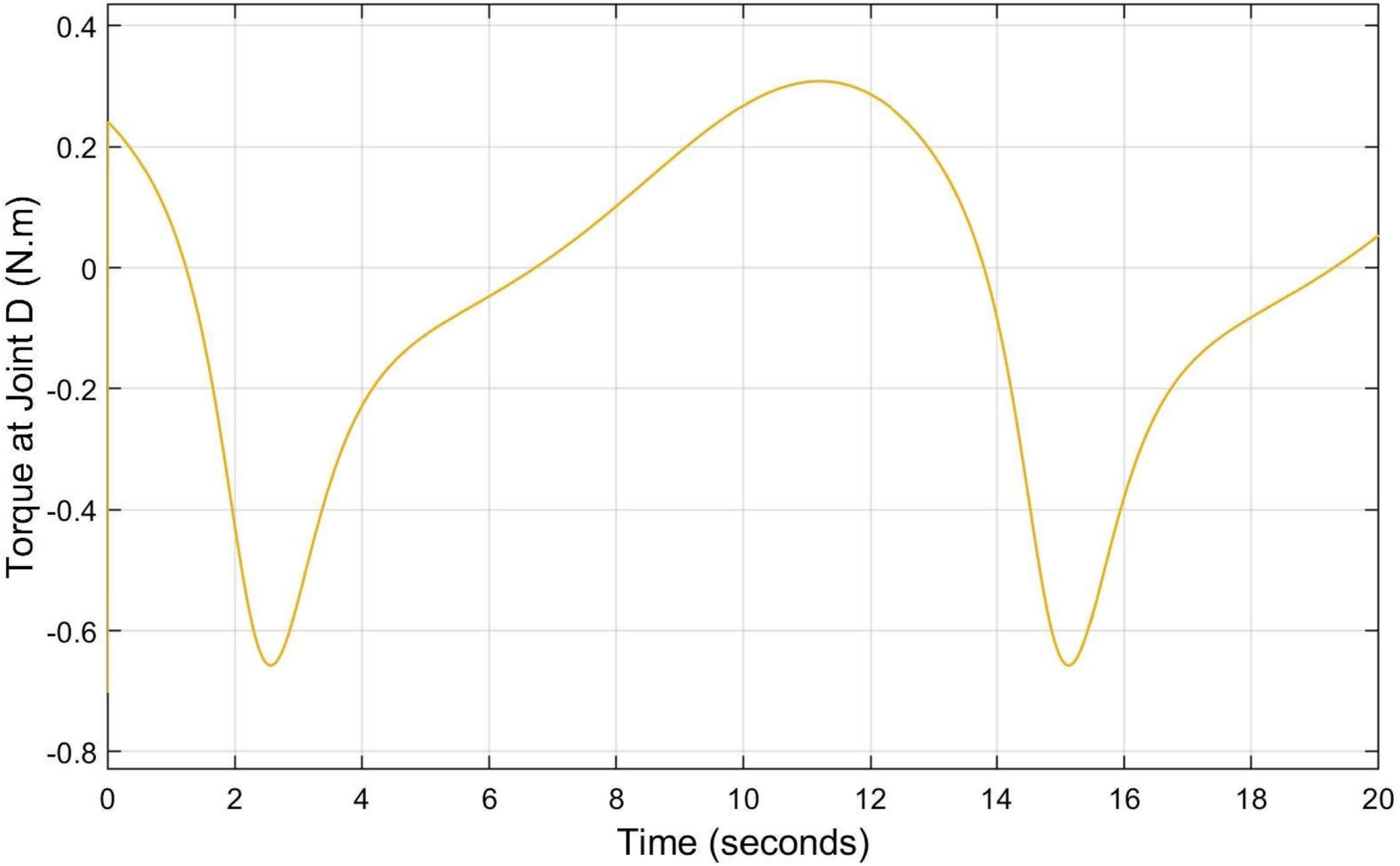




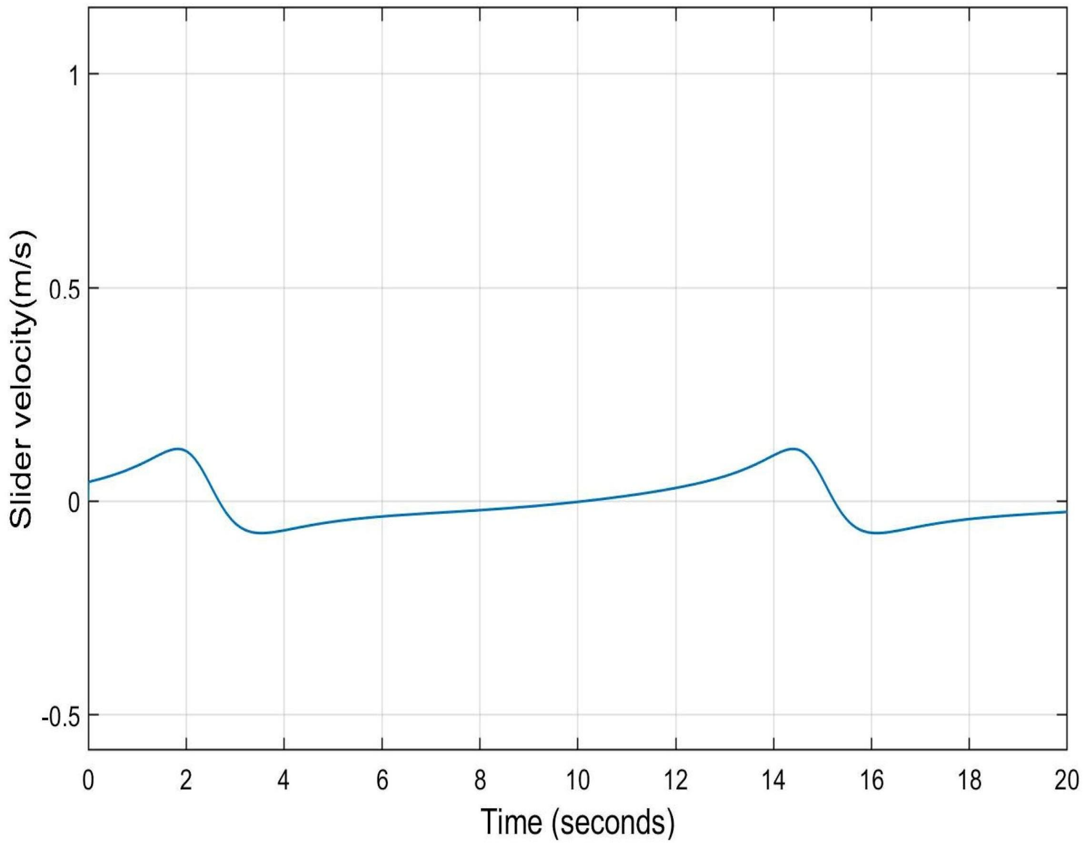
Dynamic Analysis

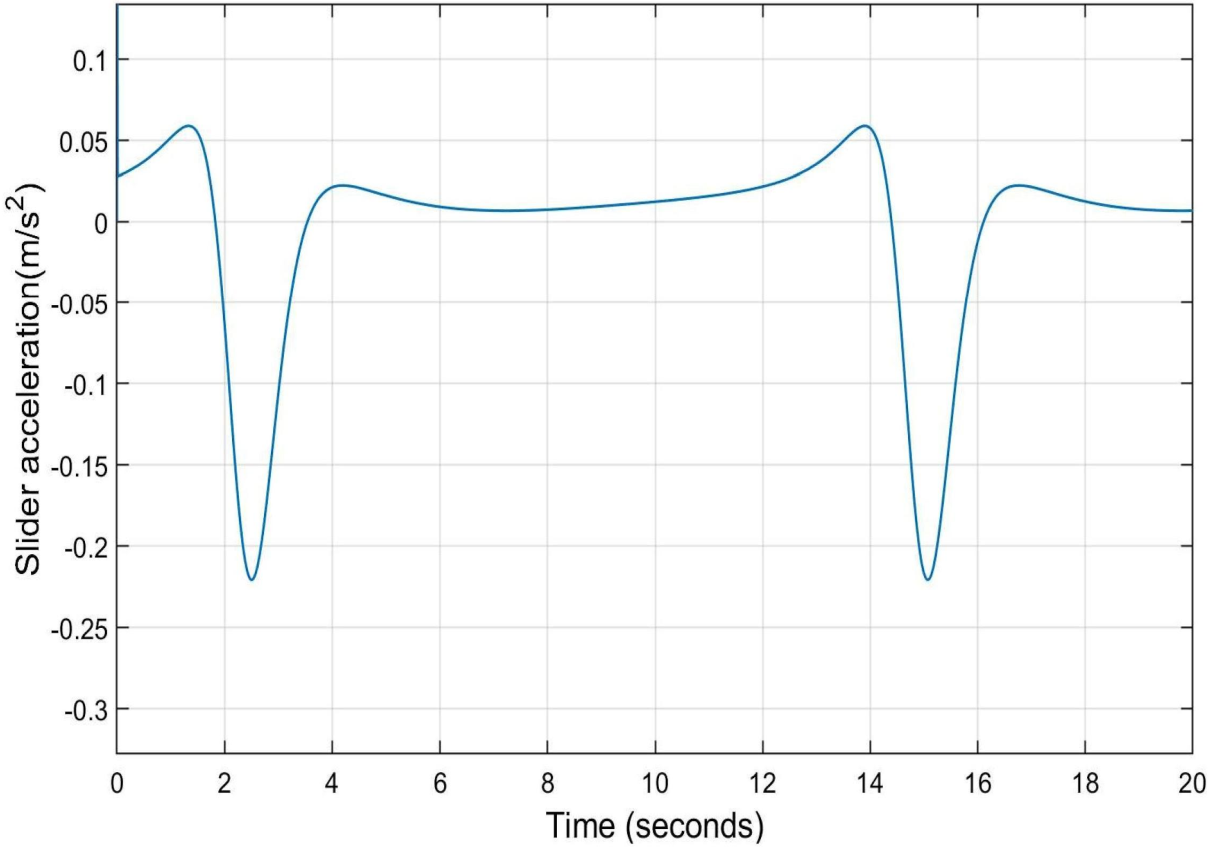
- Dynamic and kinematic analysis helps in designing mechanism which is suitable for taking measurements.



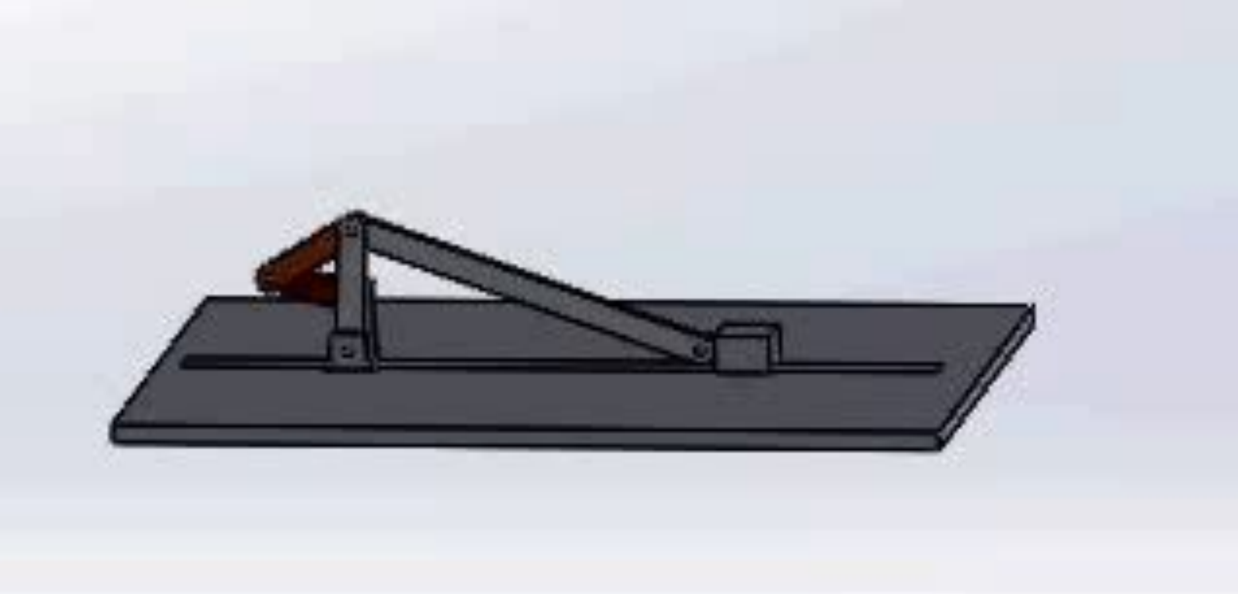


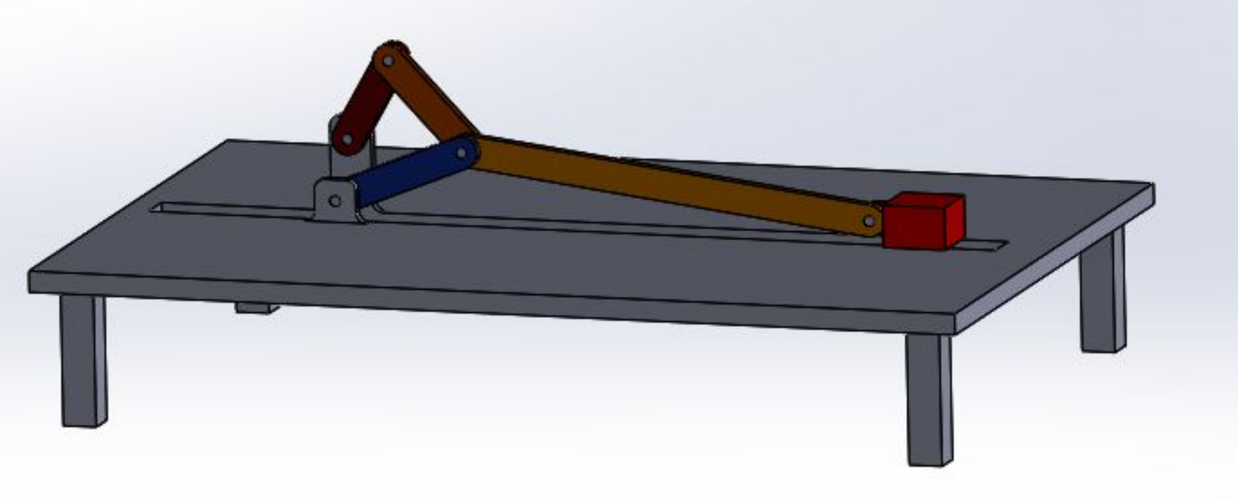
Results

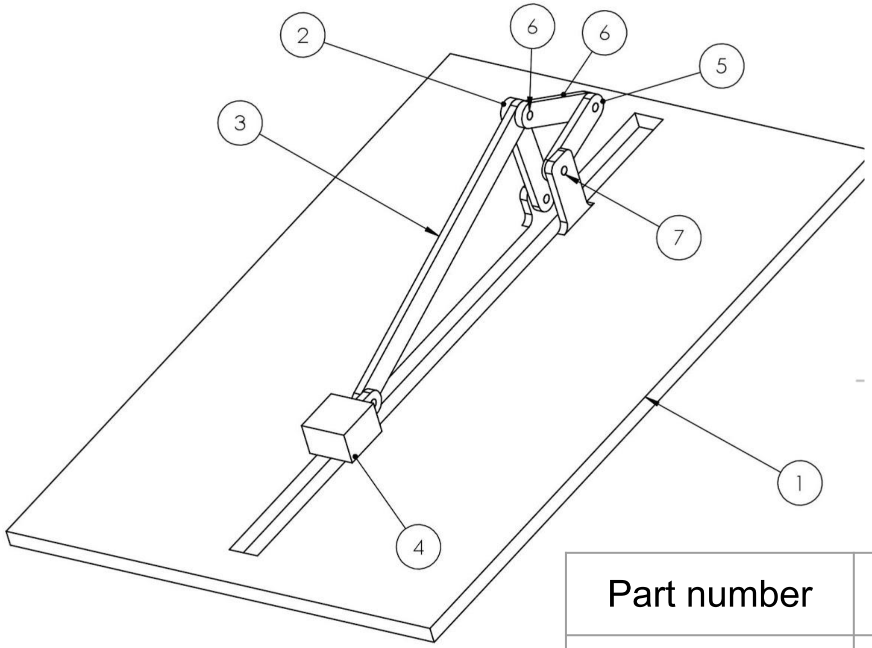

Slider velocity(m/s)
1
0.5
0
-0.5
0 2 4 6 8 10 12 14 16 18 20
Time (seconds)


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)

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

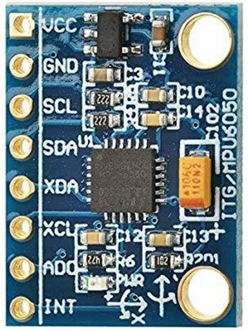
Sensor selection

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.

Future Work

Actuator selection → **Final Design** → **Fabrication**

Actuator selection

- Need to find the best actuator with its control system.

Final Design

- Final prototype model consisting of links, bearings, motors, sensors, etc.

Fabrication

- Fabrication and assembling of links.
- Experimentation, testing and validation.

References

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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

Thanks to all those who helped us during the course of our B.Tech. project at IIT Tirupati. We are thankful to and fortunate enough to get constant encouragement, support and guidance from Dr. Sriram Sundar of Mechanical Engineering Department which helped us in successfully completing first phase of our project work. We would also like to extend our sincere esteems to all staff in laboratory for their timely support.

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

Updates

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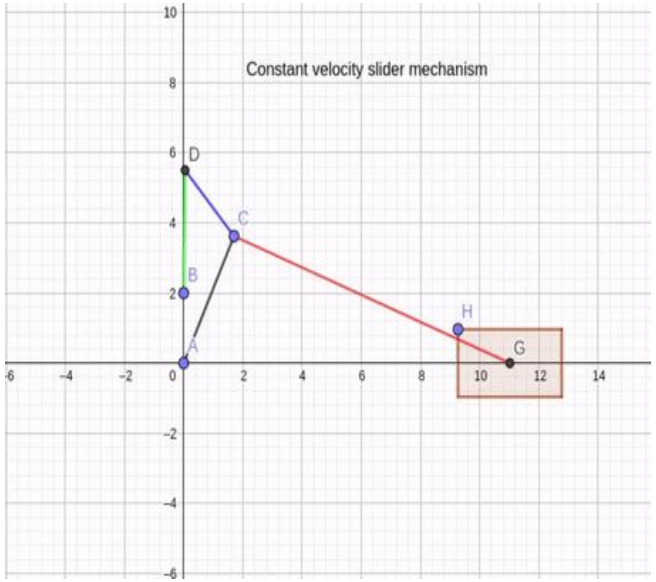
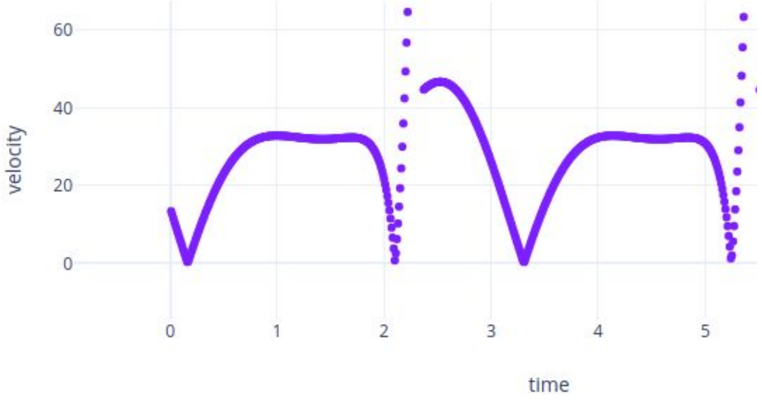
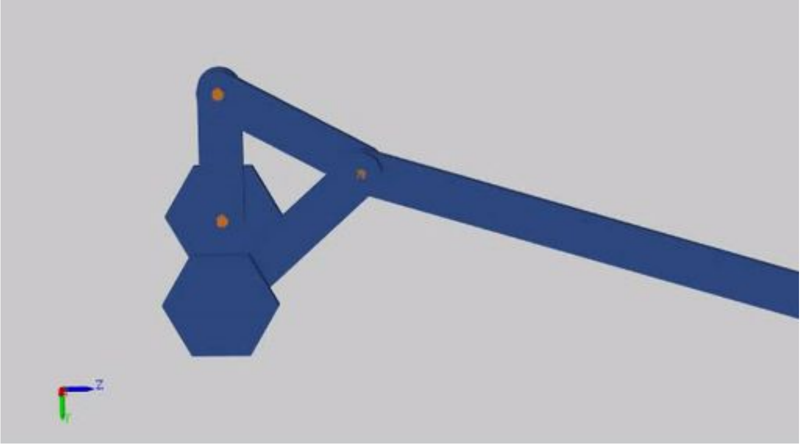
B. Tech Final Year Project Presentation

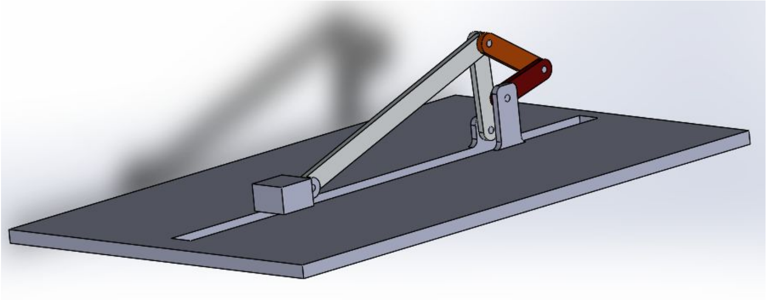
GeoGebra → Python → Simscape → Sensors selection





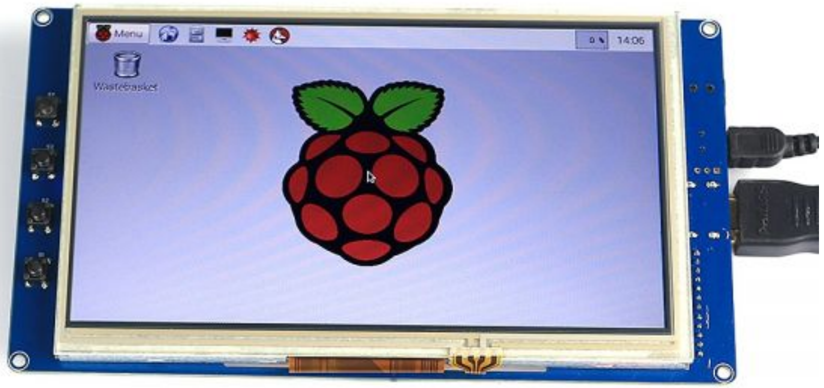
Velocity (unit/s) vs time



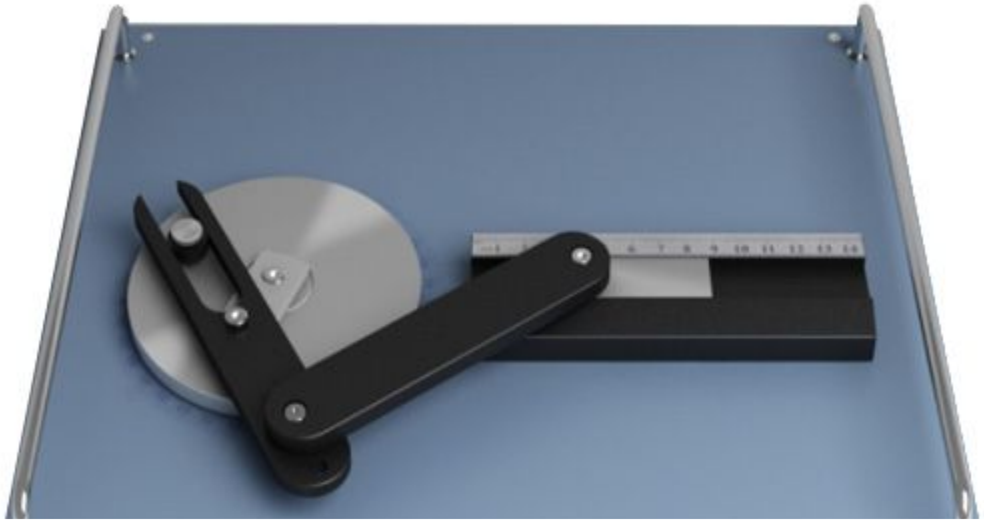


Introduction and Objectives

- 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.

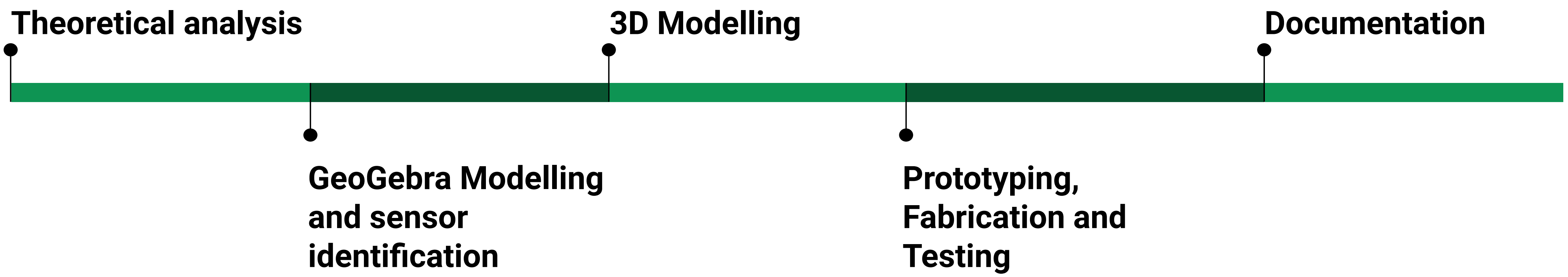


source: ardubotics.com



source: sun labtech

Plan

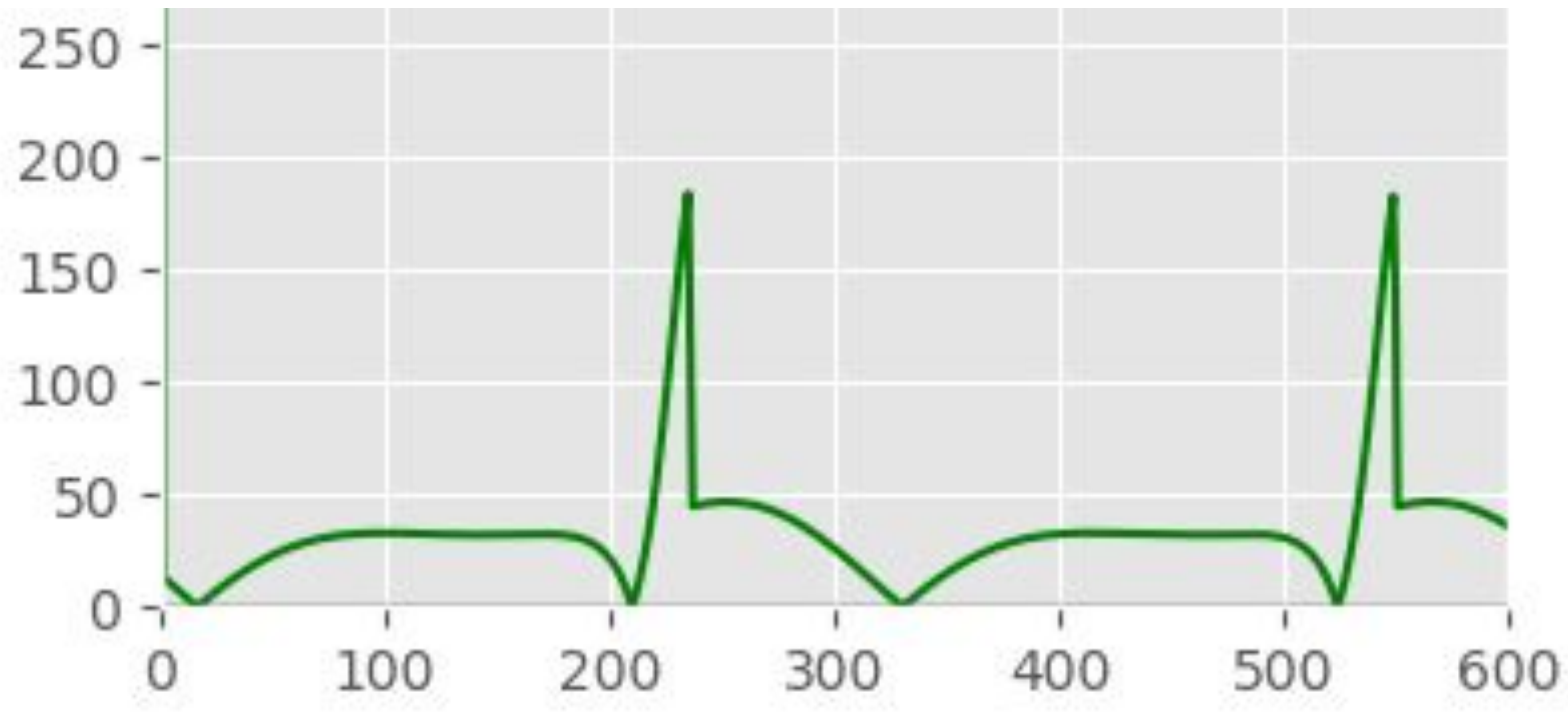


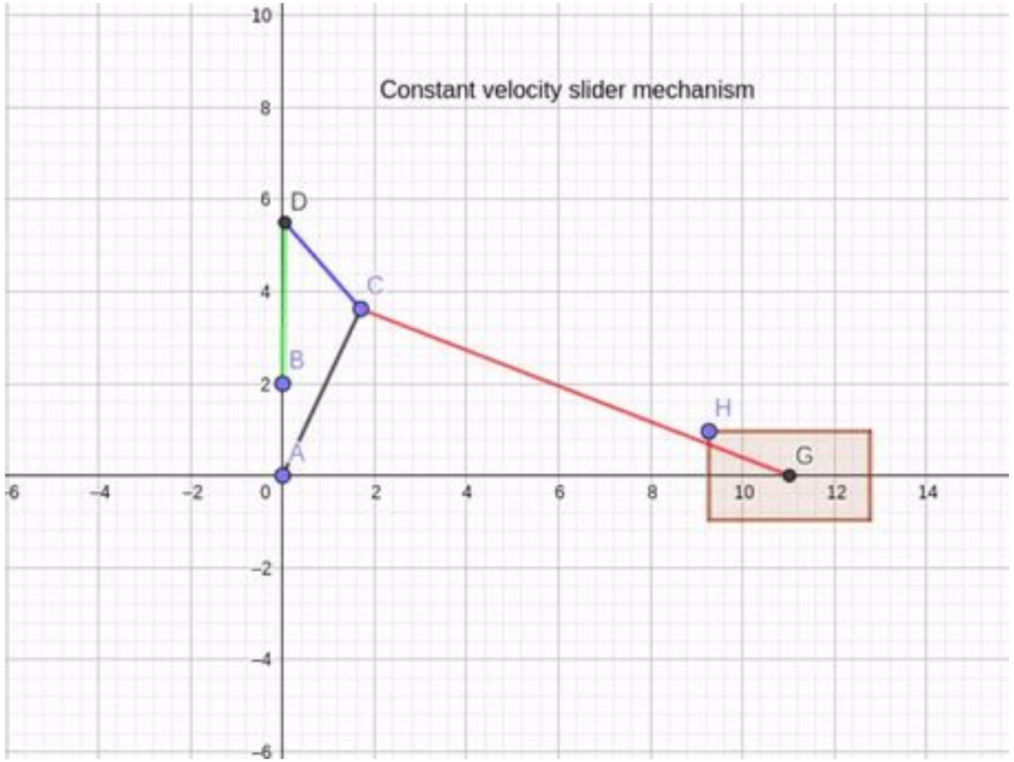
Estimated budget : INR 25,000.00 - 30,000.00

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

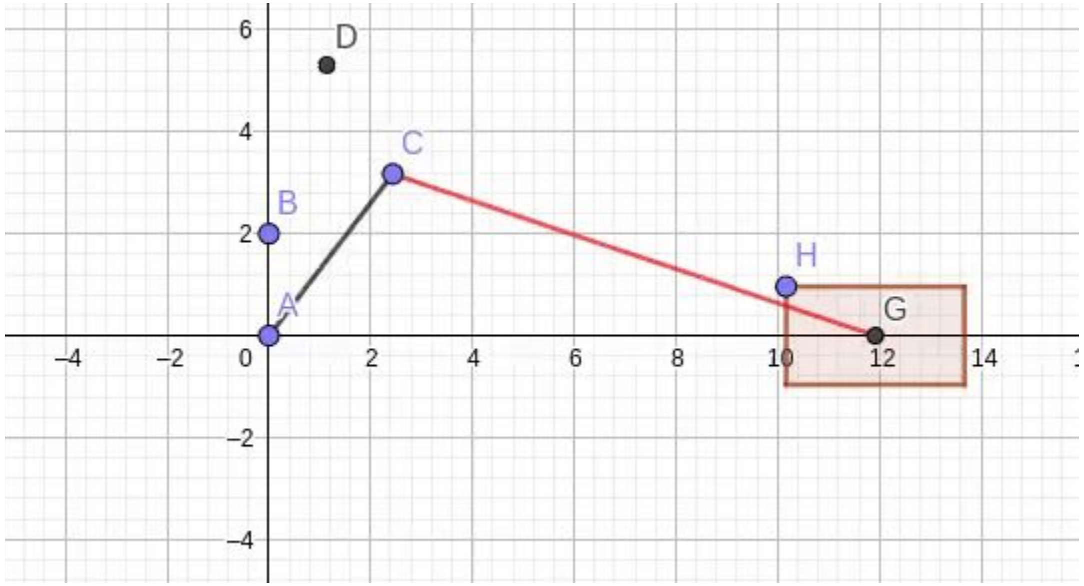
Literature Review

- 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





Constant velocity slider mechanism
A
B
C
D
G
H



A
B
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D
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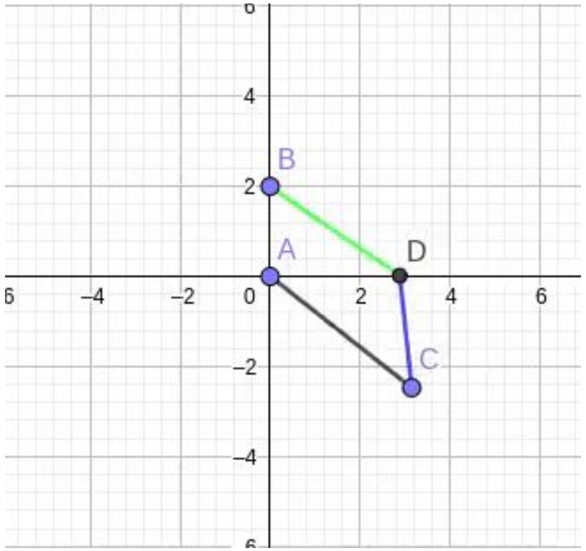

A
B
C
D