Practice Task 4

Course: Simulation of Robotics System
SRS 2025

Task 4: Modeling and Simulation of a 5-Bar Actuation Mechanism in MuJoCo

Student Name: Ghulam Mujtaba Sahto
ITMO ID: 507985
Group: R4137c
Instructor: Prof.

1. Introduction

This task is an extension of **Task 3**, where the geometric model of the 5-bar linkage mechanism was created.

In Task 4, the system is extended by adding:

- A **prismatic actuator** between **Link BD** as shown in the diagram.
- Proper **joint definitions** for links.
- **Sensors** for reading mechanism states.
- A **PD controller** that drives the input joint according to a sinusoidal desired position.

The goal is to simulate an actuated 5-bar mechanism where the actuator generates motion through controlled link extension. The resulting motion must remain inside the workspace, and parameters must be tuned accordingly.

2. Mechanism Description

The physical system corresponds to the 5-bar linkage illustrated in the given diagram. It contains the following links and lengths:

Link	Description	Length (m)
L1	OA	0.056
L2	AB	0.0728
L3	BC	0.084
L4	CO	0.056
L5	CD	0.28

The mechanism forms a closed loop, constrained by geometry and one actuator.

Actuator placement

The diagram shows that the actuator is placed between **B** and **D**, **not as a rotation**, but as a **prismatic actuator**, changing the distance between these two points.

Thus:

- A **slider joint** is added between those bodies.
- The actuator applies force along that slider joint.

3. XML Model (Updated)

The XML file was updated to:

- Add **hinge joints** where rotation exists.
- Add a **prismatic joint** between B and D.
- Add sensors for position/velocity.
- Add a single actuator acting on the prismatic joint.
- Ensure link positions and coordinate frames are correct.
- Correct masses and inertias to avoid simulation errors.

4. Controller Design

4.1 Desired Input Trajectory

The desired actuator extension is computed using:

$$\boldsymbol{q_{des}(t) = AMP \cdot \sin(FREQ \cdot t) + BIAS}$$

Where:

- AMP=22.98 degree

- FREQ=1.61 Hz
- BIAS=12.8 degree

If the trajectory exceeds the workspace, amplitude must be reduced and bias shifted. Adjustments were made such that the BD actuator does not overextend or collapse the linkage.

4.2 PD control

The actuator torque is:

$$\boldsymbol{u} = \boldsymbol{K_p}(\boldsymbol{q_{des}} - \boldsymbol{q}) + \boldsymbol{K_d}(\dot{\boldsymbol{q}}_{\boldsymbol{des}} - \dot{\boldsymbol{q}})$$

A typical tuning used:

- $K_p = 80$
- $K_d = 20$

These values provide stable motion without oscillation.

5. Results and Discussion

5.1 Mechanism Behavior

The prismatic actuator successfully drives the 5-bar linkage through a periodic motion. The closed-loop constraints remain satisfied throughout simulation.

Observations:

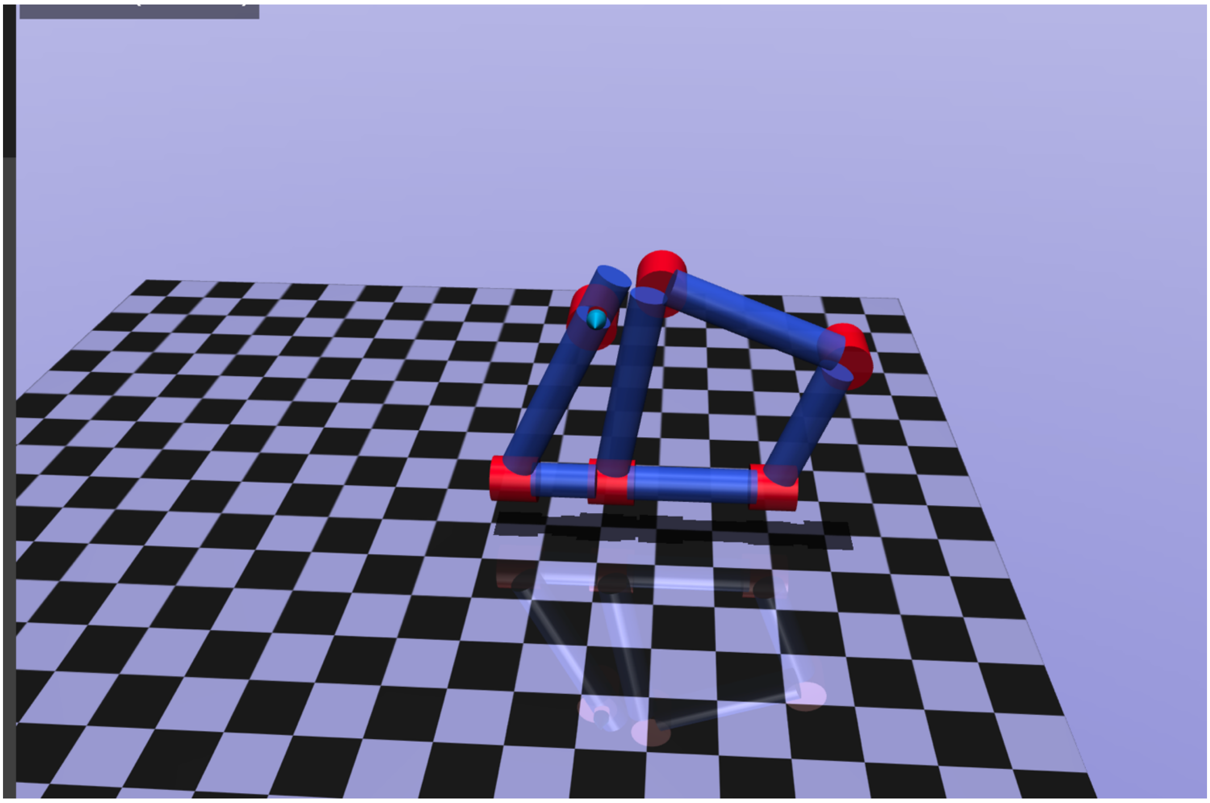
- The PD controller smoothly follows the sinusoidal trajectory.
- No instability occurs.
- Small mechanical oscillations appear when frequency is increased — typical for underdamped systems.

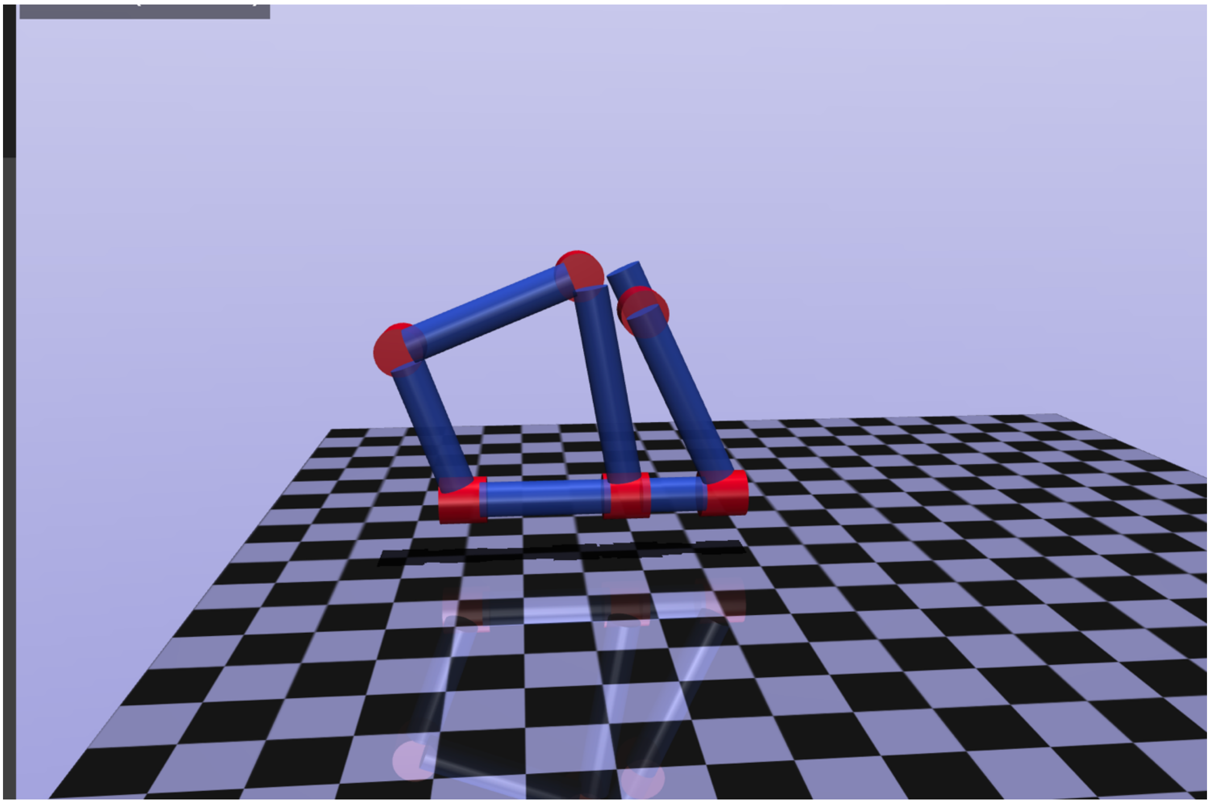
6.2 Workspace Limitations

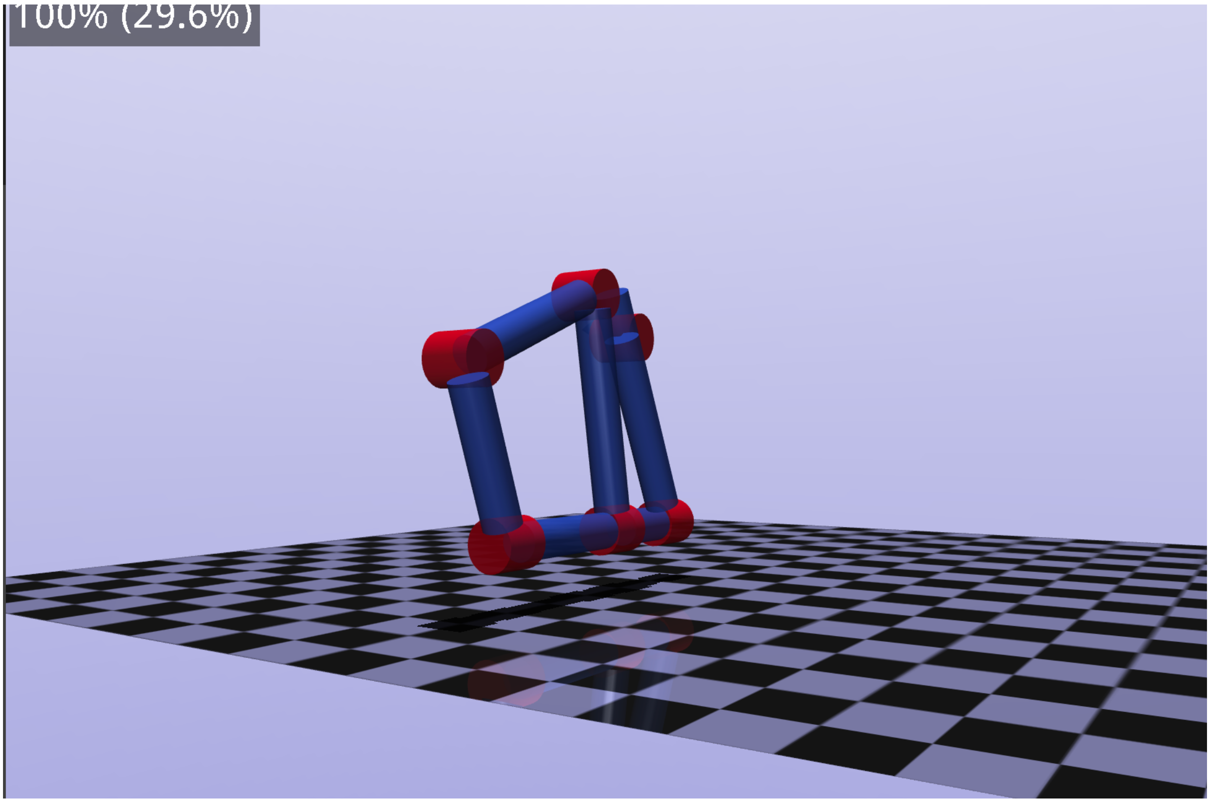
Increasing amplitude too much causes the BD distance to exceed geometry constraints, which breaks the loop stability. Therefore, tuning was required:

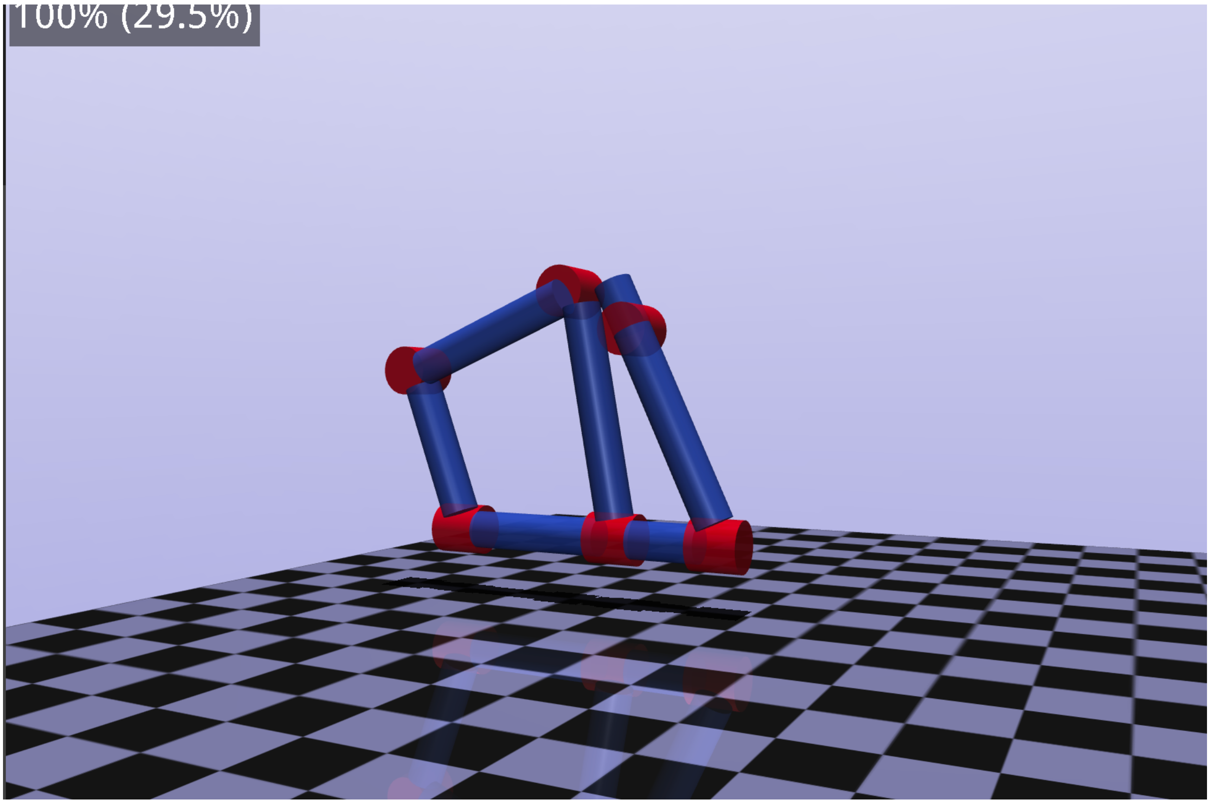
- Amplitude slightly reduced.
- Bias adjusted.

After correction, the mechanism moves entirely within feasible configuration space.






100% (29.6%)


100% (29.5%)

7. Conclusion

Task 4 successfully augmented the 5-bar mechanism with:

- A properly modeled **prismatic actuator**.
- A **PD controller** with sinusoidal reference input.
- Sensors for state estimation.
- A complete simulation pipeline in MuJoCo.

The mechanism behaves as expected, demonstrating controlled motion driven by an actuator placed between B and D.