# Lab 1 Report

## Methods

### Formulation

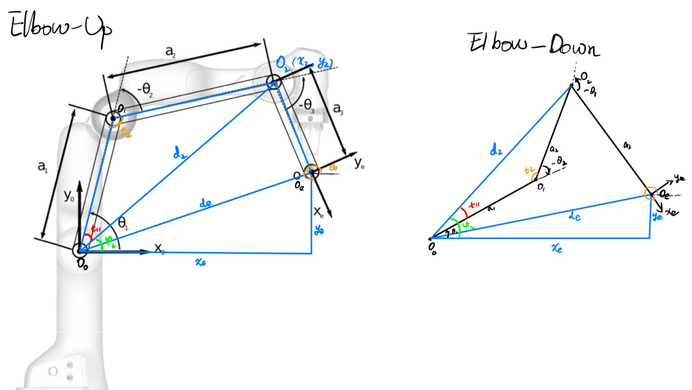
(TODO)

### FK

(TODO)

### IK

- Compute position of $O_2(x_2, y_2)$
- Compute $d_2, d_e, \phi_2$
- Draw the elbow-up and elbow-down solutions
  - Compute intermediate angles $t_{11}, t_2$ using law of cosines
  - Compute $\theta_1, \theta_2$ for each solution using the intermediate $\phi_2, t_{11}, t_2$:




- Compute $\theta_3 = \theta_e - \theta_1 - \theta_2$

## Evaluation

### FK

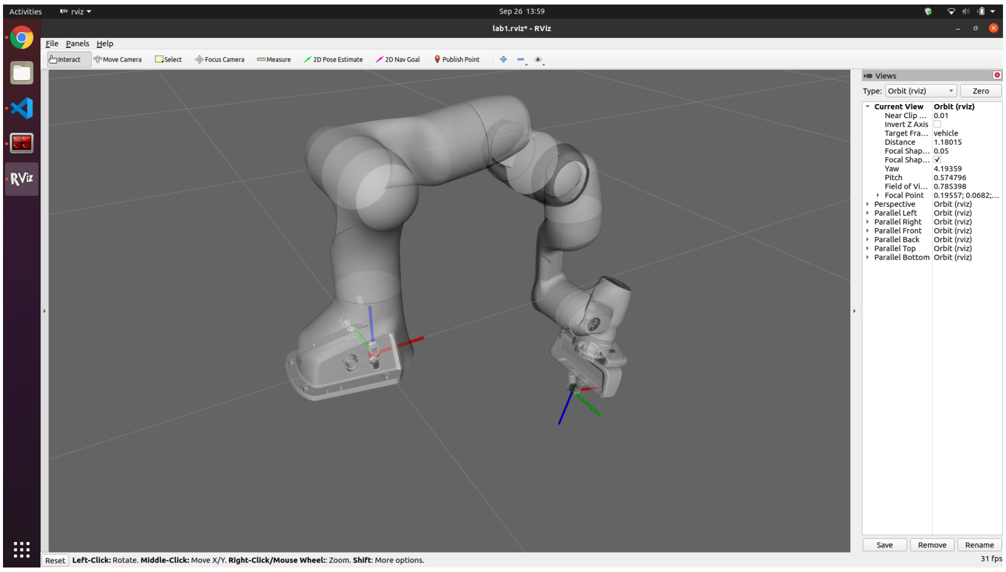
(TODO)

### IK

If the end effector can reach the target with desired position and orientation, then the IK solution is correct.

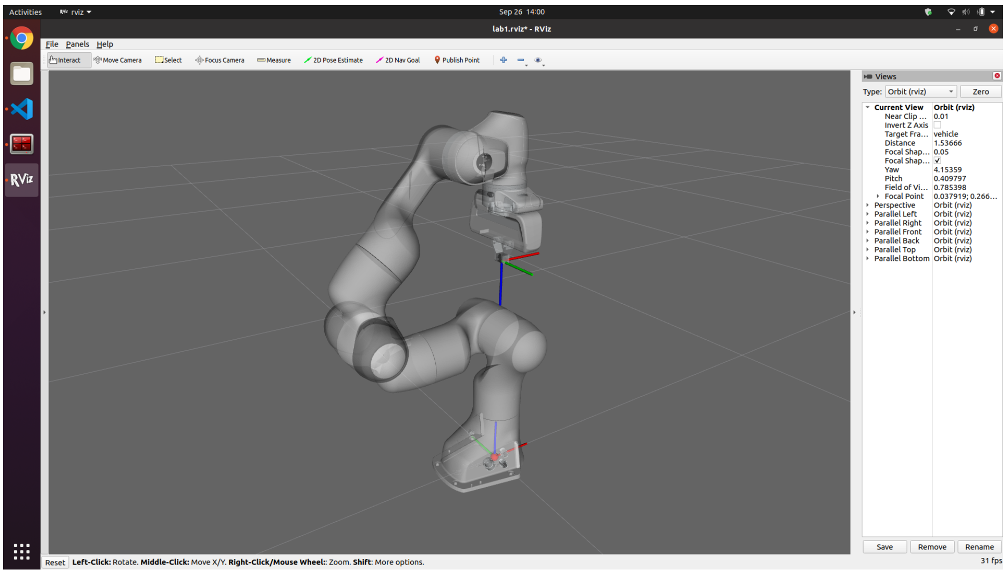
**Target 1**

```
{ # IK target 1
    'o': np.array([0.5, -0.3]),
    'theta': pi/2+0.3
}
```



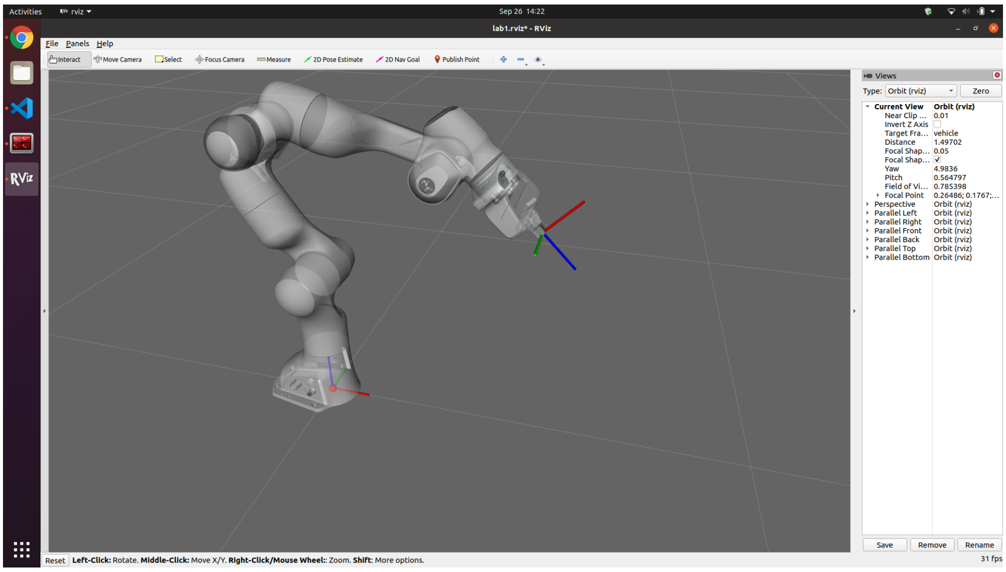
#### Target 2

```
{ # IK target 2
    'o': np.array([0, 0.5]),
    'theta': pi/2
}
```



#### Target 3

```
{ # IK target 3
    'o': np.array([0.5, 0.5]),
    theta': 1/4 * pi
}
```




# Analysis

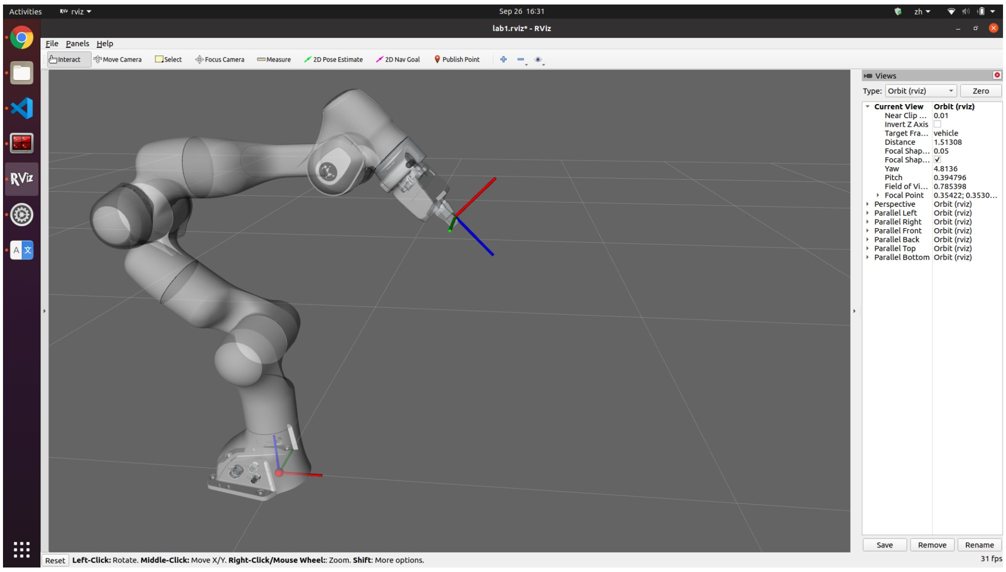
## Gravity

### FK

(TODO)

### IK

With gravity, the manipulator tends to move faster and will have a little shake when reaching the target. The final posiiton of the end effector might be a little below the target.



The reason might be with gravity, the joints cannot reach the exact computed values because of the external gravity force.

### Reachable workspace

(TODO)

### Extending Inverse Kinematics to 3D

Panda does have a spherical wrist. However, kinematic decoupling does not work on the full Panda robot because it has 7 dofs, and you have to solve the first 4 joint variables with only 3 equations (the position of the wrist center). The appropriate way I can think of is to use geometric approach to solve the first 4 joint variables, and then the 3 joint variables of the wrist can be solved using Euler angles.