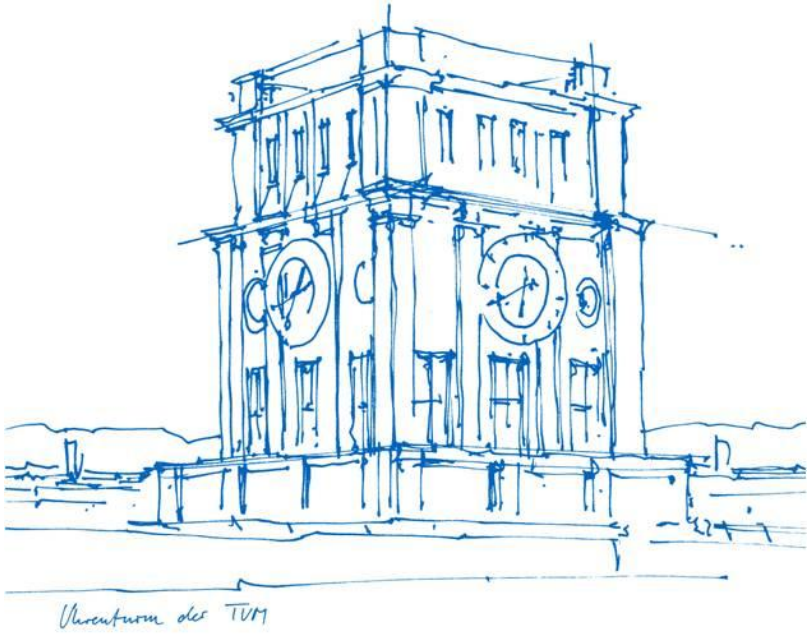
Fundamentals of Human-Centered Robotics - 2024 SS: Final Presentation

Robothon - Team H

Team members:

Theresa Gräbner, Peishi Liu

20.August 2024



Overview

Software

Simulation:	**CoppeliaSim 4.1.0 , rviz**
Robot Model:	**Provided, Pyrep's Panda, Panda URDF**
Prog. Languages:	**Python, CPP**
Important Libraries:	**Pyrep, Pinocchio, MoveIt**

Task Distribution

Theresa Gräbner

Task 1
Task 3

Peishi Liu

Task 2

Task 1

Task 1.1

Goal: Test joint configurations for their validity

Model: Given Franka Panda robot

Implementation:

- Self-Collision check:

```
for entity_1 in range(7):
    for entity_2 in range(9):
        # don't test neighboring links for collision
        if entity_1 < entity_2 - 1:
            if sim.simCheckCollision(link[entity_1], link[entity_2]):
```

- Write result in json format in “task1_1_self_collision.data”

```
{"collision": "false", "collision groups": {}}
{"collision": "true", "collision groups": {"1": "Franka_link1 Franka_link6", "2": "Franka_link1 Franka_link7"}}
```

Task 1.2

Goal:

Joint Configuration	Cartesian Pose
• Check validity • Plan normalized Path • Replan alternative path	• Check validity • Plan linear Path • Replan alternative, nonlinear path

Model: Pyrep's Panda Robot

Implementation:

- Scene without floor → not interested in collision with floor
- Plan cartesian trajectory
- Plan joint trajectory

Task 1.2: Cartesian Trajectories

Implementation:

- Load Cartesian Pose
- Extract quaternions and position coordinates via Pinocchio
- Test Cartesian Pose
  - Reachability: Sample valid joint configuration
  - Linear Trajectory: Pyrep's *get_linear_path*
  - Nonlinear Trajectory: Pyrep's *get_nonlinear_path*
- Write result in json format in "task1_2_cartesian_trajectory.data"

```
{"reachable pose": true, "valid linear trajectory": true, "valid trajectory": true}
{"reachable pose": true, "valid linear trajectory": false, "valid trajectory": true}
{"reachable pose": false, "valid linear trajectory": false, "valid trajectory": false}
```

Task 1.2: Joint Trajectories

Implementation:

- Load joint configuration
- Reachability: Test if joint configurations are within the limits defined by Franka's official website
- Validity: Configuration does not cause self-collision
- Normalized Trajectory:
  - Calculate trajectory
  - Validate each path point

```
# calculate joint positions for normalized path
for k in range(20):
    trajectory.append((start + (k/20) * difference).tolist())
```

- Alternative Path: Modified PyRep's *get_path*
- Write result in json format in "task1_2_joint_trajectory.data"

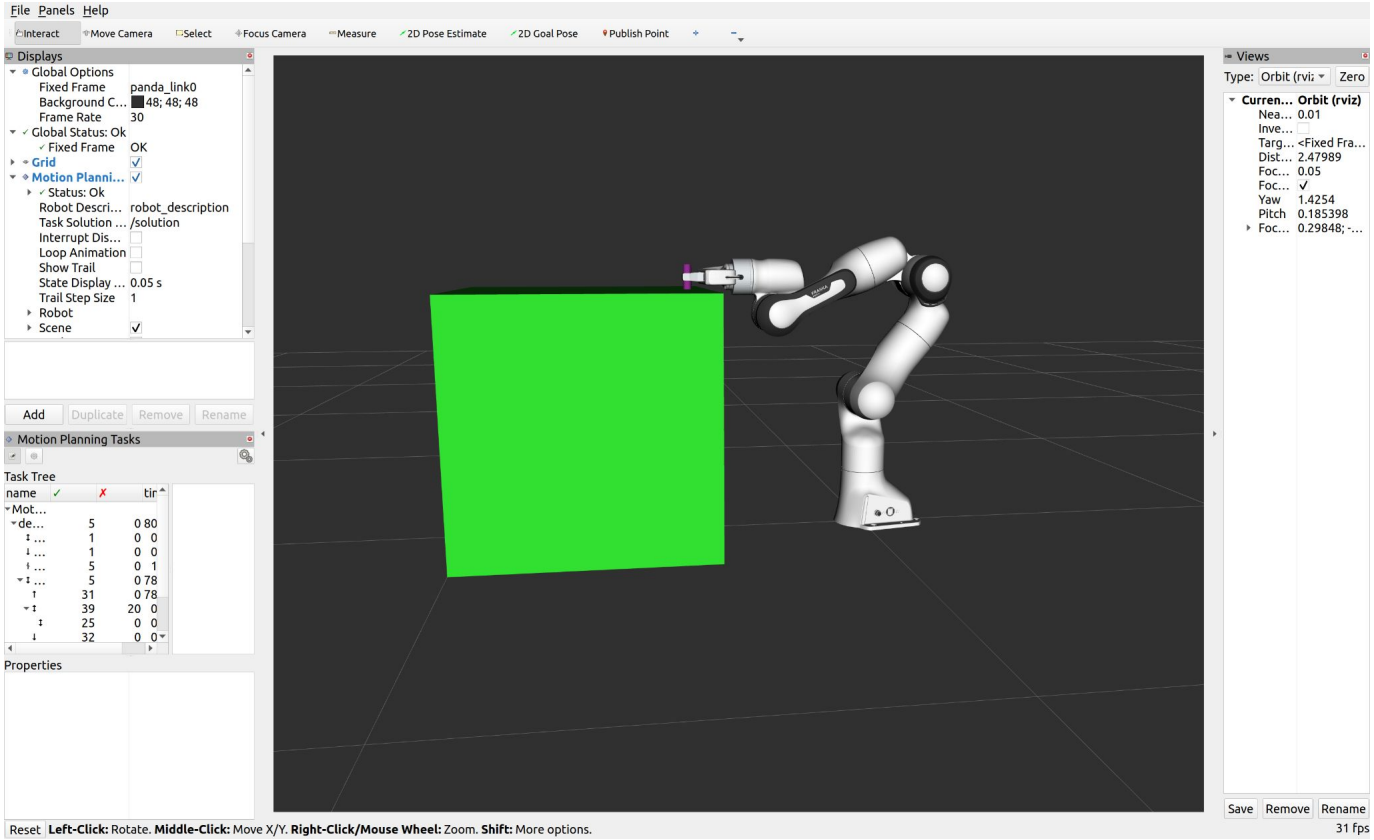

```
{"reachable": true, "valid_configuration": true, "valid normalized trajectory": true, "valid trajectory": true}
{"reachable": false, "valid_configuration": false, "valid normalized trajectory": false, "valid trajectory": false}
```

Task 2

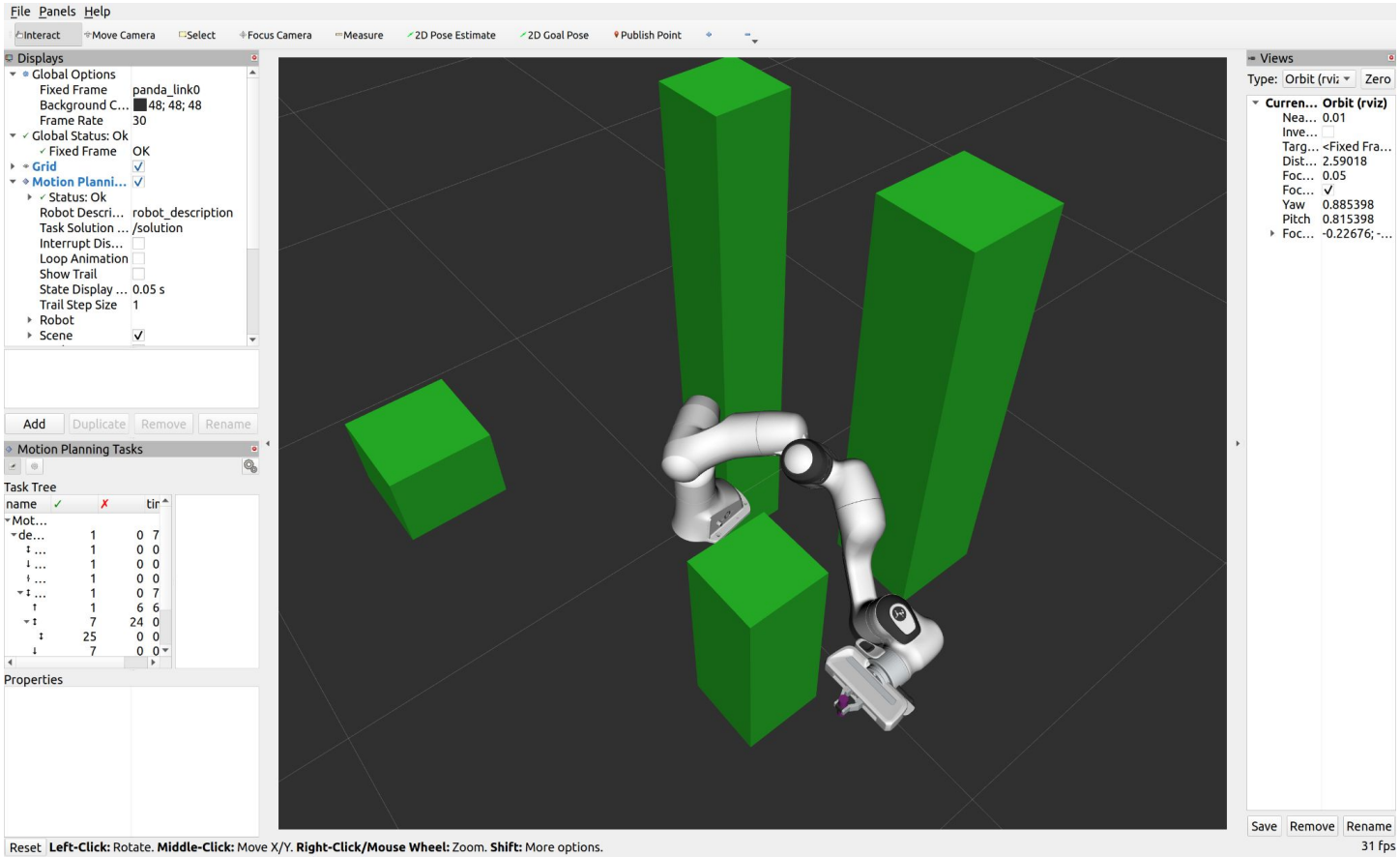
Task 2.1

- Goal : reach the central of point of Cylinder and grasp it
- Model : Panda description URDF from https://github.com/justagist/franka_panda_description
- Tools : ROS2 Humble , MoveIt , Rviz
- Structure : MoveIt Task Constructor (MTC):
- Planning algorithmus : OMPL , RRT , Interpolation Plan, Cartesian Plan

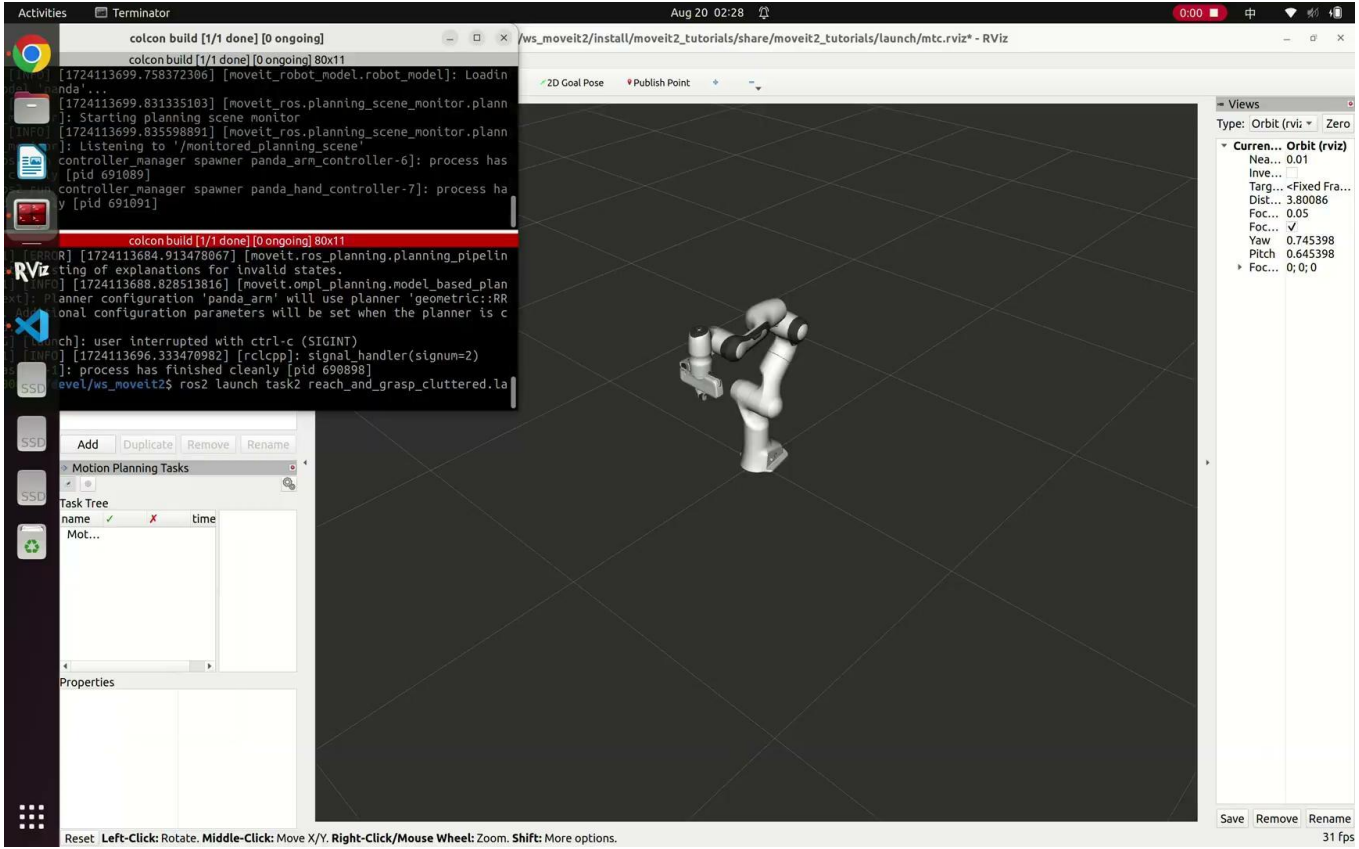
Task 2.1


File Panels Help
Interact
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
2D Goal Pose
Publish Point
Displays
Global Options
Fixed Frame panda_link0
Background C... 48; 48; 48
Frame Rate 30
Global Status: Ok
Fixed Frame OK
Grid
Motion Planni...
Status: Ok
Robot Descri... robot_description
Task Solution ... /solution
Interrupt Dis...
Loop Animation
Show Trail
State Display ... 0.05 s
Trail Step Size 1
Robot
Scene
Add
Duplicate
Remove
Rename
Motion Planning Tasks
Task Tree
name
Properties
Views
Type: Orbit (rvi
Zero
Curren... Orbit (rviz)
Nea... 0.01
Inve...
Targ... <Fixed Fra...
Dist... 2.47989
Foc... 0.05
Foc...
Yaw 1.4254
Pitch 0.185398
Foc... 0.29848; -...
Save
Remove
Rename
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel: Zoom. Shift: More options.
31 fps

Task 2.1


File Panels Help
Interact
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
2D Goal Pose
Publish Point
Displays
Global Options
Fixed Frame panda_link0
Background C... 48; 48; 48
Frame Rate 30
Global Status: Ok
Fixed Frame OK
Grid
Motion Planni...
Status: Ok
Robot Descri... robot_description
Task Solution ... /solution
Interrupt Dis...
Loop Animation
Show Trail
State Display ... 0.05 s
Trail Step Size 1
Robot
Scene
Add
Duplicate
Remove
Rename
Motion Planning Tasks
Task Tree
name
Properties
Views
Type: Orbit (rvi
Zero
Curren... Orbit (rviz)
Nea... 0.01
Inve...
Targ... <Fixed Fra...
Dist... 2.59018
Foc... 0.05
Foc... ✓
Yaw 0.885398
Pitch 0.815398
Foc... -0.22676; -...
Save
Remove
Rename
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel: Zoom. Shift: More options.
31 fps

Task 2.1


Activities
Terminator
Aug 20 02:28
colcon build [1/1 done] [0 ongoing]
/ws_moveit2/install/moveit2_tutorials/share/moveit2_tutorials/launch/mtc.rviz* - RViz
2D Goal Pose
Publish Point
Views
Type: Orbit (rviz)
Zero
Add
Duplicate
Remove
Rename
Motion Planning Tasks
Task Tree
name
time
Properties
Save
Remove
Rename
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel: Zoom. Shift: More options.
31 fps

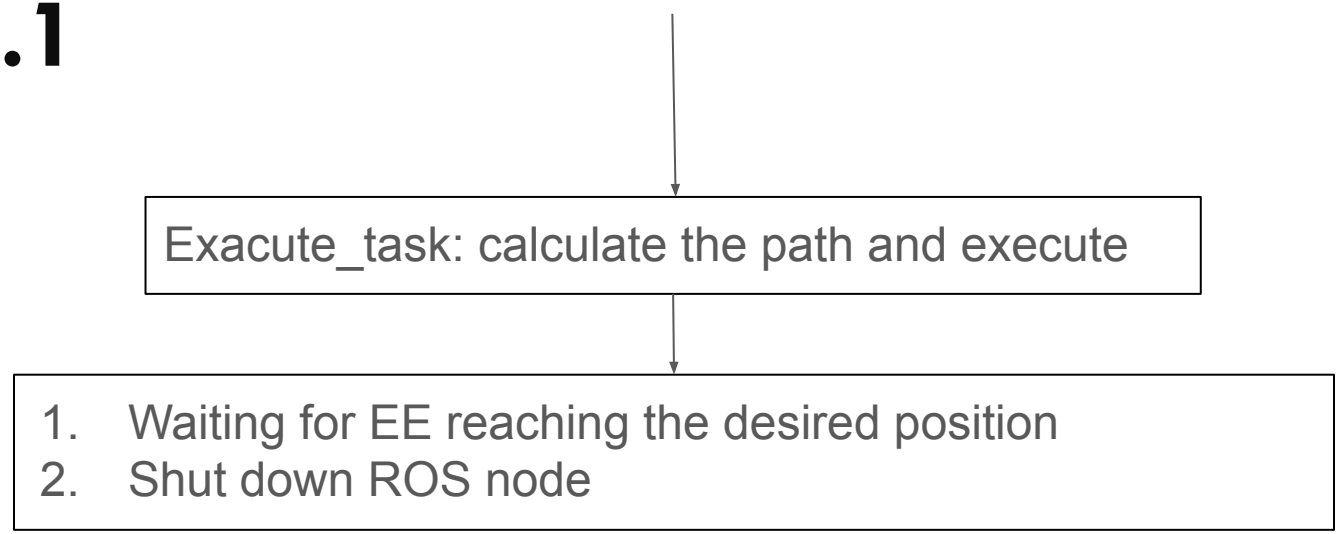
Task 2.1

Create planning scene: add collision object

Create Task

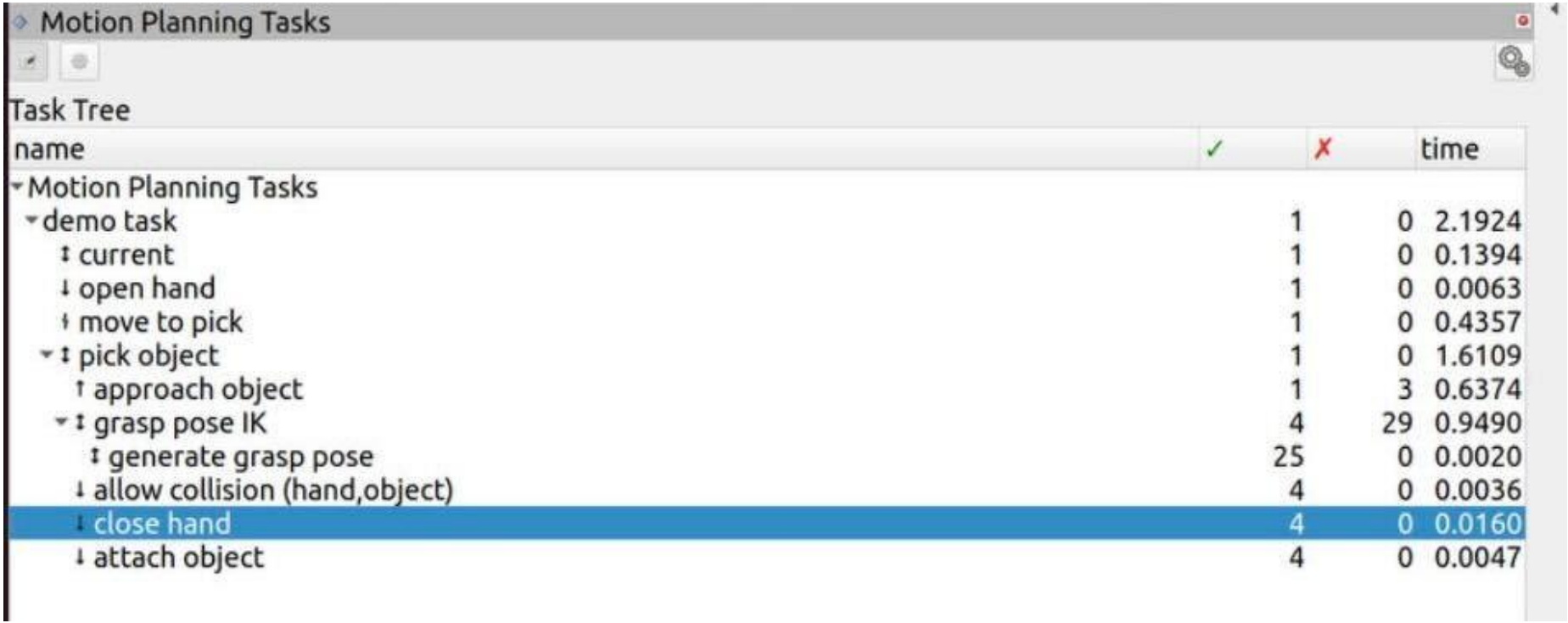
1. Initialize current state
2. Stage: open_hand (interpolation_planner)
3. Connection: move_to_pick(ompl)
4. Container: pick_object
    a. approach_object(Cartesian planner)
    b. grasp_pose(interpolation_planner)
    c. allow_collisiom
    d. close_hand
    e. attach_object
5. Return_to_initialize_position(ompl)

Task 2.1


Exacute_task: calculate the path and execute
1. Waiting for EE reaching the desired position
2. Shut down ROS node

Task 2.1

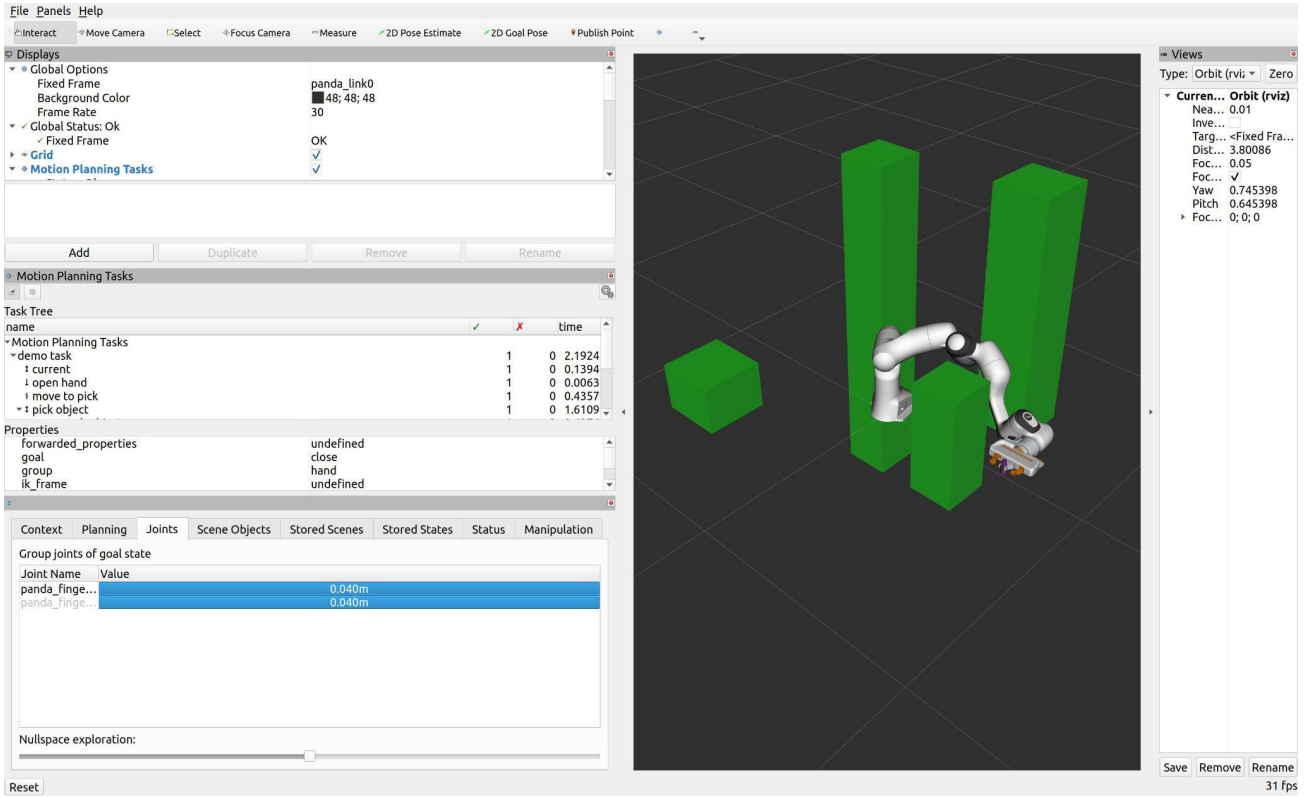
Planning time



Task 2.2

Null Space:

As shown in the figure, the null space of the robot is limited to the movement of the finger, which ensures the static position of the end effector. Ideally, it should allow for greater internal freedom. However, due to time constraints, further investigation into additional factors is needed



Further Improvement

- Divide the planning task into more detailed subtasks and create a Behavior Tree to activate different algorithms under different scenarios.
- Adjust the boundary conditions and search steps, furthermore using weighted planning algorithms to speed up searching in relative empty space.

Task 3

Task 3.1

Goal: Pick up cuboid and hold it with both robots

Model: Pyrep's Panda Robot

Libraries: PyRep

Implementation:

- Move robots into starting position
  - Right Robot → 0.55 | 0 | 0.01
  - Left Robot → 0.7 | -0.1 | 0.3
- Right Robot grasps cuboid + moves to [0.7, -0.01, 0.3]
- Left Robot moves to [0.7, 0.01, 0.3] + grasps cuboid
- Save times and paths

Turnover Time	1.60 s
Right grasps	1.59 s
Left grasps	3.19 s

Task 3.2

Goal: Pick up Cuboid and move it in dual-mode along a circular path

Model: Pyrep's Panda Robot

Libraries: PyRep

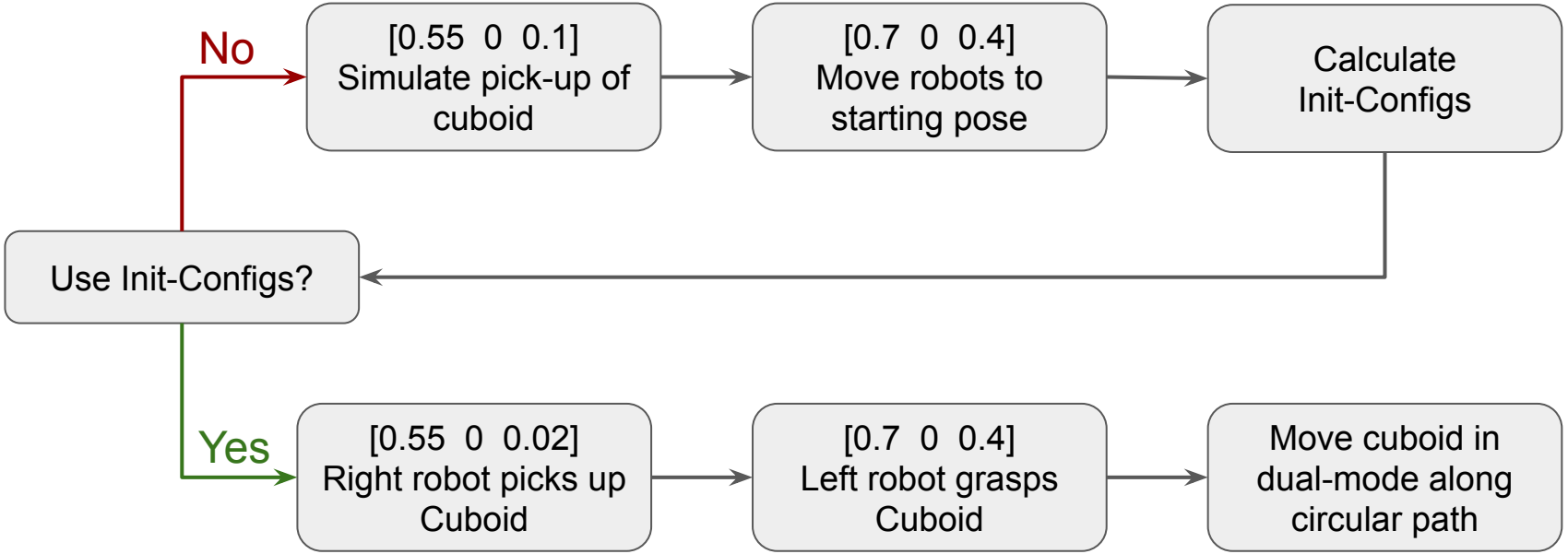
Implementation: circular path in dual mode

- Move robots to starting position
- Calculate waypoints every 30 degree
- For every waypoint:
  - Move robots to initialization configuration of waypoint
  - Calculatel 4 intermediate waypoints
  - Pyrep's *get_path_from_cartesian_path*

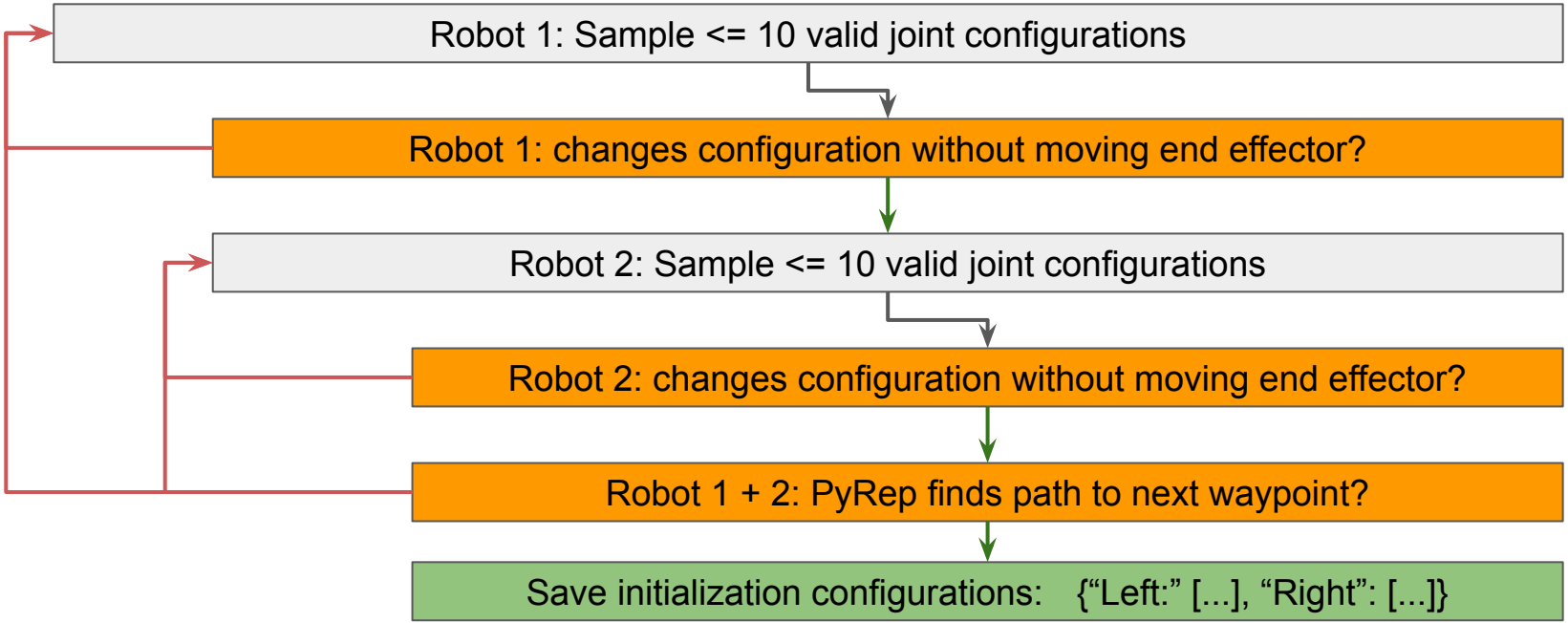
Average time: 25.30 s

Measured without picking up cuboid

Task 3.2: Schema



Task 3.2: Initialization Configurations



```
y
moved along circular path in dual-mode with time in seconds: 27.667392253875732
[CoppeliaSim:loadinfo]   done.
QObject::~QObject: Timers cannot be stopped from another thread
theresa@medical-robots:~/Documents/master/2_human-centered_Robotics/repositories/team_h/Task3/src$ python Task3_2.py
Do you want to reuse the initialization configurations calculated from last solution?[y,n]
 If not new initialization configurations will be calculated before starting the scenario

y
moved along circular path in dual-mode with time in seconds: 28.090522289276123
[CoppeliaSim:loadinfo]   done.
QObject::~QObject: Timers cannot be stopped from another thread
theresa@medical-robots:~/Documents/master/2_human-centered_Robotics/repositories/team_h/Task3/src$ python Task3_2.py
Do you want to reuse the initialization configurations calculated from last solution?[y,n]
 If not new initialization configurations will be calculated before starting the scenario

y
moved along circular path in dual-mode with time in seconds: 25.624794006347656
[CoppeliaSim:loadinfo]   done.
QObject::~QObject: Timers cannot be stopped from another thread
theresa@medical-robots:~/Documents/master/2_human-centered_Robotics/repositories/team_h/Task3/src$ python Task3_2.py
Do you want to reuse the initialization configurations calculated from last solution?[y,n]
 If not new initialization configurations will be calculated before starting the scenario

yes
moved along circular path in dual-mode with time in seconds: 25.13677144050598
[CoppeliaSim:loadinfo]   done.
QObject::~QObject: Timers cannot be stopped from another thread
theresa@medical-robots:~/Documents/master/2_human-centered_Robotics/repositories/team_h/Task3/src$ python Task3_2.py
Do you want to reuse the initialization configurations calculated from last solution?[y,n]
 If not new initialization configurations will be calculated before starting the scenario

y
moved along circular path in dual-mode with time in seconds: 22.301575422286987
[CoppeliaSim:loadinfo]   done.
QObject::~QObject: Timers cannot be stopped from another thread
theresa@medical-robots:~/Documents/master/2_human-centered_Robotics/repositories/team_h/Task3/src$ python Task3_2.py
Do you want to reuse the initialization configurations calculated from last solution?[y,n]
 If not new initialization configurations will be calculated before starting the scenario

y
moved along circular path in dual-mode with time in seconds: 24.762553930282593
[CoppeliaSim:loadinfo]   done.
QObject::~QObject: Timers cannot be stopped from another thread
theresa@medical-robots:~/Documents/master/2_human-centered_Robotics/repositories/team_h/Task3/src$ python Task3_2.py
Do you want to reuse the initialization configurations calculated from last solution?[y,n]
 If not new initialization configurations will be calculated before starting the scenario

y
moved along circular path in dual-mode with time in seconds: 23.060485363006592
[CoppeliaSim:loadinfo]   done.
QObject::~QObject: Timers cannot be stopped from another thread
theresa@medical-robots:~/Documents/master/2_human-centered_Robotics/repositories/team_h/Task3/src$
```

Task 3.2: Limitations + Improvements

- Discards configurations → initialization configurations takes longer to calculate
- Needs to interrupt dual mode at 180 degrees

Improvement: Implement special control mechanism

- Does not move end effector while moving to any new configuration leading to the new pose
- No need to interrupt at 180 degrees

References

- https://github.com/stepjam/PyRep
- https://moveit.picknik.ai/humble/doc/tutorials/pick_and_place_with_moveit_task_constructor/pick_and_place_with_moveit_task_constructor.html
- ARCL_23_24: team b

Questions?