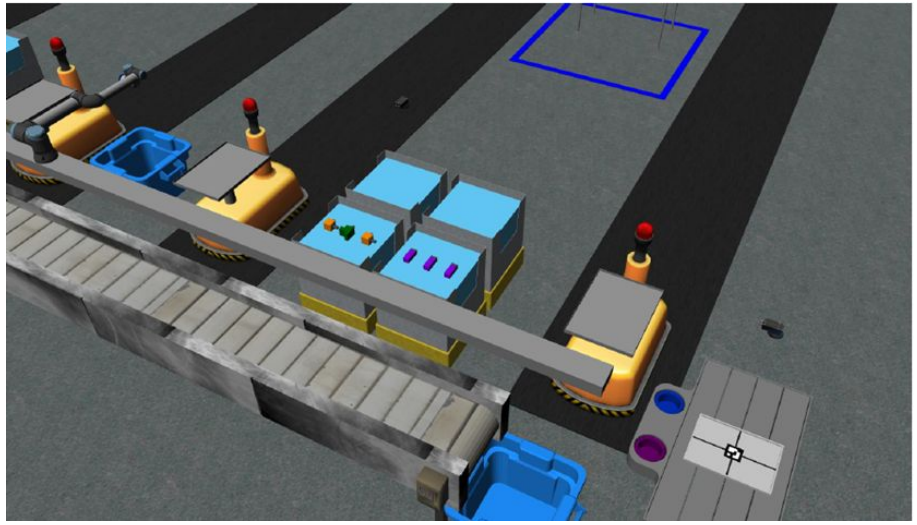
ENPM663: Building a Manufacturing Robotic Software System
RWA67



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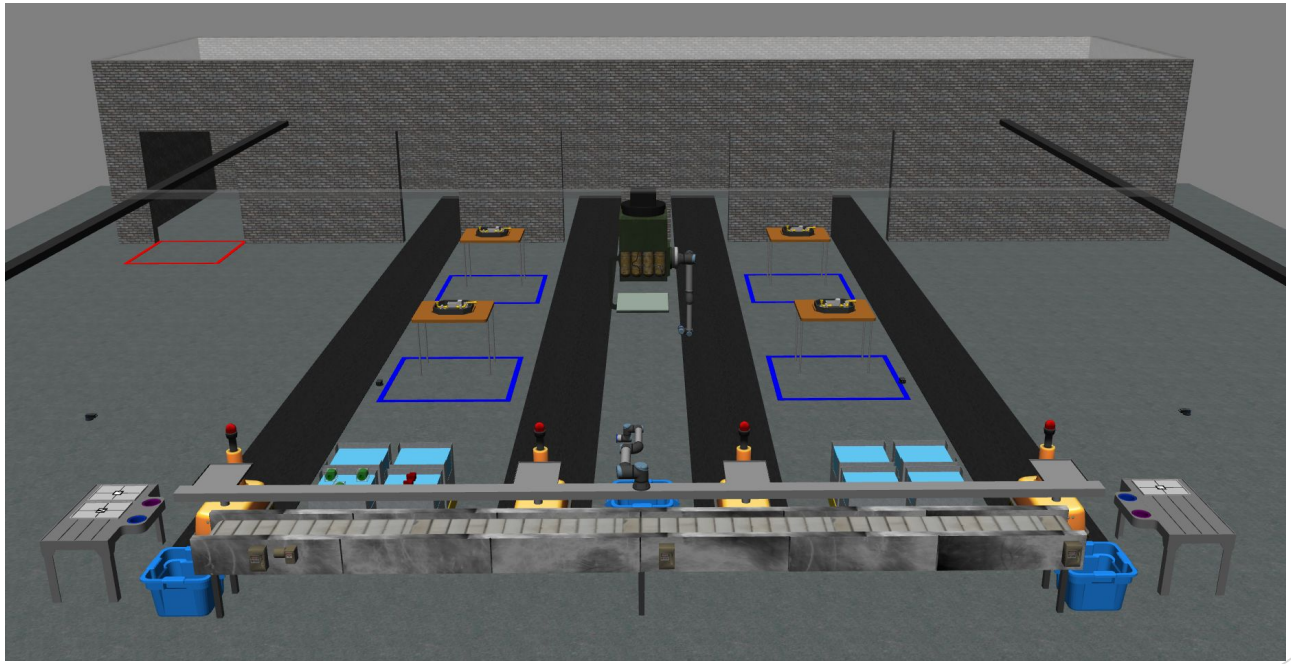
Introduction:

ARIAC is hosted by National Institute of Standards and Technology (**NIST**) to test the **agility** of the industrial robot system.

The purpose of ARIAC is to make industrial robots **more autonomous, productive** with **minimum human input.**

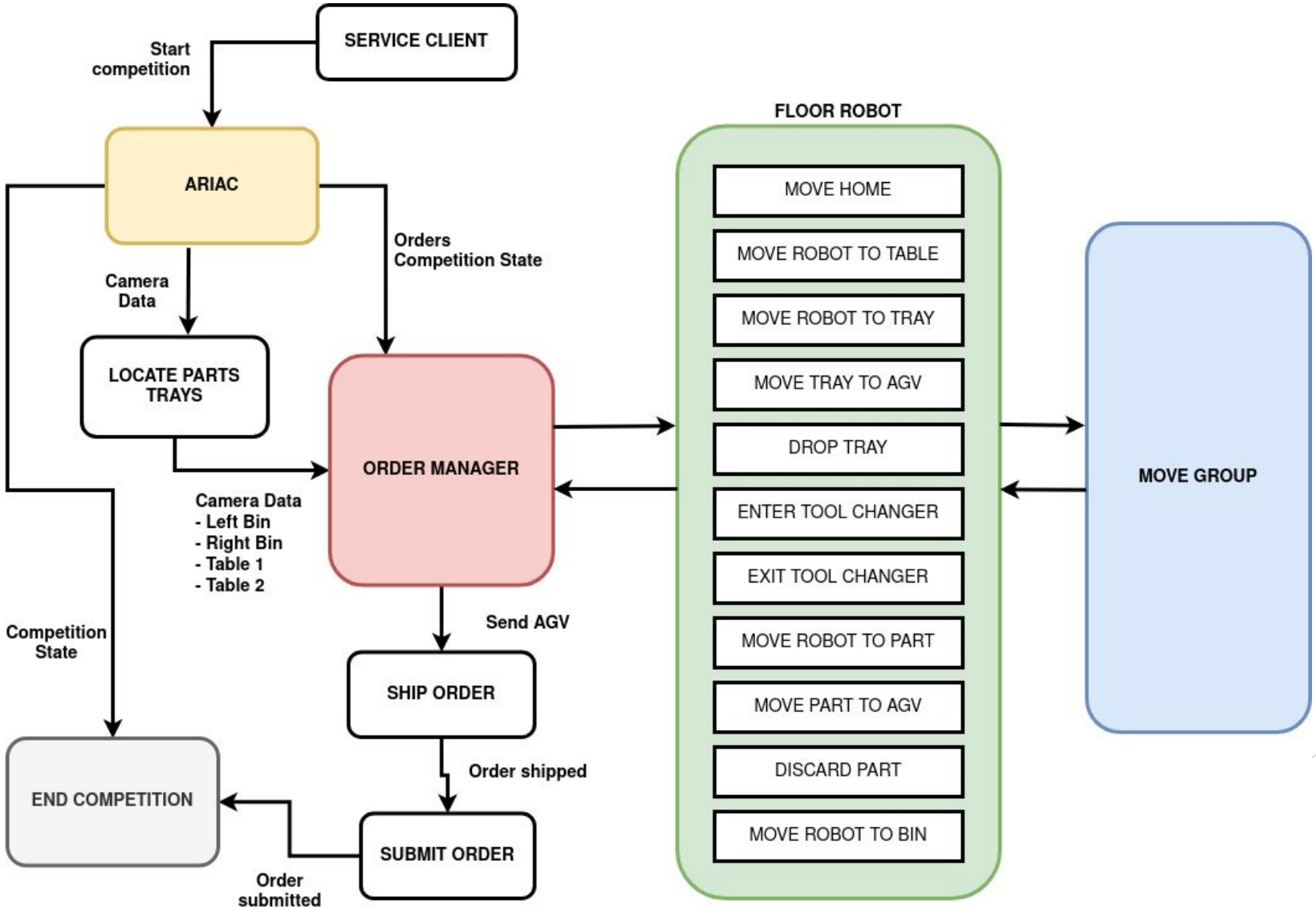


Problem Statement:

For this course the problem was to test the agility of an industrial floor robot to complete kitting tasks with the challenges of:

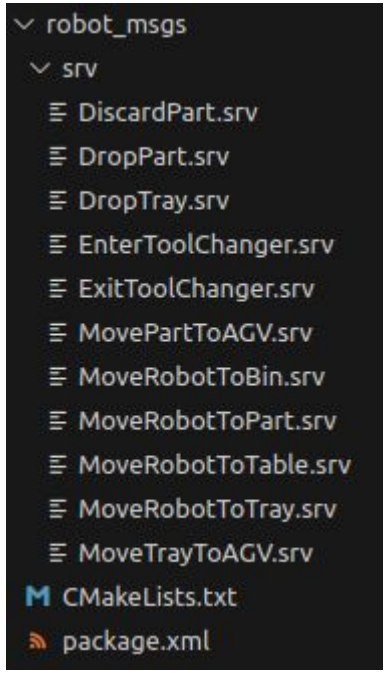
- Faulty part
  - Parts placed in certain quadrants for the first time are deemed faulty. They must be properly disposed of in the discard bin to avoid penalty
- Insufficient part
  - There are not enough parts to fulfill an order. The order must be complete to its fullest and still submitted.

Code Block Diagram:

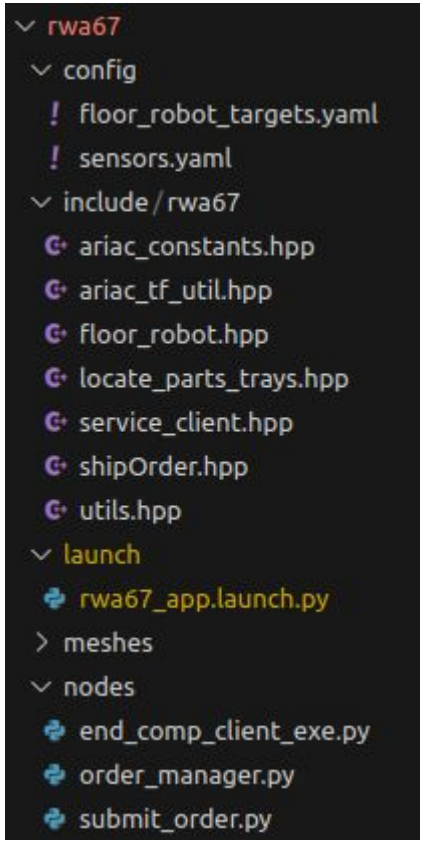


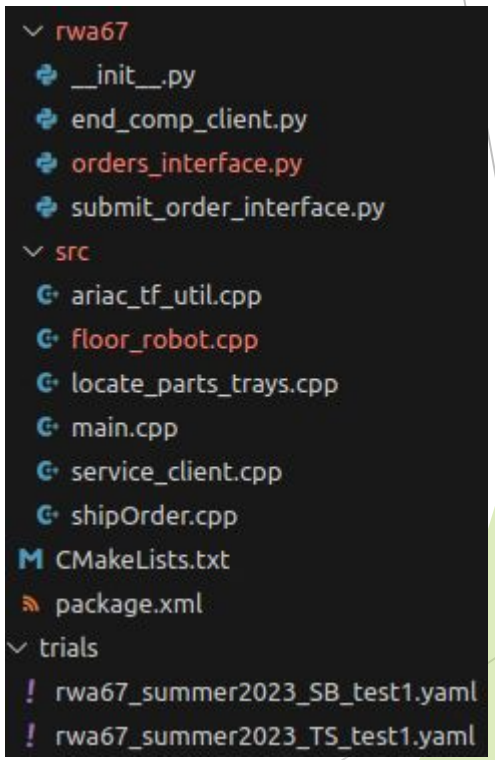
Package Contents:

- Robot_msgs
  - Custom Service Messages



- Rwa67
  - Main Competitor Package





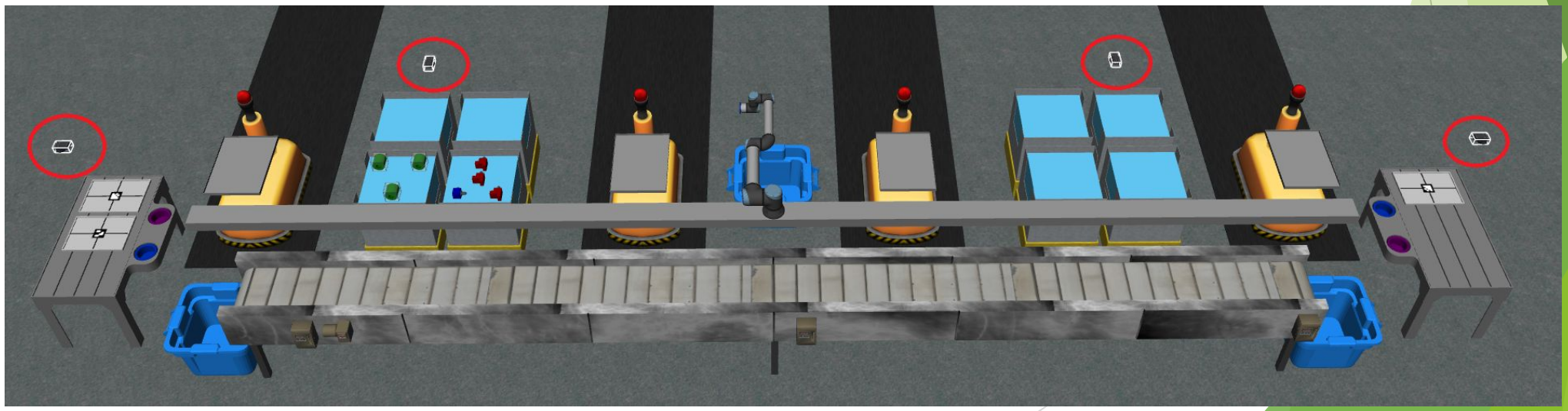
Approx. Lines of code = 5053

Environment Sensors:

- Provide control system with information necessary to build world model
- 4x Advanced Logical Sensors
  - Provide tray id and pose
  - Provide part pose, color, and type
- AGV Tray Sensors
  - Located on each AGV
  - Provide quality information of tray and parts

sensors.yaml

```yaml
sensors:
  left_bins_camera:
    type: advanced_logical_camera
    pose:
      xyz: [-2.286, -2.96, 1.8]
      rpy: [pi, pi/2, 0]

  right_bins_camera:
    type: advanced_logical_camera
    pose:
      xyz: [-2.286, 2.96, 1.8]
      rpy: [pi, pi/2, 0]

  kts1_camera:
    type: advanced_logical_camera
    pose:
      xyz: [-1.3, -5.8, 1.8]
      rpy: [pi, pi/2, pi/2]

  kts2_camera:
    type: advanced_logical_camera
    pose:
      xyz: [-1.3, 5.8, 1.8]
      rpy: [pi, pi/2, -pi/2]
```



Order Manager - In Depth:

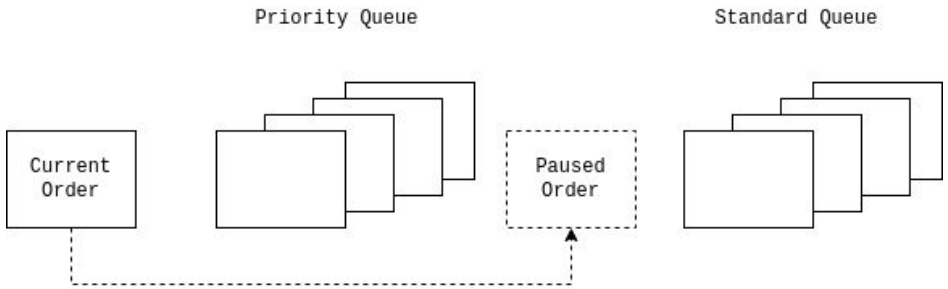
The Order Manager node is the heart of the competition package.

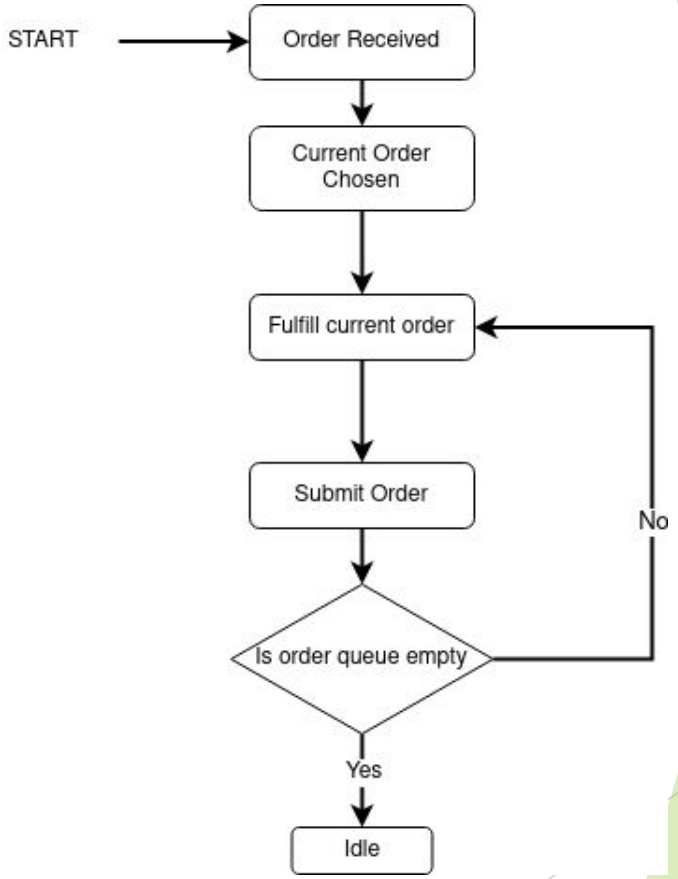
Subscriptions

- `ariac/competition_state`
  Begins fulfilling orders

- `ariac/orders`
  Adds orders to the queues

- `/left_bin_camera_data`
  `/right_bin_camera_data`
  `/kitting_tray1_camera_data`
  `/kitting_tray2_camera_data`
  Records the poses of parts and trays. These have been obtained by locate_parts_trays, translated to world pose, then republished





Order Manager - In Depth (cont.):

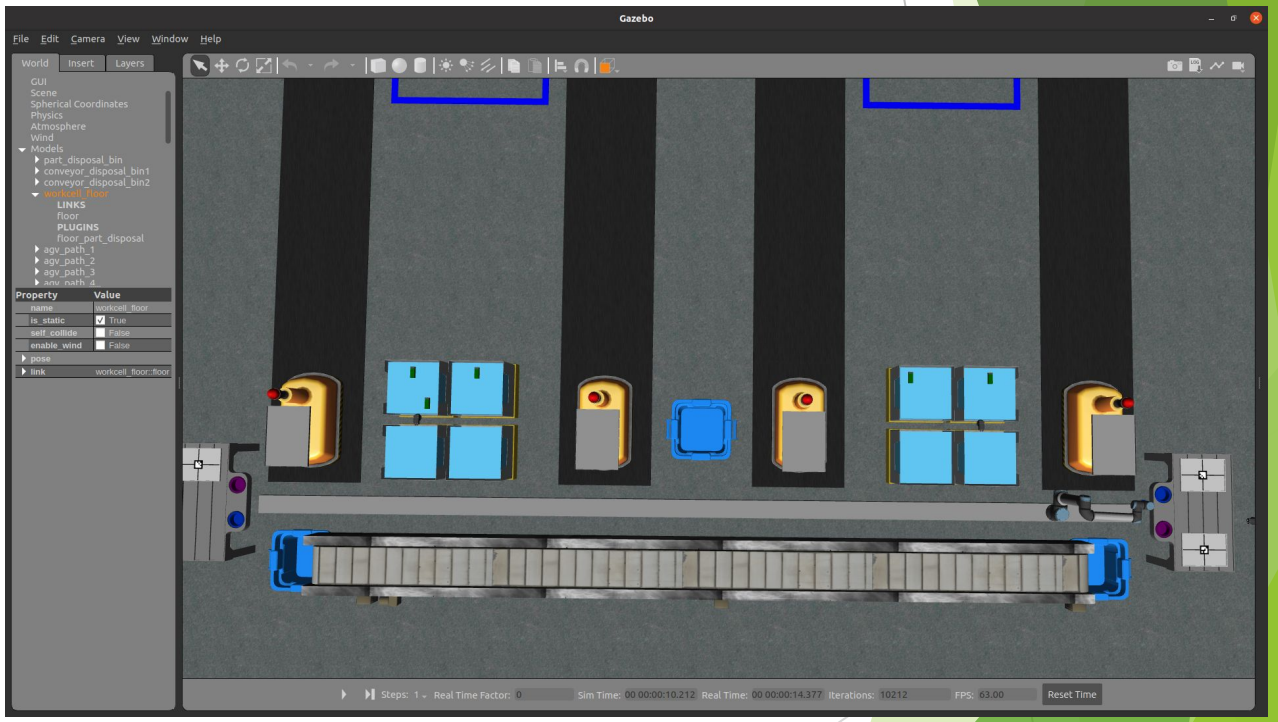
The Order Manager node is the heart of the competition package. It contains the main logic and makes the service requests to floor_robot

```
Fullfill_order:
    order = current_order
    tray = order.tray
    agv = order.agv

    tray_pose = search_tray_inventory(tray)
    move_robot_to_table()
    change_to_tray_gripper()
    grab_tray()
    place_tray_on_agv()
    remove_tray_from_inventory()

    move_robot_to_table()
    change_to_part_gripper()
    for (part in list_of_parts):
        part_pose = search_part_inventory(part)
        If (part_pose == None):
            Continue  #part not found… Moving on
        place_part_on_tray()
        perform_quality_check()
        If (faulty):
            Move part to bin
            Add part back to list_of_parts
        Remove_part_from_inventory()
    complete_order()
```

Trial Files:

The Order Manager node is the heart of the competition package:

- rwa67_summer2023.yaml
- rwa67_summer2023_SB_test1.yaml
  - 4 orders
  - Multiple Faulty Parts
  - Insufficient Parts
- rwa67_summer2023_TS_test1.yaml
  - Order contains 3 faulty parts and only 5 available



Testing: faulty parts lead to missing parts

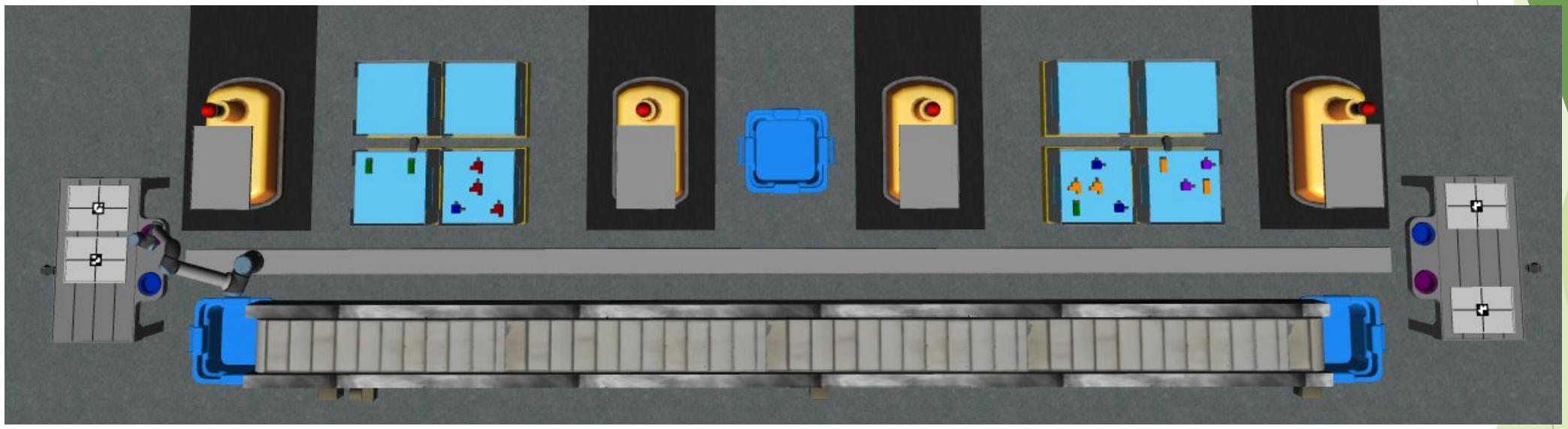
rwa67_summer2023_SB_test1.yaml

```yaml
parts:
  bins:
    bin1:
      - type: 'battery'
        color: 'orange'
        slots: [1,6]
      - type: 'regulator'
        color: 'purple'
        slots: [3,5]
    bin2:
      - type: 'regulator'
        color: 'blue'
        slots: [2,9]
      - type: 'sensor'
        color: 'orange'
        slots: [4,5]
      - type: 'battery'
        color: 'green'
        slots: [7]
    bin5:
      - type: 'battery'
        color: 'green'
        slots: [1,3]
    bin6:
      - type: 'sensor'
        color: 'red'
        slots: [2,5,9]
      - type: 'regulator'
        color: 'blue'
        slots: [7]
```

```yaml
orders:
  - id: 'KITTING1'
    type: 'kitting'
    announcement:
      time_condition: 0
    priority: false
    kitting_task:
      agv_number: 2
      tray_id: 3
      destination: 'warehouse'
      products:
        - type: 'battery'
          color: 'green'
          quadrant: 1
        - type: 'sensor'
          color: 'red'
          quadrant: 3
  - id: 'KITTING2'
    type: 'kitting'
    announcement:
      part_place_condition:
        agv: 2
        type: 'sensor'
        color: 'red'
    priority: false
    kitting_task:
      agv_number: 3
      tray_id: 5
      destination: 'warehouse'
      products:
        - type: 'battery'
          color: 'green'
          quadrant: 2
        - type: 'regulator'
          color: 'blue'
          quadrant: 4
```

```yaml
- id: 'KITTING3'
  type: 'kitting'
  announcement:
    part_place_condition:
      agv: 2
      type: 'sensor'
      color: 'red'
  priority: false
  kitting_task:
    agv_number: 4
    tray_id: 7
    destination: 'warehouse'
    products:
      - type: 'sensor'
        color: 'red'
        quadrant: 1
      - type: 'battery'
        color: 'green'
        quadrant: 2
- id: 'KITTING4'
  type: 'kitting'
  announcement:
    part_place_condition:
      agv: 4
      type: 'sensor'
      color: 'red'
  priority: false
  kitting_task:
    agv_number: 1
    tray_id: 7
    destination: 'warehouse'
    products:
      - type: 'battery'
        color: 'orange'
        quadrant: 2
      - type: 'regulator'
        color: 'purple'
        quadrant: 4
```

```yaml
challenges:
  - faulty_part:
      order_id: 'KITTING1'
      quadrant3: true
  - faulty_part:
      order_id: 'KITTING2'
      quadrant2: true
  - faulty_part:
      order_id: 'KITTING4'
      quadrant2: true
```



rwa67_summer2023_TS_test1.yaml

```yaml
parts:
  bins:
    bin1:
      - type: 'battery'
        color: 'green'
        slots: [1]
    bin2:
      - type: 'battery'
        color: 'green'
        slots: [2]
    bin5:
      - type: 'battery'
        color: 'green'
        slots: [2]
    bin6:
      - type: 'battery'
        color: 'green'
        slots: [2, 9]
```

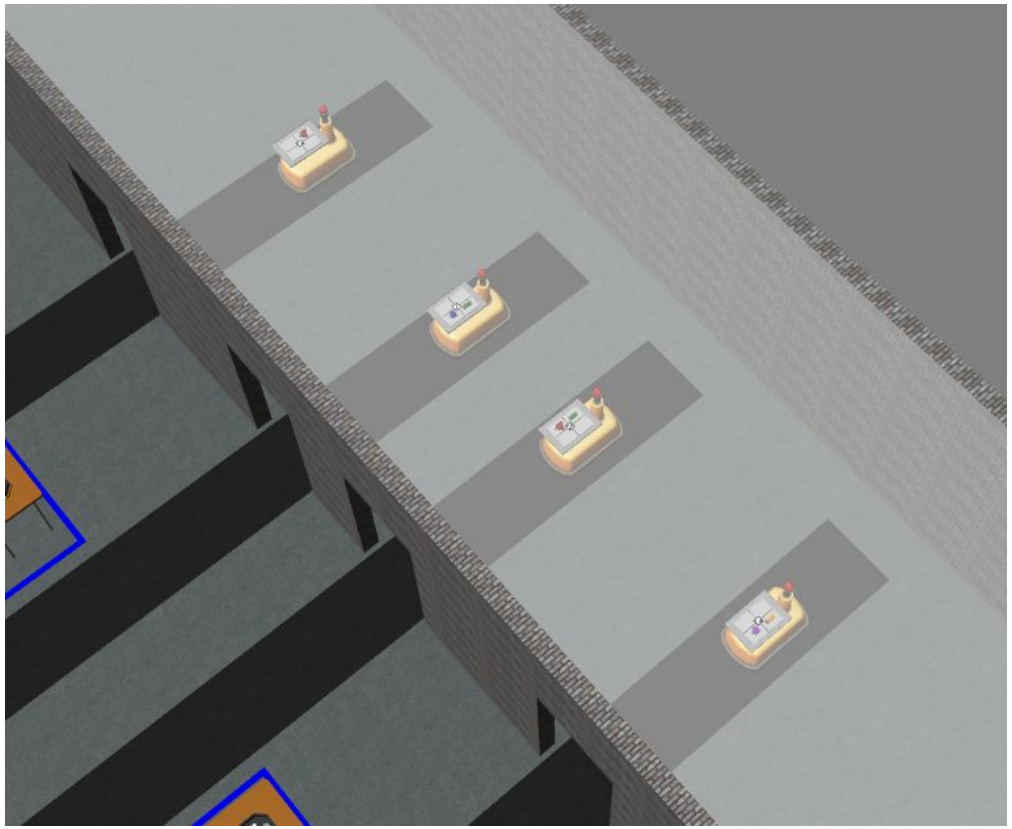
```yaml
orders:
  - id: 'KITTING1'
    type: 'kitting'
    announcement:
      time_condition: 0
    priority: false
    kitting_task:
      agv_number: 2
      tray_id: 5
      destination: 'warehouse'
      products:
        - type: 'battery'
          color: 'green'
          quadrant: 1
        - type: 'battery'
          color: 'green'
          quadrant: 2
        - type: 'battery'
          color: 'green'
          quadrant: 3
        - type: 'battery'
          color: 'green'
          quadrant: 4
```

```yaml
challenges:
  - faulty_part:
      order_id: 'KITTING1'
      quadrant1: true
      quadrant2: true
      quadrant3: true
```

Result:

rwa67_summer2023_SB_test1.yaml:

- completion time: 162 sec
- Score: 39

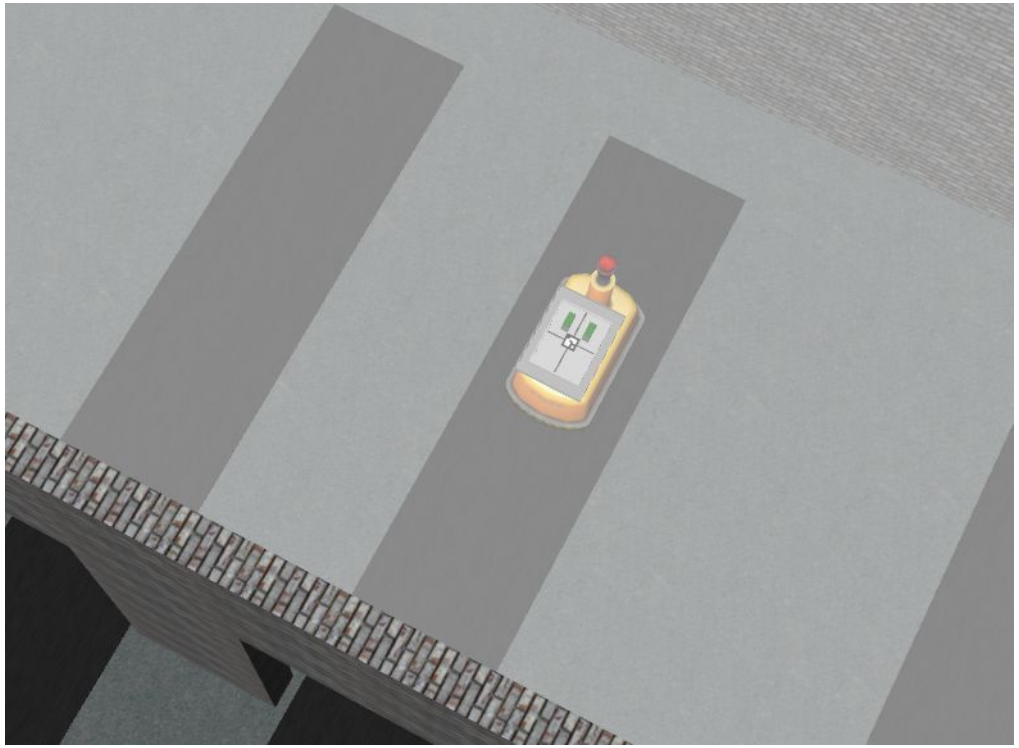


```
[gzserver-2] ========================================
[gzserver-2] END OF TRIAL
[gzserver-2] ========================================
[gzserver-2] Trial file: rwa67_summer2023_SB_test1.yaml
[gzserver-2] Trial time limit: -1.000000
[gzserver-2] Trial completion time: 161.585000
[gzserver-2] Trial score: 39
[gzserver-2] ========================================
```

Result (cont.):

rwa67_summer2023_TS_test1.yaml:

- completion time: 97 sec
- Score: 9



```
[gzserver-2] ========================================
[gzserver-2] END OF TRIAL
[gzserver-2] ========================================
[gzserver-2] Trial file: rwa67_summer2023_TS_test1.yaml
[gzserver-2] Trial time limit: -1.000000
[gzserver-2] Trial completion time: 96.396000
[gzserver-2] Trial score: 9
[gzserver-2] ========================================
```

Challenges Faced:

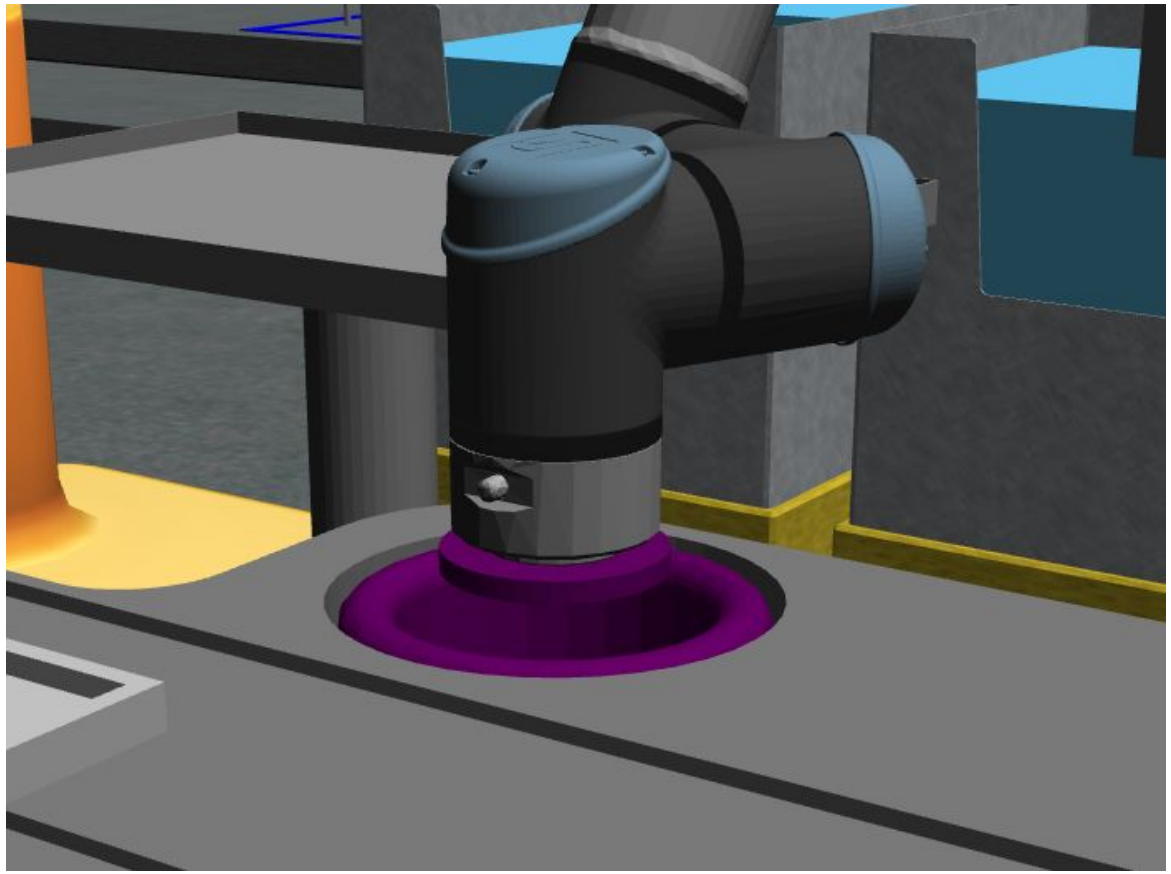
Numerous obstacles were faced during this project such as:

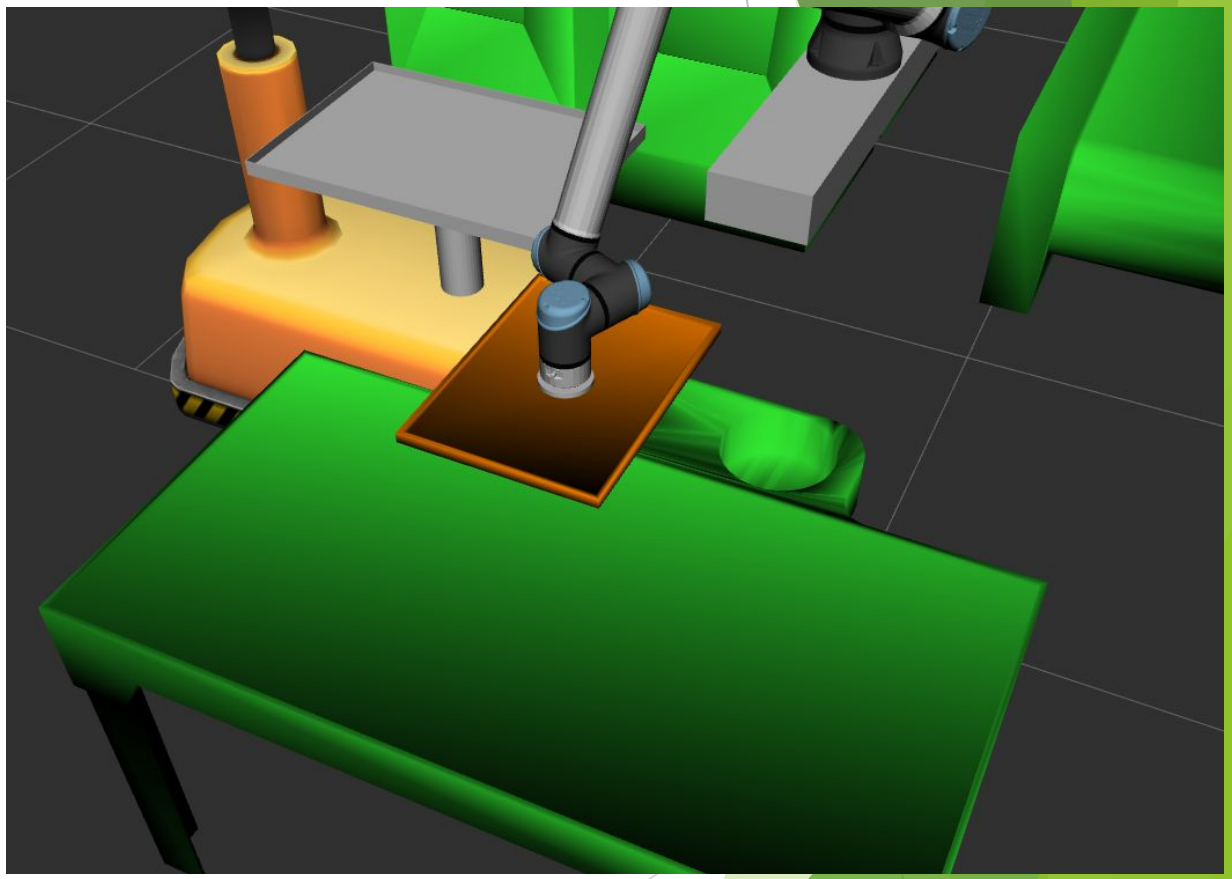
- Building a robust control architecture to handle challenges in orders.
- Parsing camera data to manager the order providing by the competition.
- Writing servers and using appropriate services to perform Kitting task in Gazebo environment.
- Breaking down services for a smoother simulation.
- Establishing appropriate communication between servers (written in C++) and clients (written in Python).

Challenges Faced (cont.):

- Fine tuning parameters in server callback methods for the floor robot to perform pick and place task for various parts and tray.
- Ensuring parts were properly added to planning scene before attempting to interact with them.
- Adjusting waypoints and targets to avoid collision with objects not in planning scene (objects still in bin).
- What to snack on at midnight when floor robot goes rogue, dancing on the rail.

Challenges Faced (cont.):

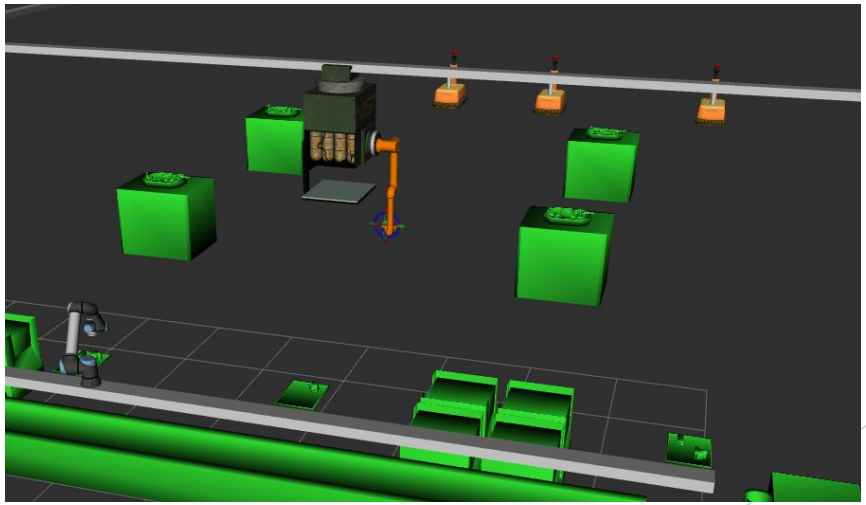




Robot would not enter gripper changer because the planning scene still had the tray attached.

How can the results be made better?

- Tray and Part inventories are determined at start. Ideally, part and tray locations should be continuously updated (bumped parts, dropped parts)
- Integrate ceiling robot to reach all parts in bins
- Attach trays/parts to AGVs in planning view. Current implementation would cause collisions when using the AGV for a second time.
- Finish Priority order logic



Conclusion

- The ‘rwa67’ accomplishes its objectives:
  - Perform motion planning to complete up to 4 orders
    - 1 per AGV
  - Cater for insufficient parts & faulty parts

Demo:

Build the packages:
cd ~/ariac_ws/
colcon build --packages-select robot_msgs
colcon build --packages-select rwa67

Launch:
ros2 launch rwa67 rwa67_app.launch.py