Collision avoidance and Task distribution on a conveyor belt

Group Project - Final

Team ID : 33

Team Composition

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Problem Statement

Simulation of two SCARA robot collaboratively sorting items from a conveyor belt with collision avoidance and task distribution.

Project Description

- In this project two SCARA robot collaboratively sort items from a conveyor belt with collision avoidance and Task distribution.
- Collision avoidance uses a algorithm to dynamically allocate each robot's workspace.
- Task distribution follows a first come, first get principle. And the motion planners are considered to be independent, hence one planner for one SCARA robot.
- The URDF (Universal Robot Description Format) model is a collection of files that describe a robot's physical description to ROS. Here it is used for the SCARA robot, conveyor belt, and the cylinder blocks .
- A spanner node that can automatically spawn cylinder blocks and let them slide on conveyor belt with an initial speed is used.
- A gripper control action server node keeps gripper at desired location and directs gripper to perform action based on command it received.
- A cylinder blocks position publisher node was added to publish the 3-D position of all current cylinders we switch joint control method from off-the shelf ros_control to self defined PD controller.

Software Compatibility

1. Ubuntu 20.04
2. ROS & GAZEBO
3. C++
4. URDF

Packages

The packages used in this project are:

ros_control

- joint_trajectory_planner

Control_Manager

- Joint_state_controller

Two_Scara_Collaboration (USER DEFINED)

- scara_left_motion_planner
- scara_right_motion_planner

ROSCPP

We chose C++ over python as python code in ROS runs slower as it is being compiled real-time and there are higher chances of the program crashing.

Pros of programming ROS in C++:

- The code runs really fast.
- By having to compile, you can catch a lot of errors during compilation time, instead of having them in run time.
- C++ has an infinite number of libraries that allow you to do whatever you want with C++.

SCARA

- Scara is a type of Industrial robot.
- The SCARA robot is most commonly used for pick-and-place or assembly operations where high speed and high accuracy is required.
- Robot provides consistent reliable performance, repetitive accuracy and are able to handle heavy work loads and perform in harsh environments.
- SCARA kinematics makes this robot particularly suitable to perform assembly tasks with tight tolerances, such as putting a shaft into a hole, thanks to the capability to adjust the movement on the horizontal plane, while at the same time maintaining high rigidity on the vertical direction.

PD

- The PD controller is a commonly used **feedback controller consisting of proportional, and derivative terms.**

- A PD controller is an instrument used in industrial control applications **to regulate pressure, speed and other process variables**.

- **P controller** stabilizes the gain but produces a constant steady state error.
- **D controller** reduces the rate of change of error.

Demonstration

VIDEO :

https://drive.google.com/file/d/1O7vuwDO9UJCQHXkbqCpK2DCZ46djJiBF/view?usp=sharing

Demonstration

RQT Graph :

https://drive.google.com/file/d/1rR2hnTKEg0HY2w9_WcNbVMmzCPOmhHUt/view?usp=sharing

Code Explanation

- **Gazebo simulator is paused when initialized.**
  Starting the simulation by clicking the start button.

- *cylinder_acitive_pool.cpp* ->
  - In this file , a node is defined to maintain a pool of reachable blocks, (*reachable means in the range of the the scara robots and could be fetched before it leaves robot's range*).
  - The cylinder active pool has read/write property: published for public read access, write by sending a service request.
    - Add into the pool only when it goes into the reachable range.
    - Delete from the pool when it goes out the range & when it is claimed by one of the robot motion planner.

Code Explanation

- *cylinder_blocks_spawner.cpp* ->
  - In this file , we try to spawn the red and blue cylinders on the conveyor belt and give them initial speed to slide on conveyor.

- *cylinder_blocks_poses_publisher.cpp* ->
  - In this file , the node will publish the topic "cylinder_blocks_poses", including all current cylinder blocks, pose is 3-D position.

- *scara_gripper_action_server.cpp* ->
  - Describes the action server for the gripper control except receiving command from client, it keeps the gripper in its last status.
- *scara_upper_boundary_maintainer.cpp* ->
  - In this file, a node is published on following two topics:- **"/scara_left_upper_boundary"** & **"/scara_left_upper_boundary"**. These two topics describe the upper boundary in their planned motion, are used as state machines for the purpose of collision avoidance.

Code Explanation

- *scara_left_motion_planner.cpp /scara_right_motion_planner.cpp*

  Contains program for scara motion control, control the scara robot by publishing joint angles on corresponding topic of one of the two independent motion planner. As the two scara robots which are implemented as such:-

  4 motion steps decomposed:

1. standby position -> target cylinder position
2. target cylinder hovering (for cylinder grasping operation)
3. target cylinder position -> drop position
4. drop position -> stand by position

Code Explanation

only in motion step 1, the operation may be delayed when the other robot is in operation range

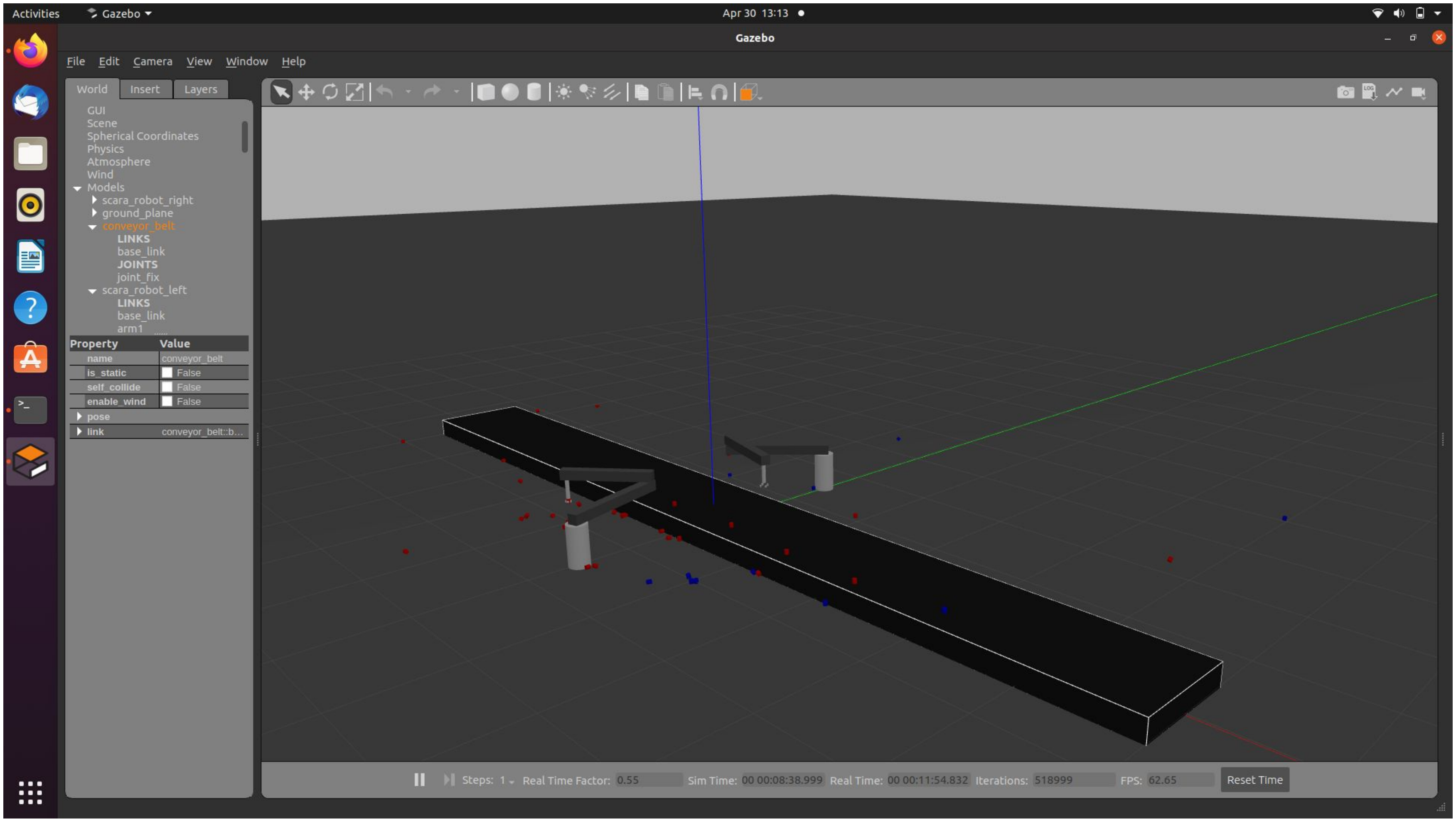
Upper boundary control method:

1. Each robot has a state machine contains a boolean and a number
2. The boolean indicate if the robot is at upper area of the conveyor
3. The number indicate the upper boundary the robot goes
4. Each robot check the other robot's state and make change to its own

Results

https://drive.google.com/file/d/12GkRljgXEtYycyRz_fYHPQdkT1NuO0bU/view

Results


Activities
Gazebo
Apr 30 13:13
Gazebo
File
Edit
Camera
View
Window
Help
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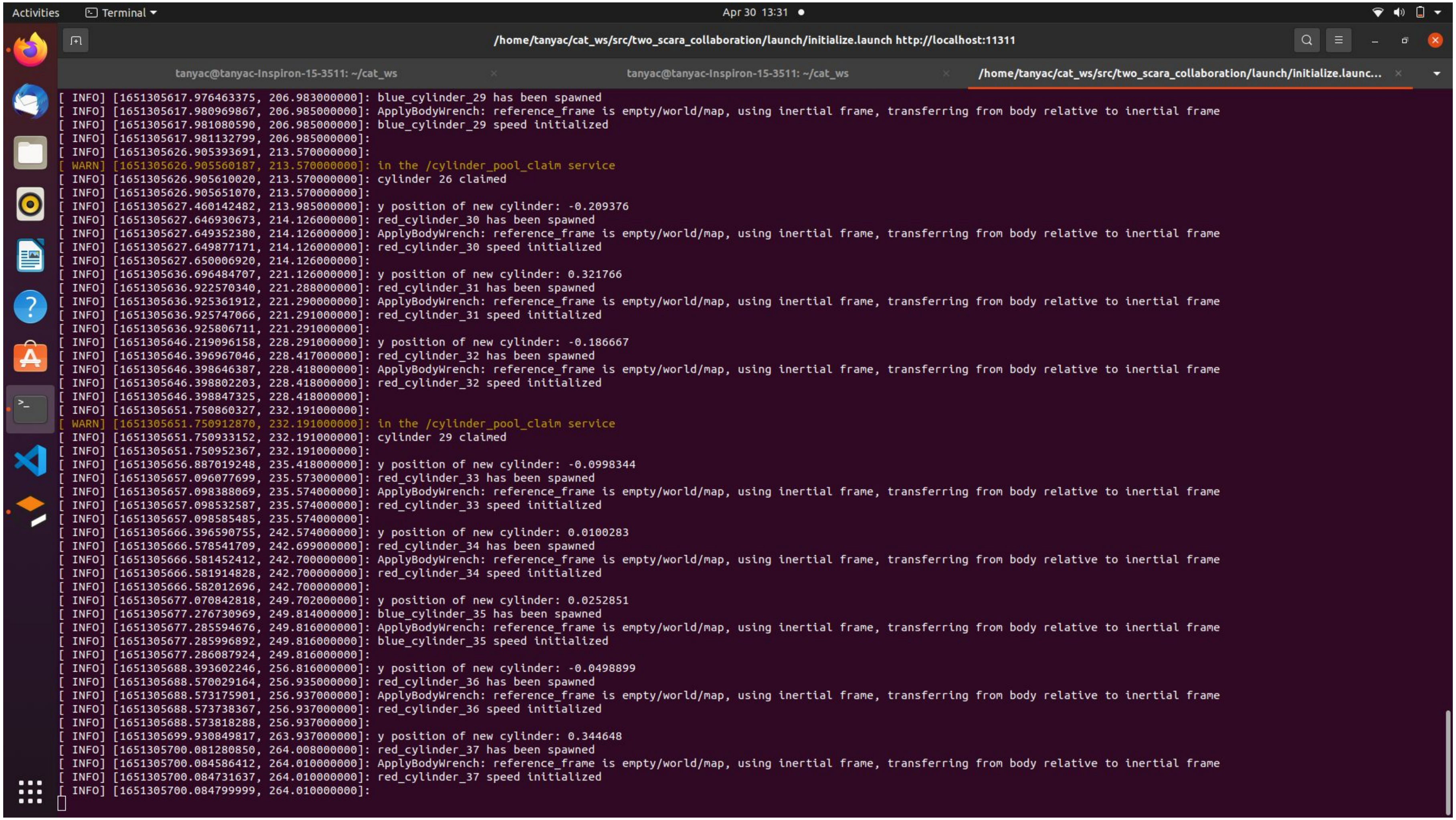
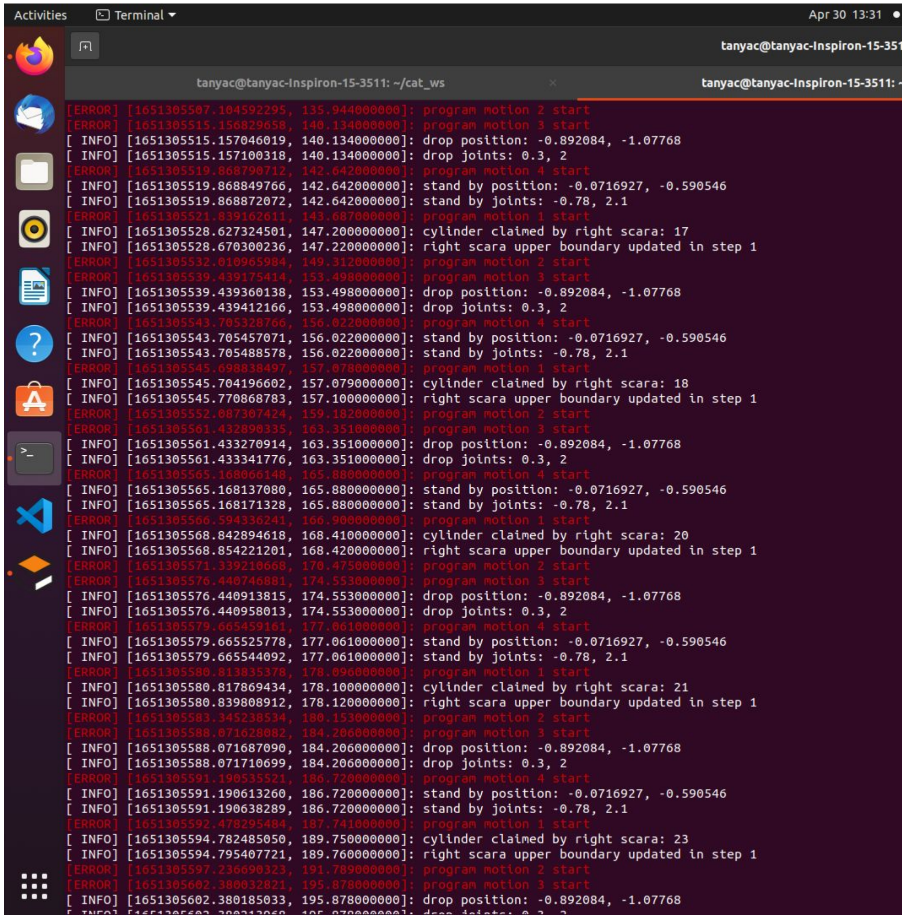
Layers
GUI
Scene
Spherical Coordinates
Physics
Atmosphere
Wind
Models
scara_robot_right
ground_plane
conveyor_belt
LINKS
base_link
JOINTS
joint_fix
scara_robot_left
LINKS
base_link
arm1
Property
Value
name
conveyor_belt
is_static
False
self_collide
False
enable_wind
False
pose
link
conveyor_belt::b...
Steps: 1
Real Time Factor: 0.55
Sim Time: 00 00:08:38.999
Real Time: 00 00:11:54.832
Iterations: 518999
FPS: 62.65
Reset Time

Results

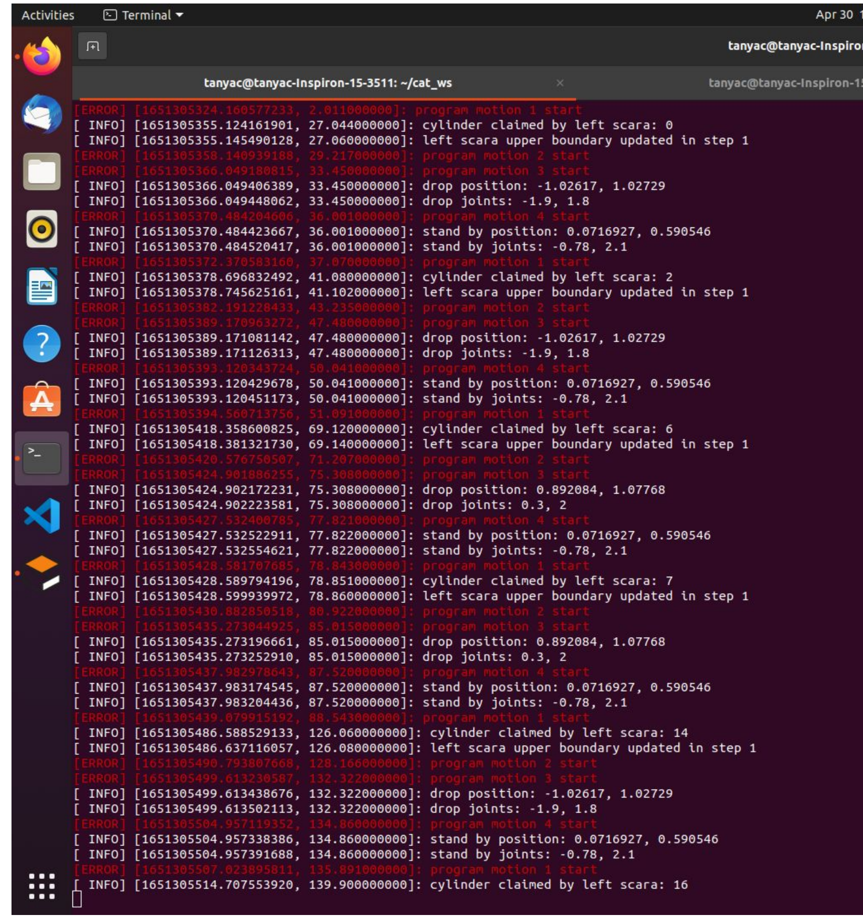


Activities
Terminal
Apr 30 13:31
/home/tanyac/cat_ws/src/two_scara_collaboration/launch/initialize.launch http://localhost:11311
tanyac@tanyac-Inspiron-15-3511: ~/cat_ws
tanyac@tanyac-Inspiron-15-3511: ~/cat_ws
/home/tanyac/cat_ws/src/two_scara_collaboration/launch/initialize.launc...
[INFO] [1651305617.976463375, 206.983000000]: blue_cylinder_29 has been spawned
[INFO] [1651305617.980969867, 206.985000000]: ApplyBodyWrench: reference_frame is empty/world/map, using inertial frame, transferring from body relative to inertial frame
[INFO] [1651305617.981080590, 206.985000000]: blue_cylinder_29 speed initialized
[INFO] [1651305617.981132799, 206.985000000]:
[INFO] [1651305626.905393691, 213.570000000]:
[WARN] [1651305626.905560187, 213.570000000]: in the /cylinder_pool_claim service
[INFO] [1651305626.905610020, 213.570000000]: cylinder 26 claimed
[INFO] [1651305626.905651070, 213.570000000]:
[INFO] [1651305627.460142482, 213.985000000]: y position of new cylinder: -0.209376
[INFO] [1651305627.646930673, 214.126000000]: red_cylinder_30 has been spawned
[INFO] [1651305627.649352380, 214.126000000]: ApplyBodyWrench: reference_frame is empty/world/map, using inertial frame, transferring from body relative to inertial frame
[INFO] [1651305627.649877171, 214.126000000]: red_cylinder_30 speed initialized
[INFO] [1651305627.650006920, 214.126000000]:
[INFO] [1651305636.696484707, 221.126000000]: y position of new cylinder: 0.321766
[INFO] [1651305636.922570340, 221.288000000]: red_cylinder_31 has been spawned
[INFO] [1651305636.925361912, 221.290000000]: ApplyBodyWrench: reference_frame is empty/world/map, using inertial frame, transferring from body relative to inertial frame
[INFO] [1651305636.925747066, 221.291000000]: red_cylinder_31 speed initialized
[INFO] [1651305636.925806711, 221.291000000]:
[INFO] [1651305646.219096158, 228.291000000]: y position of new cylinder: -0.186667
[INFO] [1651305646.396967046, 228.417000000]: red_cylinder_32 has been spawned
[INFO] [1651305646.398646387, 228.418000000]: ApplyBodyWrench: reference_frame is empty/world/map, using inertial frame, transferring from body relative to inertial frame
[INFO] [1651305646.398802203, 228.418000000]: red_cylinder_32 speed initialized
[INFO] [1651305646.398847325, 228.418000000]:
[INFO] [1651305651.750860327, 232.191000000]:
[WARN] [1651305651.750912870, 232.191000000]: in the /cylinder_pool_claim service
[INFO] [1651305651.750933152, 232.191000000]: cylinder 29 claimed
[INFO] [1651305651.750952367, 232.191000000]:
[INFO] [1651305656.887019248, 235.418000000]: y position of new cylinder: -0.0998344
[INFO] [1651305657.096077699, 235.573000000]: red_cylinder_33 has been spawned
[INFO] [1651305657.098388069, 235.574000000]: ApplyBodyWrench: reference_frame is empty/world/map, using inertial frame, transferring from body relative to inertial frame
[INFO] [1651305657.098532587, 235.574000000]: red_cylinder_33 speed initialized
[INFO] [1651305657.098585485, 235.574000000]:
[INFO] [1651305666.396590755, 242.574000000]: y position of new cylinder: 0.0100283
[INFO] [1651305666.578541709, 242.699000000]: red_cylinder_34 has been spawned
[INFO] [1651305666.581452412, 242.700000000]: ApplyBodyWrench: reference_frame is empty/world/map, using inertial frame, transferring from body relative to inertial frame
[INFO] [1651305666.581914828, 242.700000000]: red_cylinder_34 speed initialized
[INFO] [1651305666.582012696, 242.700000000]:
[INFO] [1651305677.070842818, 249.702000000]: y position of new cylinder: 0.0252851
[INFO] [1651305677.276730969, 249.814000000]: blue_cylinder_35 has been spawned
[INFO] [1651305677.285594676, 249.816000000]: ApplyBodyWrench: reference_frame is empty/world/map, using inertial frame, transferring from body relative to inertial frame
[INFO] [1651305677.285996892, 249.816000000]: blue_cylinder_35 speed initialized
[INFO] [1651305677.286087924, 249.816000000]:
[INFO] [1651305688.393602246, 256.816000000]: y position of new cylinder: -0.0498899
[INFO] [1651305688.570029164, 256.935000000]: red_cylinder_36 has been spawned
[INFO] [1651305688.573175901, 256.937000000]: ApplyBodyWrench: reference_frame is empty/world/map, using inertial frame, transferring from body relative to inertial frame
[INFO] [1651305688.573738367, 256.937000000]: red_cylinder_36 speed initialized
[INFO] [1651305688.573818288, 256.937000000]:
[INFO] [1651305699.930849817, 263.937000000]: y position of new cylinder: 0.344648
[INFO] [1651305700.081280850, 264.008000000]: red_cylinder_37 has been spawned
[INFO] [1651305700.084586412, 264.010000000]: ApplyBodyWrench: reference_frame is empty/world/map, using inertial frame, transferring from body relative to inertial frame
[INFO] [1651305700.084731637, 264.010000000]: red_cylinder_37 speed initialized
[INFO] [1651305700.084799999, 264.010000000]:

Results



Activities
Terminal
Apr 30 13:31
tanyac@tanyac-Inspiron-15-3511: ~/cat_ws
[ERROR] [1651305507.104592295, 135.944000000]: program motion 2 start
[ERROR] [1651305515.156829658, 140.134000000]: program motion 3 start
[INFO] [1651305515.157046019, 140.134000000]: drop position: -0.892084, -1.07768
[INFO] [1651305515.157100318, 140.134000000]: drop joints: 0.3, 2
[ERROR] [1651305519.868790712, 142.642000000]: program motion 4 start
[INFO] [1651305519.868849766, 142.642000000]: stand by position: -0.0716927, -0.590546
[INFO] [1651305519.868872072, 142.642000000]: stand by joints: -0.78, 2.1
[ERROR] [1651305521.839162611, 143.687000000]: program motion 1 start
[INFO] [1651305528.627324501, 147.200000000]: cylinder claimed by right scara: 17
[INFO] [1651305528.670300236, 147.220000000]: right scara upper boundary updated in step 1
[ERROR] [1651305532.010965984, 149.312000000]: program motion 2 start
[ERROR] [1651305539.439175414, 153.498000000]: program motion 3 start
[INFO] [1651305539.439360138, 153.498000000]: drop position: -0.892084, -1.07768
[INFO] [1651305539.439412166, 153.498000000]: drop joints: 0.3, 2
[ERROR] [1651305543.705328766, 156.022000000]: program motion 4 start
[INFO] [1651305543.705457071, 156.022000000]: stand by position: -0.0716927, -0.590546
[INFO] [1651305543.705488578, 156.022000000]: stand by joints: -0.78, 2.1
[ERROR] [1651305545.698838497, 157.078000000]: program motion 1 start
[INFO] [1651305545.704196602, 157.079000000]: cylinder claimed by right scara: 18
[INFO] [1651305545.770868783, 157.100000000]: right scara upper boundary updated in step 1
[ERROR] [1651305552.087307424, 159.182000000]: program motion 2 start
[ERROR] [1651305561.432890335, 163.351000000]: program motion 3 start
[INFO] [1651305561.433270914, 163.351000000]: drop position: -0.892084, -1.07768
[INFO] [1651305561.433341776, 163.351000000]: drop joints: 0.3, 2
[ERROR] [1651305565.168066148, 165.880000000]: program motion 4 start
[INFO] [1651305565.168137080, 165.880000000]: stand by position: -0.0716927, -0.590546
[INFO] [1651305565.168171328, 165.880000000]: stand by joints: -0.78, 2.1
[ERROR] [1651305566.594336241, 166.900000000]: program motion 1 start
[INFO] [1651305568.842894618, 168.410000000]: cylinder claimed by right scara: 20
[INFO] [1651305568.854221201, 168.420000000]: right scara upper boundary updated in step 1
[ERROR] [1651305571.339210668, 170.475000000]: program motion 2 start
[ERROR] [1651305576.440746881, 174.553000000]: program motion 3 start
[INFO] [1651305576.440913815, 174.553000000]: drop position: -0.892084, -1.07768
[INFO] [1651305576.440958013, 174.553000000]: drop joints: 0.3, 2
[ERROR] [1651305579.665459161, 177.061000000]: program motion 4 start
[INFO] [1651305579.665525778, 177.061000000]: stand by position: -0.0716927, -0.590546
[INFO] [1651305579.665544092, 177.061000000]: stand by joints: -0.78, 2.1
[ERROR] [1651305580.813835378, 178.096000000]: program motion 1 start
[INFO] [1651305580.817869434, 178.100000000]: cylinder claimed by right scara: 21
[INFO] [1651305580.839808912, 178.120000000]: right scara upper boundary updated in step 1
[ERROR] [1651305583.345238534, 180.153000000]: program motion 2 start
[ERROR] [1651305588.071628082, 184.206000000]: program motion 3 start
[INFO] [1651305588.071687090, 184.206000000]: drop position: -0.892084, -1.07768
[INFO] [1651305588.071710699, 184.206000000]: drop joints: 0.3, 2
[ERROR] [1651305591.190535521, 186.720000000]: program motion 4 start
[INFO] [1651305591.190613260, 186.720000000]: stand by position: -0.0716927, -0.590546
[INFO] [1651305591.190638289, 186.720000000]: stand by joints: -0.78, 2.1
[ERROR] [1651305592.478295484, 187.741000000]: program motion 1 start
[INFO] [1651305594.782485050, 189.750000000]: cylinder claimed by right scara: 23
[INFO] [1651305594.795407721, 189.760000000]: right scara upper boundary updated in step 1
[ERROR] [1651305597.236690323, 191.789000000]: program motion 2 start
[ERROR] [1651305602.380032821, 195.878000000]: program motion 3 start
[INFO] [1651305602.380185033, 195.878000000]: drop position: -0.892084, -1.07768



Activities
Terminal
Apr 30
tanyac@tanyac-Inspiron-15-3511: ~/cat_ws
[ERROR] [1651305324.160577233, 2.011000000]: program motion 1 start
[INFO] [1651305355.124161901, 27.044000000]: cylinder claimed by left scara: 0
[INFO] [1651305355.145490128, 27.060000000]: left scara upper boundary updated in step 1
[ERROR] [1651305358.140939188, 29.217000000]: program motion 2 start
[ERROR] [1651305366.049180815, 33.450000000]: program motion 3 start
[INFO] [1651305366.049406389, 33.450000000]: drop position: -1.02617, 1.02729
[INFO] [1651305366.049448062, 33.450000000]: drop joints: -1.9, 1.8
[ERROR] [1651305370.484204606, 36.001000000]: program motion 4 start
[INFO] [1651305370.484423667, 36.001000000]: stand by position: 0.0716927, 0.590546
[INFO] [1651305370.484520417, 36.001000000]: stand by joints: -0.78, 2.1
[ERROR] [1651305372.370583160, 37.070000000]: program motion 1 start
[INFO] [1651305378.696832492, 41.080000000]: cylinder claimed by left scara: 2
[INFO] [1651305378.745625161, 41.102000000]: left scara upper boundary updated in step 1
[ERROR] [1651305382.191228433, 43.235000000]: program motion 2 start
[ERROR] [1651305389.170963272, 47.480000000]: program motion 3 start
[INFO] [1651305389.171081142, 47.480000000]: drop position: -1.02617, 1.02729
[INFO] [1651305389.171126313, 47.480000000]: drop joints: -1.9, 1.8
[ERROR] [1651305393.120343724, 50.041000000]: program motion 4 start
[INFO] [1651305393.120429678, 50.041000000]: stand by position: 0.0716927, 0.590546
[INFO] [1651305393.120451173, 50.041000000]: stand by joints: -0.78, 2.1
[ERROR] [1651305394.560713756, 51.091000000]: program motion 1 start
[INFO] [1651305418.358600825, 69.120000000]: cylinder claimed by left scara: 6
[INFO] [1651305418.381321730, 69.140000000]: left scara upper boundary updated in step 1
[ERROR] [1651305420.576750507, 71.207000000]: program motion 2 start
[ERROR] [1651305424.901886255, 75.308000000]: program motion 3 start
[INFO] [1651305424.902172231, 75.308000000]: drop position: 0.892084, 1.07768
[INFO] [1651305424.902223581, 75.308000000]: drop joints: 0.3, 2
[ERROR] [1651305427.532400785, 77.821000000]: program motion 4 start
[INFO] [1651305427.532522911, 77.822000000]: stand by position: 0.0716927, 0.590546
[INFO] [1651305427.532554621, 77.822000000]: stand by joints: -0.78, 2.1
[ERROR] [1651305428.581707685, 78.843000000]: program motion 1 start
[INFO] [1651305428.589794196, 78.851000000]: cylinder claimed by left scara: 7
[INFO] [1651305428.599939972, 78.860000000]: left scara upper boundary updated in step 1
[ERROR] [1651305430.882850518, 80.922000000]: program motion 2 start
[ERROR] [1651305435.273044925, 85.015000000]: program motion 3 start
[INFO] [1651305435.273196661, 85.015000000]: drop position: 0.892084, 1.07768
[INFO] [1651305435.273252910, 85.015000000]: drop joints: 0.3, 2
[ERROR] [1651305437.982978643, 87.520000000]: program motion 4 start
[INFO] [1651305437.983174545, 87.520000000]: stand by position: 0.0716927, 0.590546
[INFO] [1651305437.983204436, 87.520000000]: stand by joints: -0.78, 2.1
[ERROR] [1651305439.079915192, 88.543000000]: program motion 1 start
[INFO] [1651305486.588529133, 126.060000000]: cylinder claimed by left scara: 14
[INFO] [1651305486.637116057, 126.080000000]: left scara upper boundary updated in step 1
[ERROR] [1651305490.793807668, 128.166000000]: program motion 2 start
[ERROR] [1651305499.613230587, 132.322000000]: program motion 3 start
[INFO] [1651305499.613438676, 132.322000000]: drop position: -1.02617, 1.02729
[INFO] [1651305499.613502113, 132.322000000]: drop joints: -1.9, 1.8
[ERROR] [1651305504.957119352, 134.860000000]: program motion 4 start
[INFO] [1651305504.957338386, 134.860000000]: stand by position: 0.0716927, 0.590546
[INFO] [1651305504.957391688, 134.860000000]: stand by joints: -0.78, 2.1
[ERROR] [1651305507.023895811, 135.891000000]: program motion 1 start
[INFO] [1651305514.707553920, 139.900000000]: cylinder claimed by left scara: 16

NOVELTY

- For collision avoidance we can use a simplified algorithm that can dynamically allocate each robot's workspace.
  - Obstacle boundary search algorithm

THANK YOU