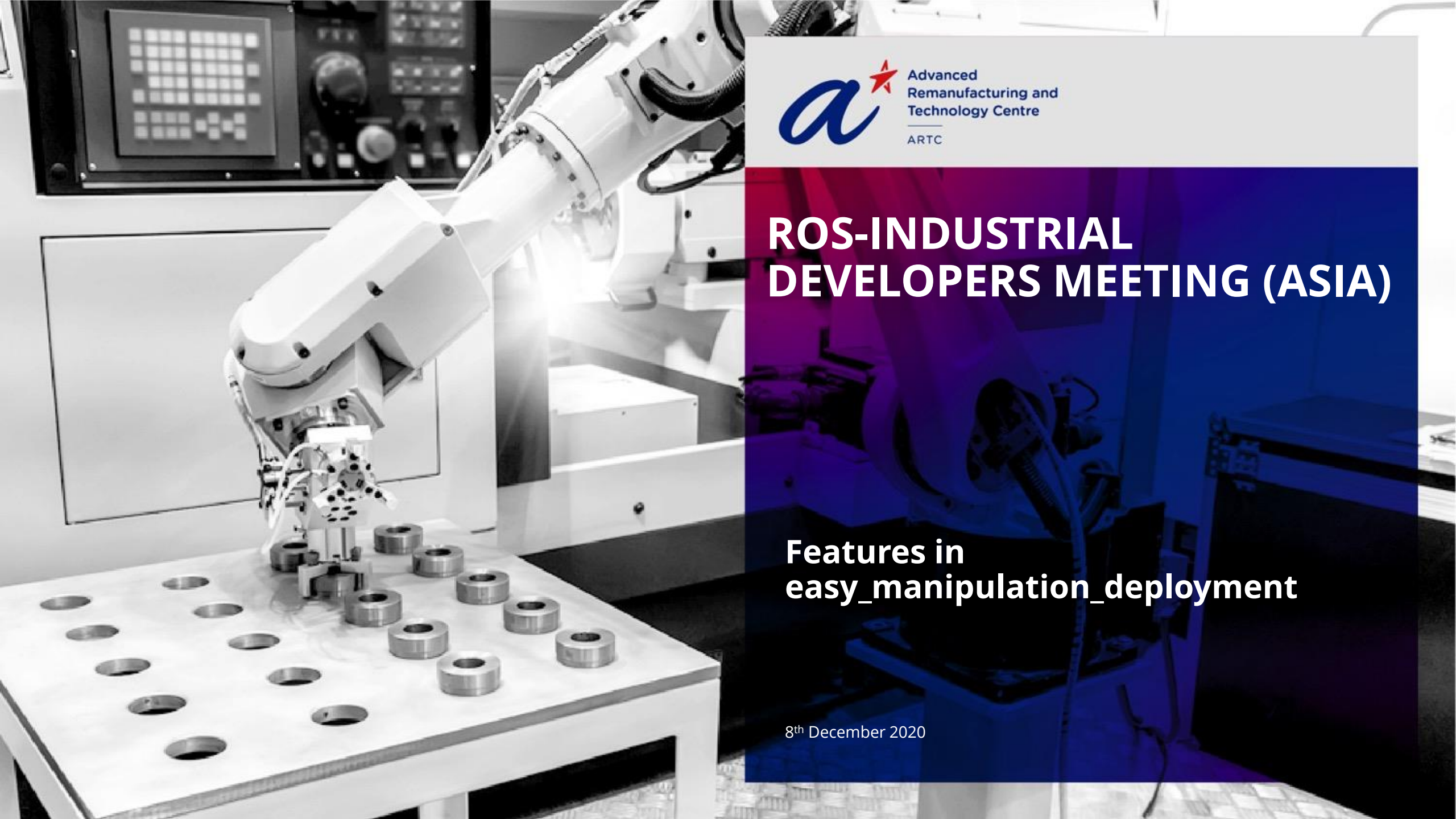


Advanced Remanufacturing and Technology Centre

ARTC

ROS-INDUSTRIAL DEVELOPERS MEETING (ASIA)

Features in easy_manipulation_deployment

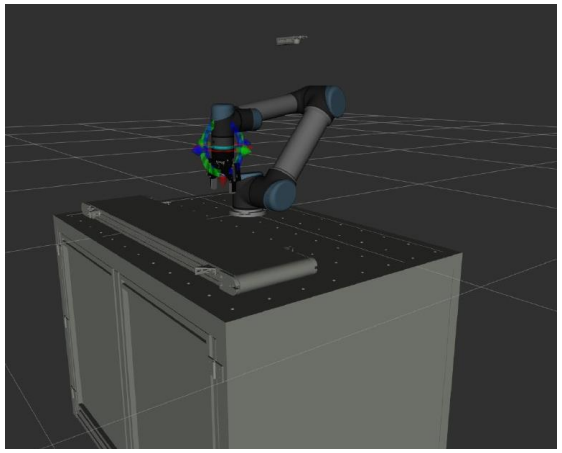
8th December 2020

easy_manipulation_deployment

An easy to use ROS2 manipulation package that uses the easy_perception_deployment output to provide a **modular** and **configurable** manipulation pipeline for pick and place tasks

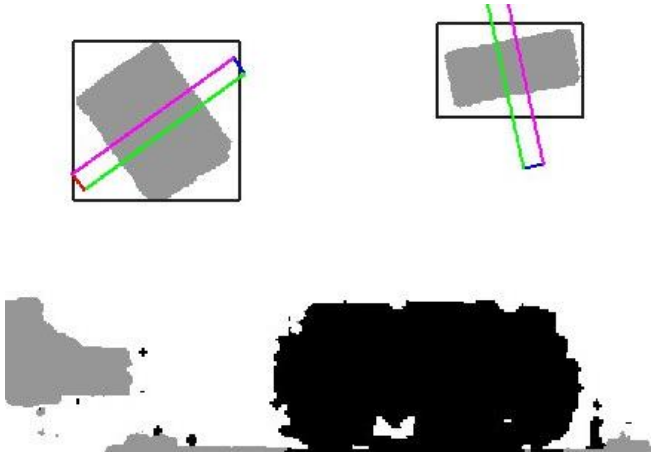
Easy_manipulation_deployment

Manipulation pipeline



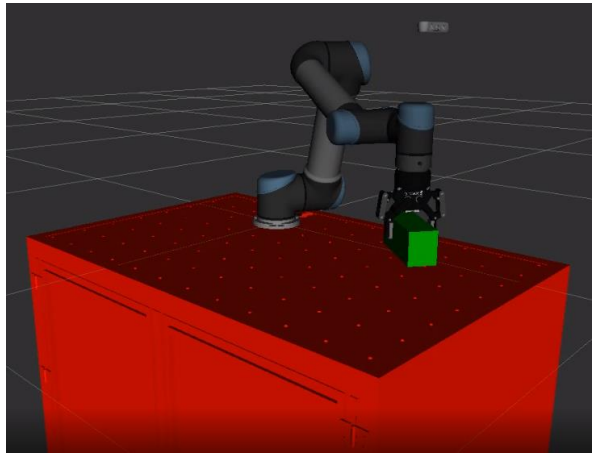
Workcell builder

Quick and Intuitive GUI for users to create a representation of the elements in a workcell



Grasp Planner

Modular and Flexible Grasp Planner that generates a (3+1) DOF End Effector specific Pose from the easy_perception deployment output



Grasp Execution

Robust Path planning process to navigate robot to the object for grasp

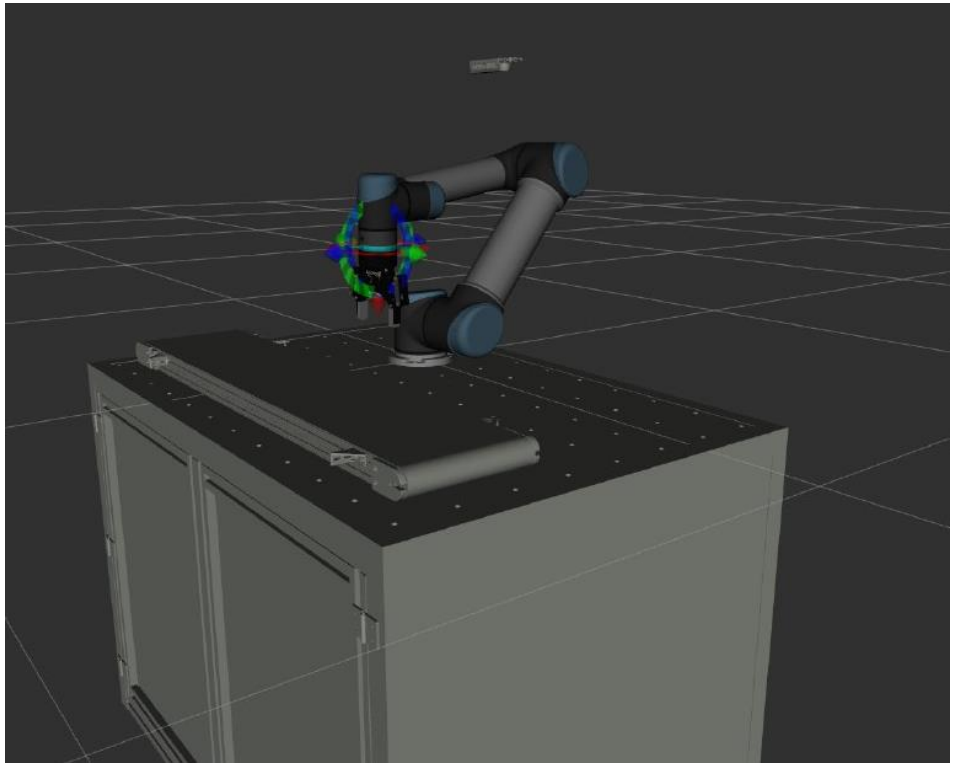
Workcell Builder

Workcell Builder

Rationale

Problem Statement:

For new users to ROS and to robotic workcell generation, it is **knowledge and time intensive** to generate the required files to prepare an environment that represents a workcell for robot manipulation

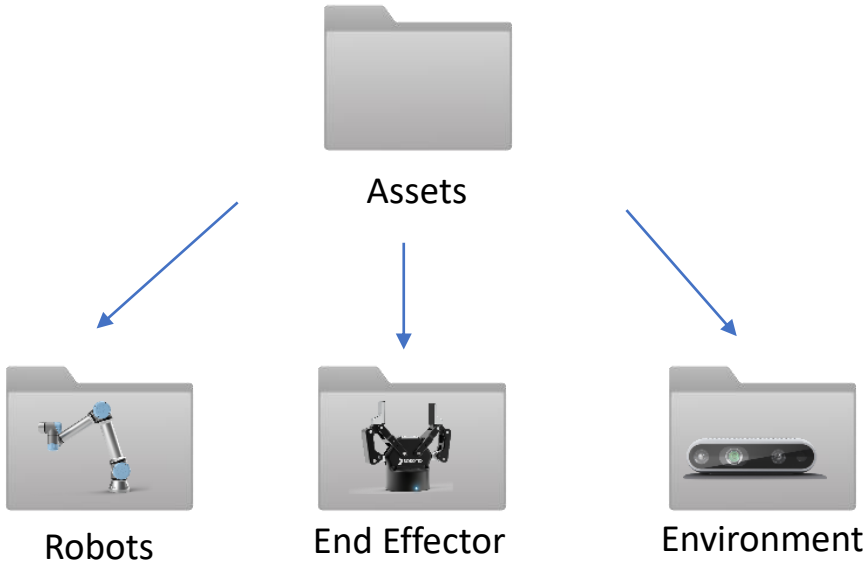


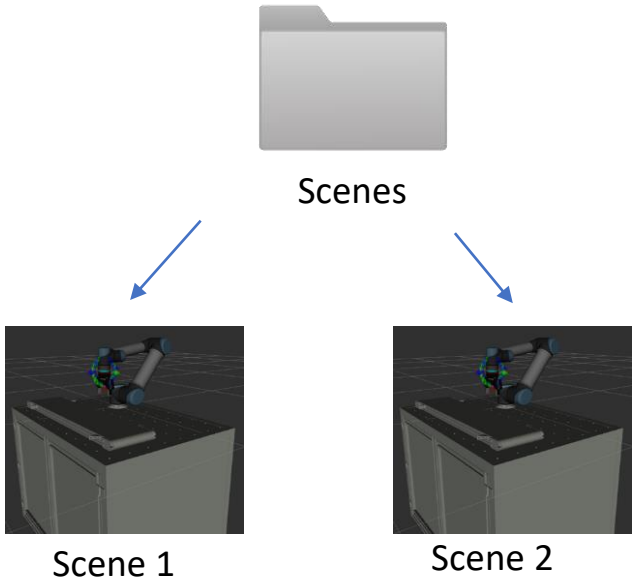
Solution:

A **simple to use Graphical User Interface** that allows the user to determine and create objects required in a robotic workcell, which generates a file that provides an easy to understand representation of the workspace. Relevant files and folders will then be generated and organized to provide an immediate simulation model for path planning.

Workcell Builder

Standardization





Folder structures

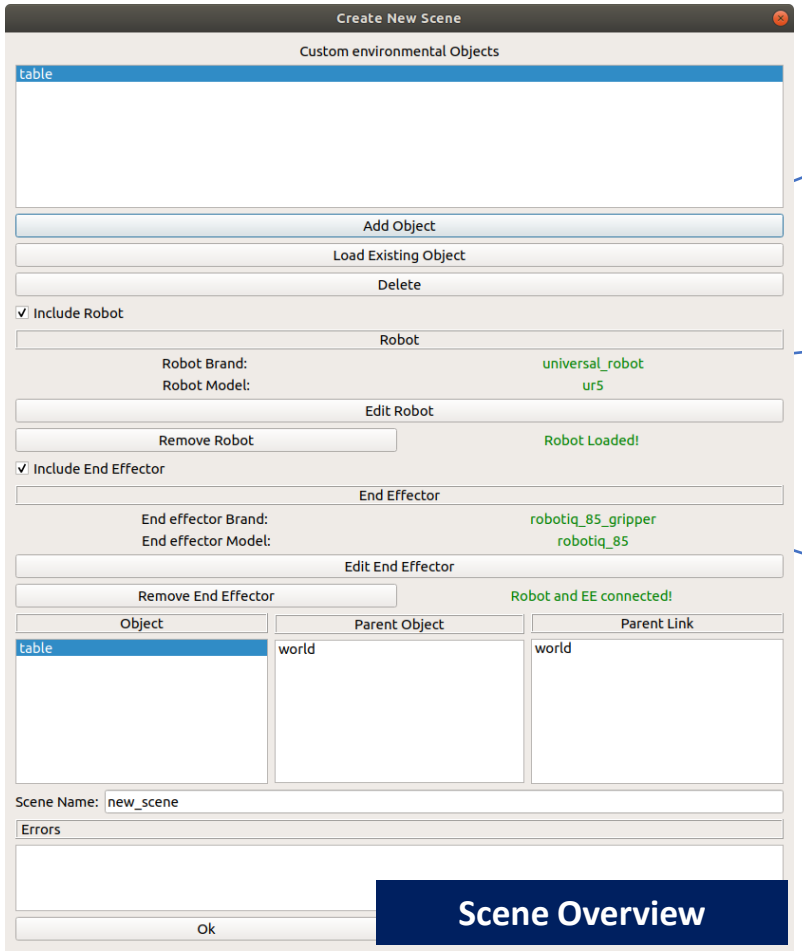
- Folder standardization has been determined to ensure:
  - Clear delineation between user's custom generated folders and pre downloaded asset packages
  - Clear segmentation of types of assets to increase user understanding and easier folder navigation

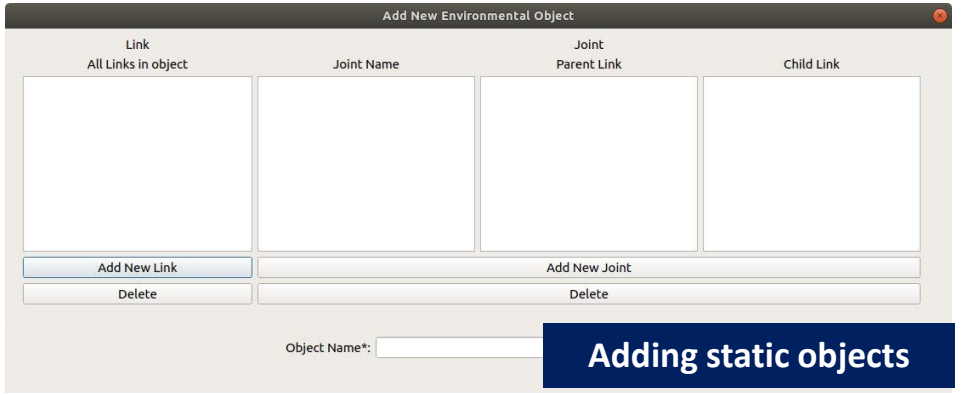
Naming Convention

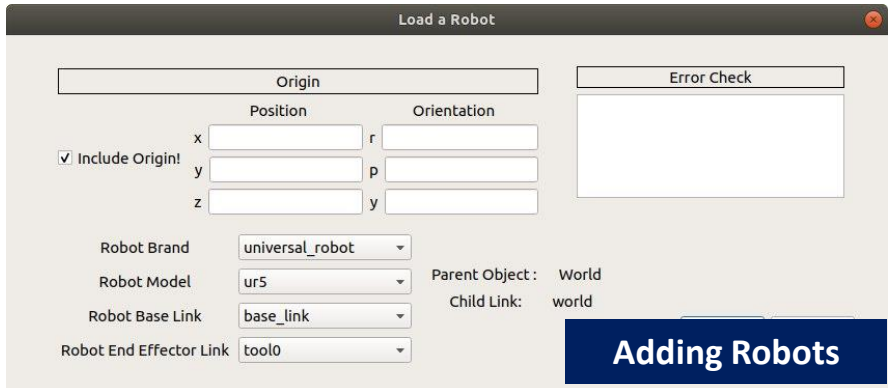
- Naming convention has been established for:
  - End Effector description and moveit configuration folder
  - Robot description and moveit configuration folder
  - URDF and SRDF files

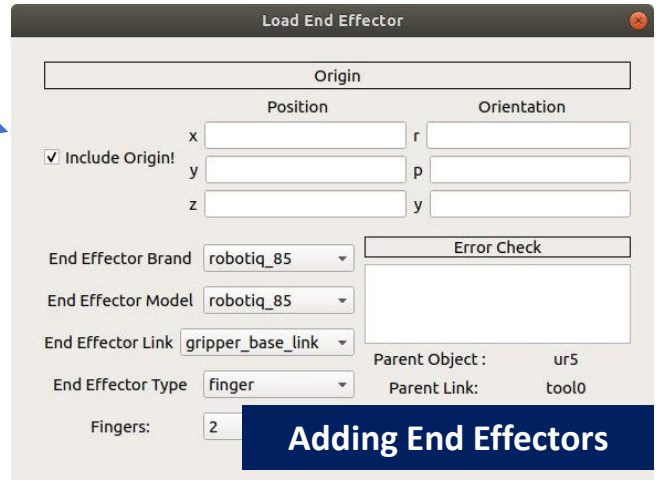
Workcell Builder

Scene building



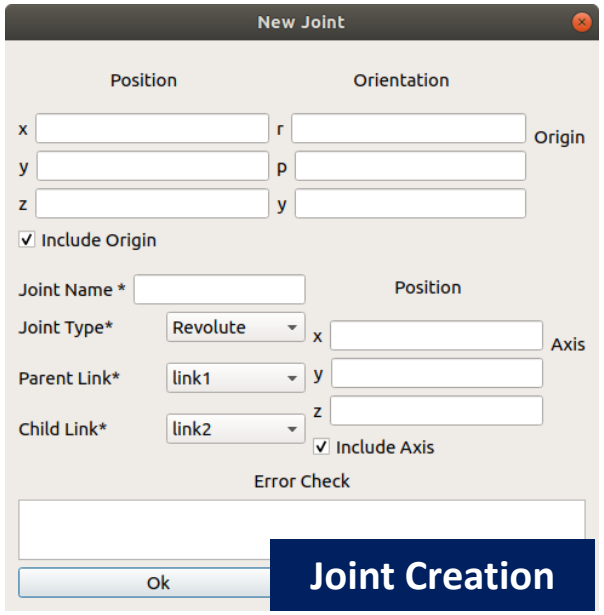


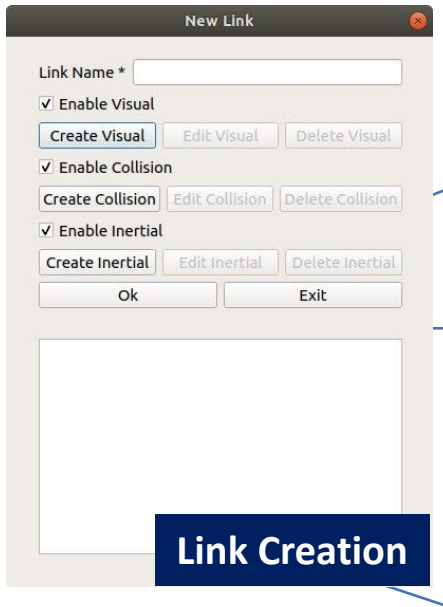


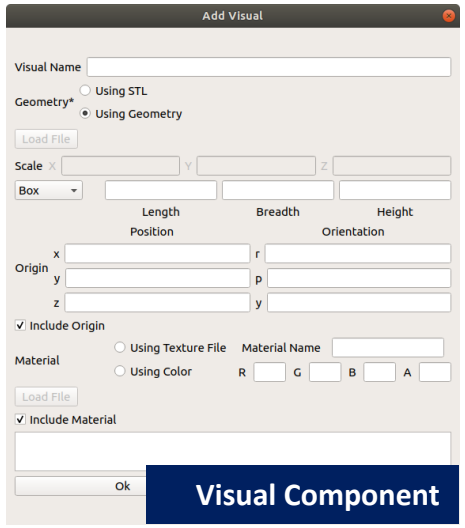


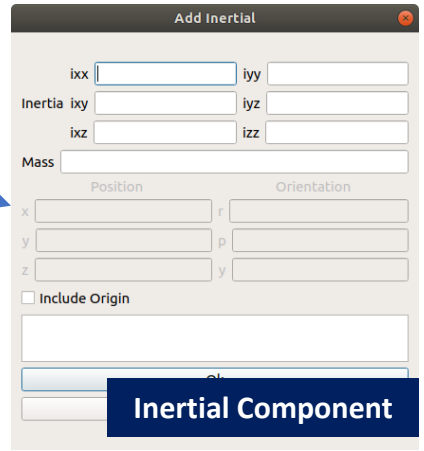
Workcell Builder

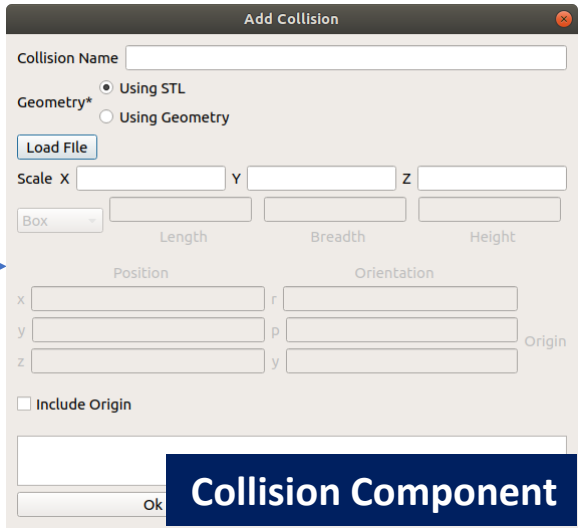
Static object building











Workcell Builder

YAML files

Robot

```yaml
robot:
  name: ur5
  origin:
    x: 0
    y: 0
    z: 0
    roll: 0
    pitch: 0
    yaw: 0
  links:
    - base_link
    - shoulder_link
    - upper_arm_link
    - forearm_link
    - wrist_1_link
    - wrist_2_link
    - wrist_3_link
    - ee_link
    - base
    - tool0
```

End effector

```yaml
end_effector:
  name: robotiq_85
  origin:
    x: 0
    y: 0
    z: 0
    roll: 0
    pitch: 0
    yaw: 0
  links:
    - gripper_base_link
    - gripper_finger1_knuckle_link
    - gripper_finger2_knuckle_link
    - gripper_finger1_finger_link
    - gripper_finger2_finger_link
    - gripper_finger1_inner_knuckle
    - gripper_finger2_inner_knuckle
    - gripper_finger1_finger_tip_li
    - gripper_finger2_finger_tip_li
```

Environment Objects

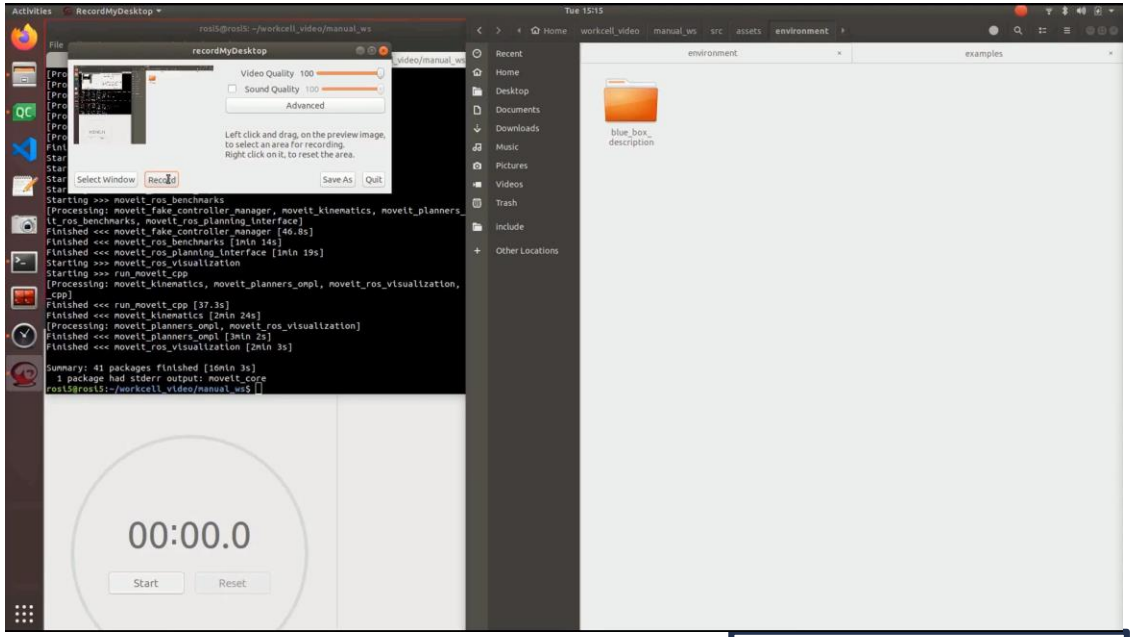
```yaml
objects:
  table:
    links:
      table:
        visual:
          name: None
          geometry:
            filepath: /home/rosi5/rect
            scale:
              scale_x: 0.00100000005
              scale_y: 0.00100000005
              scale_z: 0.00100000005
          material:
            name: aluminum
            r: 0.550000012
            g: 0.560000002
            b: 0.529999971
            a: 1
        collision:
          name: None
          geometry:
            shape: Box
            length: 2
            breadth: 2
            height: 0.00999999978
```

External Joints

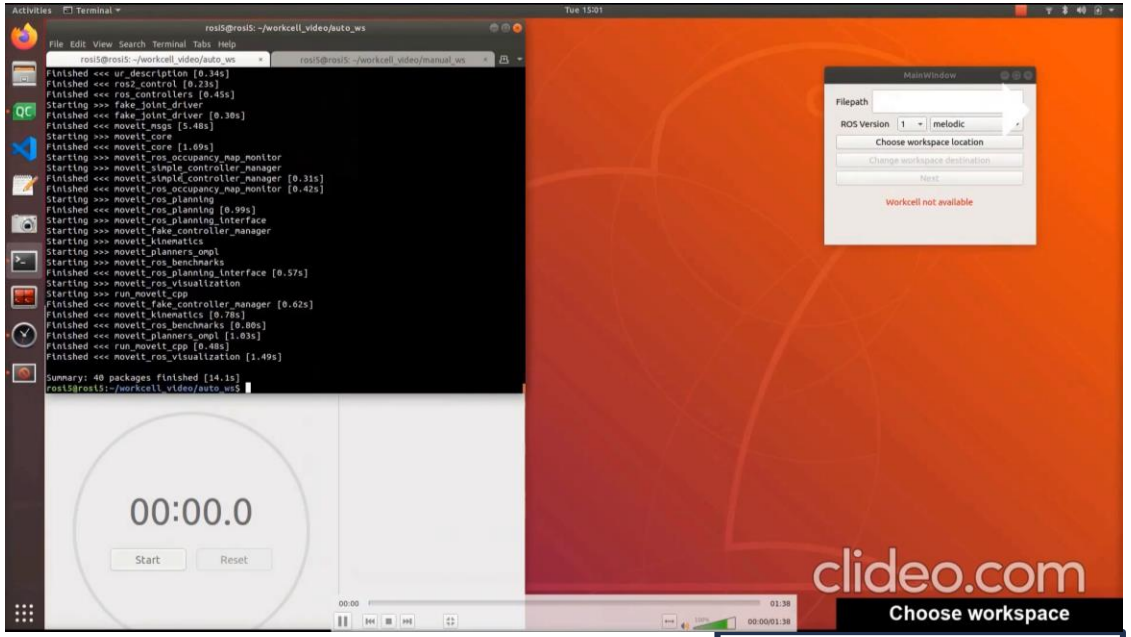
```yaml
external joints:
  robot_to_table:
    type: fixed
    parent: base_link
    child: table
    origin:
      x: 0
      y: 0
      z: 0
      roll: 0
      pitch: 0
      yaw: 0
```

Workcell Builder

Benchmarking



Without Workcell Builder



With Workcell Builder

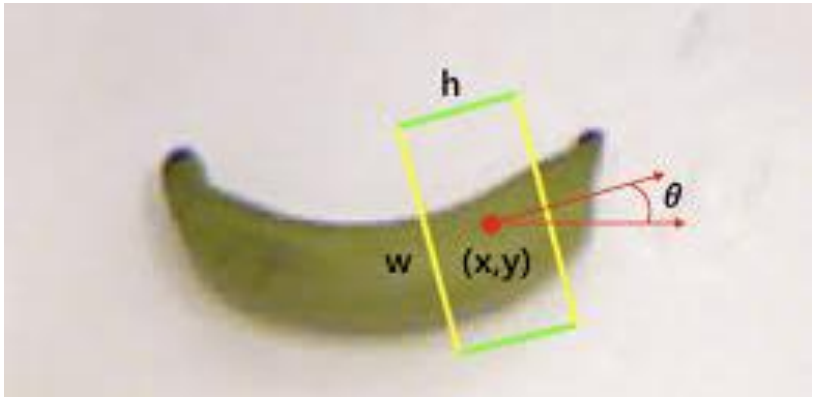
Benchmarking of workcell building process between using the Workcell Builder (**1:36**) and without (**19:51**) shows the potential time reduction and the reduction of knowledge gap faced by users

Grasp Planner

Grasp Planner

Rationale

Most grasp planners are Machine Learning based, which means that **a completely different training dataset is needed if a specific end effector is required**, leading to difficulties in implementing new models for new grippers.



Solution:

An **Algorithmic, depth based grasp planner** that uses depth values to generate valid grasp poses, accounting for finger collision and stability (Assuming objects with center of mass at the object centroid)

A **flexible representation of an end effector** to allow for extension of capabilities to other end effectors with minimal effort needed from the user

Grasp Planner

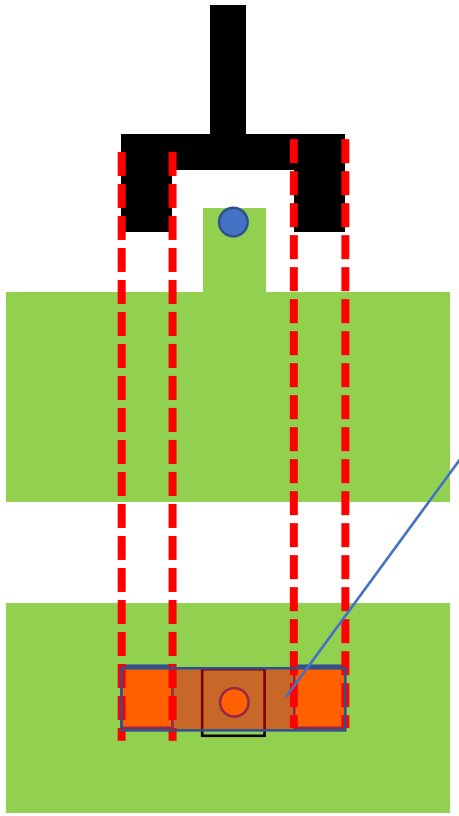
User Configuration

```yaml
end_effector:
  type: finger
  attributes:
    fingers: 2
    distance_between_fingers: 250
    longest_gripper_dim: 40
    table_height: 570
parameters:
  min_zero_angle: 0.01
  min_height_diff_to_grip: 5
  min_gdi_diff_for_comparison: 5
```

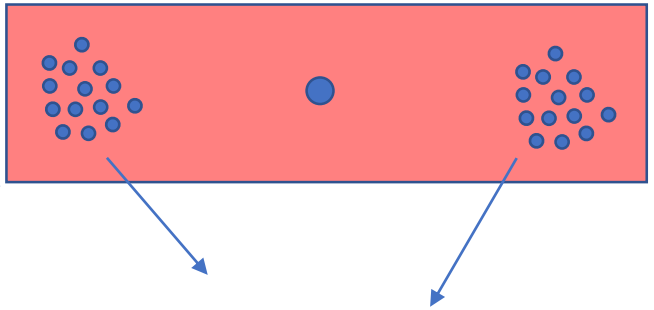
- Easy to understand configuration file for users to customize the parameters to their specific end effector

Grasp Planner

Algorithm – Finger collision avoidance

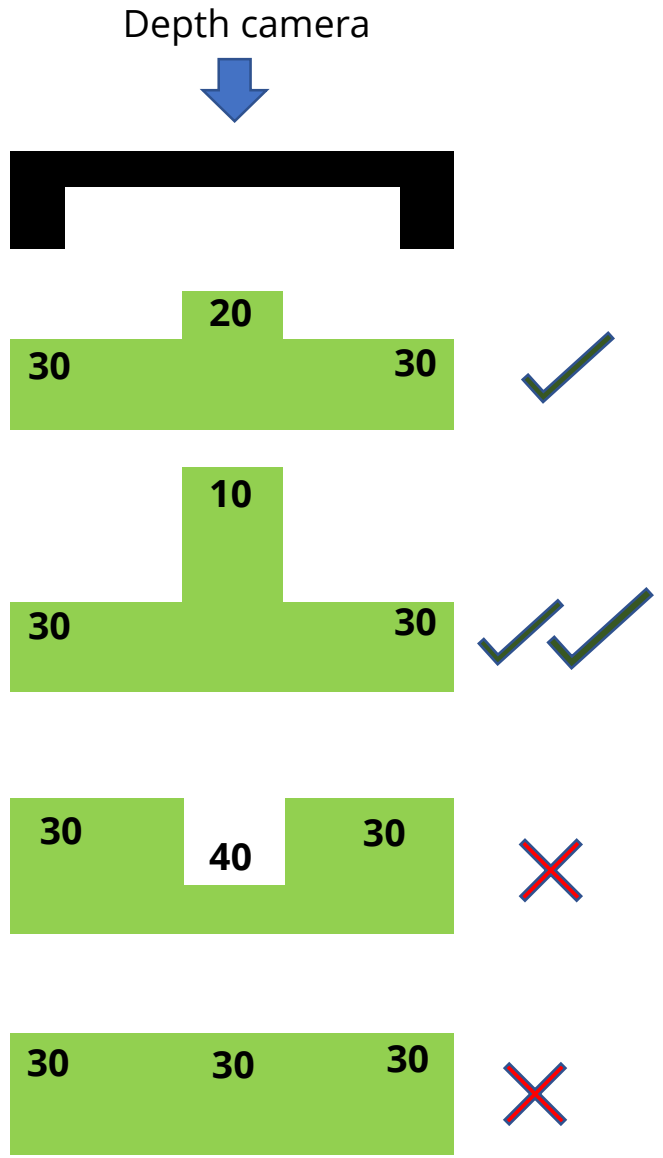


Grasp option



Depth values are sampled from the sides of the grasp option, and compared to the centre depths. **Grasp finger collision is minimized if the centre depth value is significantly lower than the sides**

The **more points** that satisfy this condition, and if the **difference is greater**, the greater the quality of grasp.

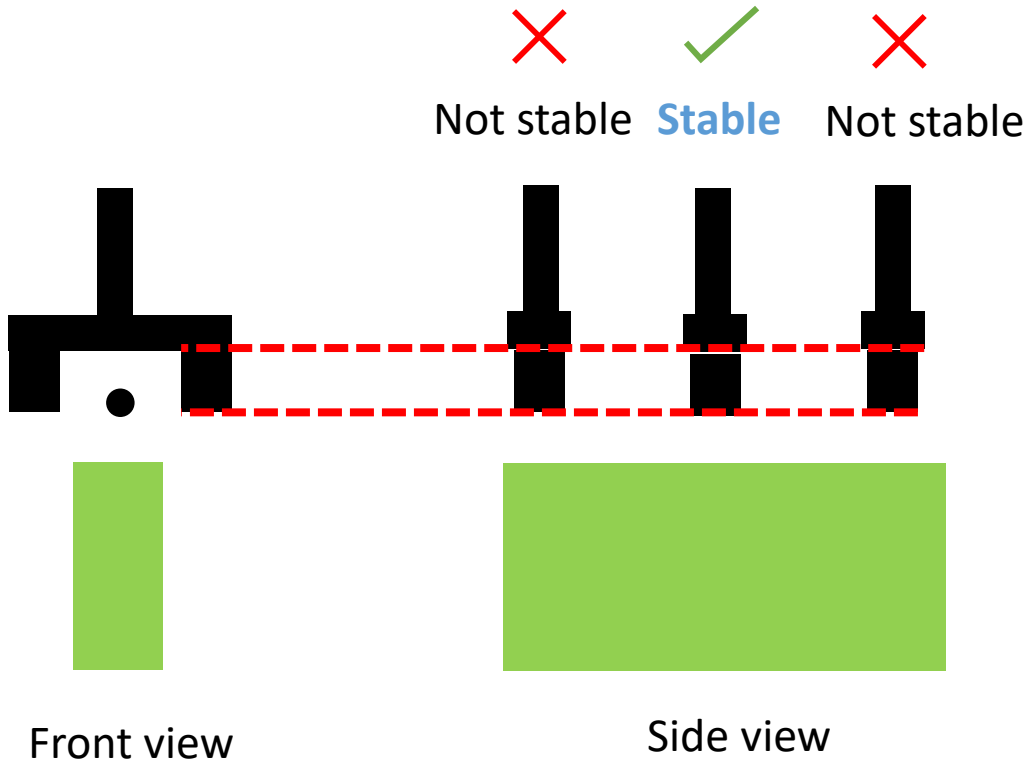


Grasp Planner

Algorithm – Grasp stability

Current assumption that the Centre of Gravity is at the centroid of the object, so we also **value grasps closer to the centroid IF the first condition of graspability is satisfied**

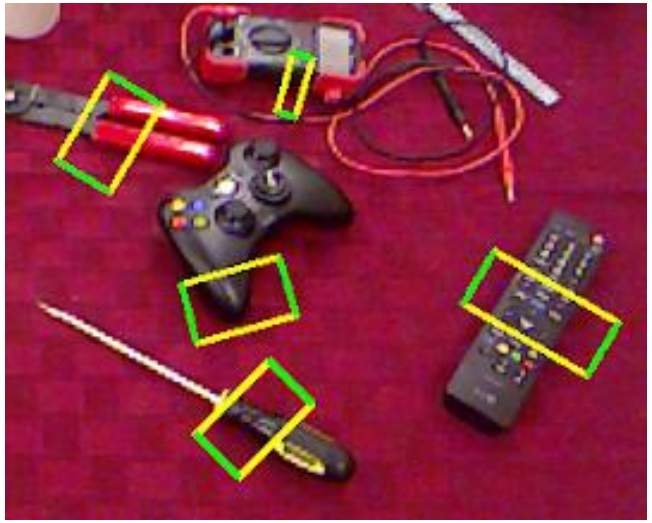
This additional condition allows for faster computation of grasp samples, and increased stability for regular objects



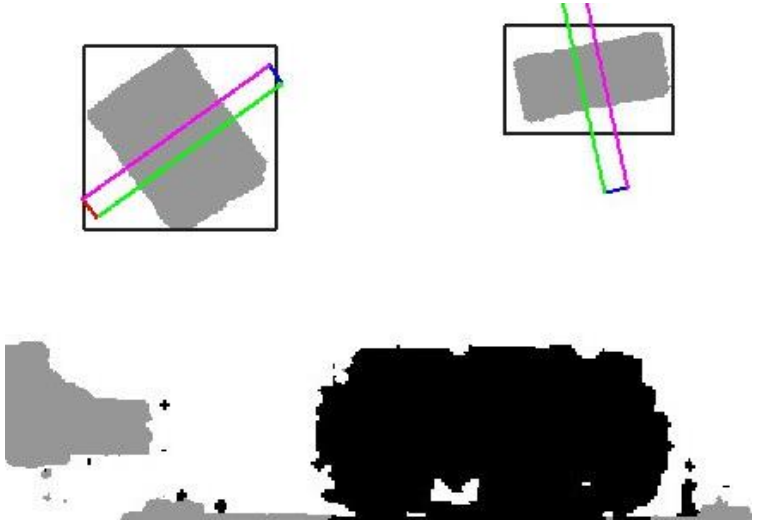
Grasp Planner

Results

Current implementation of grasp planner shows that it is possible to have a **non Machine Learning** based, **unsupervised learning grasp planner** to find **grasp poses for novel objects**



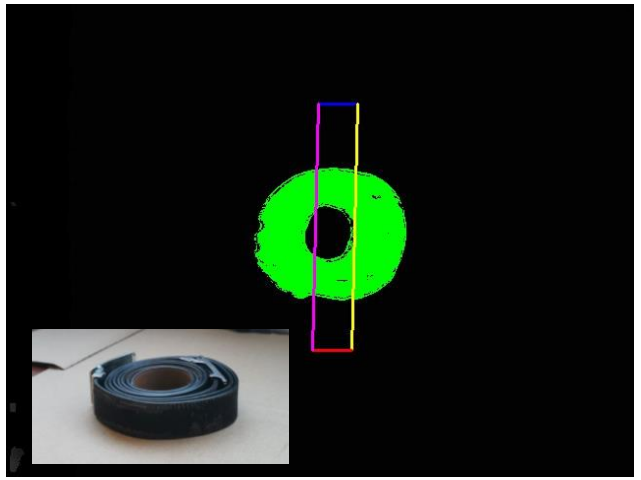
Cornell Grasping dataset output. **Requires training of Neural Network with object specific dataset to get high accuracy of grasp**

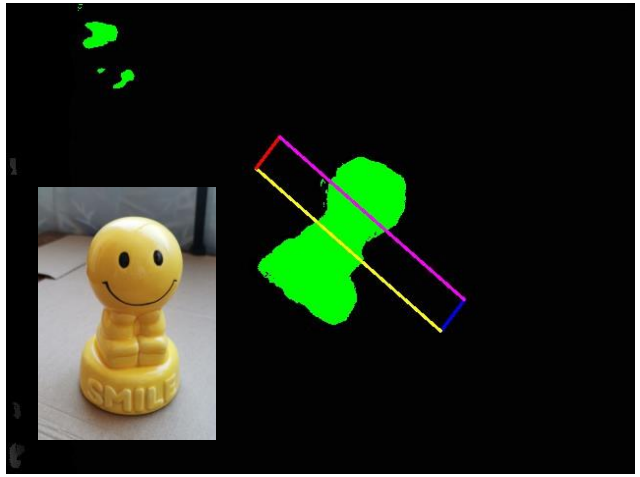


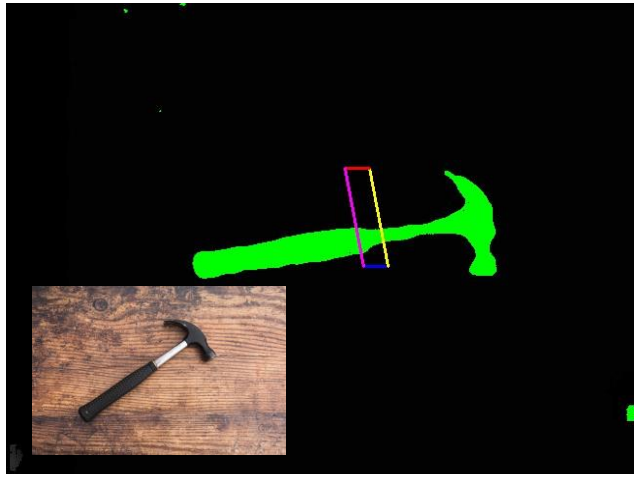
Work Package output, done with depth based grasp pose planning **without need for training.**

Grasp Planner

Further testing



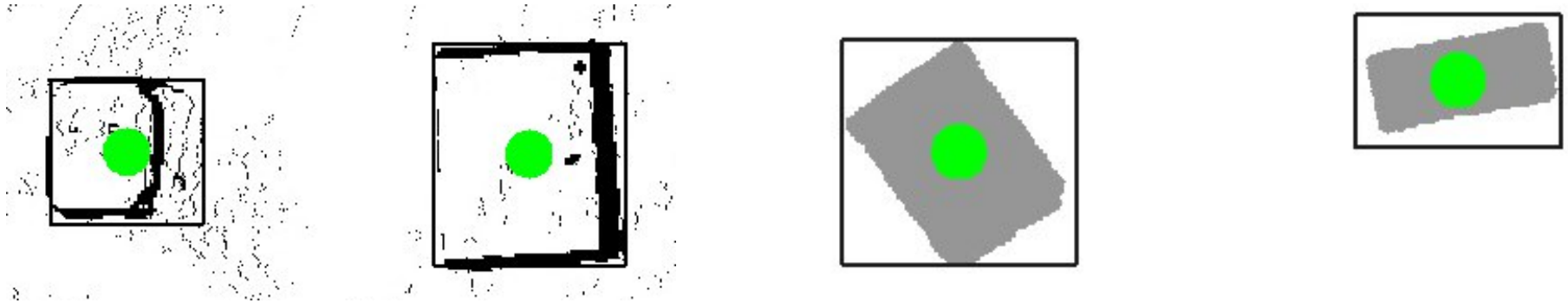




Grasp Planner

Multi-gripper support

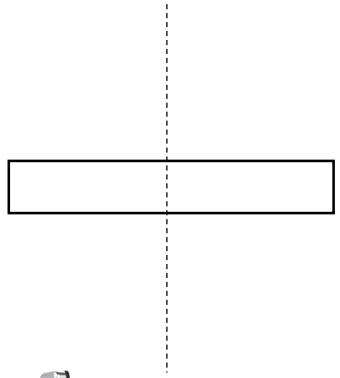
Support for suction type grippers has been added, but current functionalities only include **single cup grippers**.



Average grasp planning time: **0.25s**

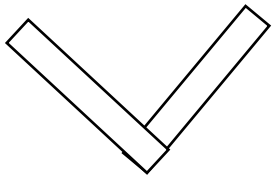
Grasp Planner

Extrapolation of fingered end effectors

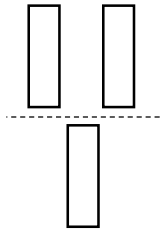


2 Finger Gripper

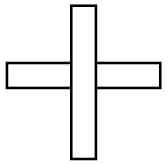
Spherical Mode

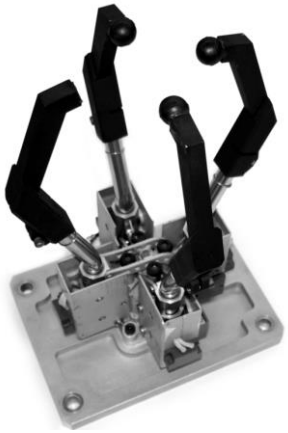


Cylindrical Mode



3 Finger Gripper



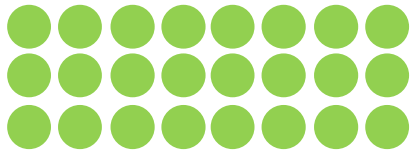


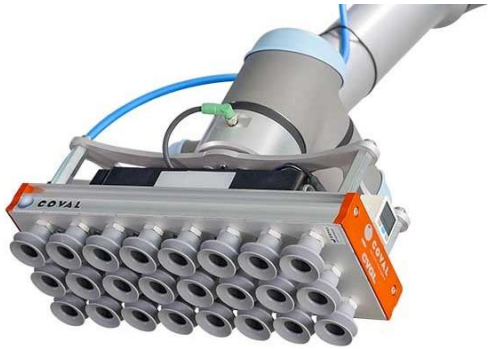
4 Finger Gripper

Grasp Planner

Extrapolation of suction end effectors

Single suction cup





Suction Cup array

Irregular suction cup array

Grasp Planner

Benchmarking

- Current grasp planning solution was run on CPU (i7-7700HQ, 4 cores) using a single thread, thus in terms of processing power there is **still significant opportunity for further improvement** in detection speeds by harnessing GPU and running multi-thread processes. Current results however, already indicate the **low hardware specifications needed for the package, which is a common problem for Machine Learning methods**
- Actual improvement in grasp times vary depending on the size of object and the profile of the object.

Solution	End Effector Supported	Grasp Planning times (s)	Training needed?
Grasp Pose Detection (GPD)	2 Finger Gripper	2.1	Yes
Superquadratic Grasping	5 Finger Gripper	1.78	Yes
ROS-I Grasp Planner	**2 Finger Gripper** **Single Suction Gripper**	**~0.42** **~0.25**	**No**
GQ-STN	2 Finger Gripper	0.024	Yes

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