ROS-Industrial Consortium Asia Pacific Updates and Industrial Grade Easy Robotic Vision and Manipulation Highlights

Presenters:

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The Advanced Remanufacturing Technology Centre (ARTC)

Leading Public-Private Partnership Research Centre in Asia

- Bridging the gap between Research and Industry
- Focus in Developing Advanced Manufacturing and Remanufacturing Capabilities
- Co-Create and Value Capture with Industry through the Implementation of Solutions
ARTC was created for a step change model to drive in Public Private Partnership for translational R&D with industry.
Focused Technical Projects (FTPs)
Focused Technical Projects – Driving Members’ Needs

Focused Technical Projects (FTP) Motivation:
• Addressing common Member needs in the spirit of co-development, creating new ROS-based platform technology and enablers (pre-competitive)
• Lower the required investment via cost sharing between members
• Solutions developed will be contributed back to the Open Source community (either directly, or after 2 year competitive advantage), which helps to:
  1) Allow Members to steer direction of de-facto standardization of ROS (components, robots, interfacing et c)
  2) Accelerates organic growth of ROS platform development – enables faster creation of further Open Source capabilities made by others that can now be leveraged back by Members free of charge to create future solutions
  3) Enables specific ROS platform components to achieve industry-grade quality faster, required for adoption

FTP Roadmaps Generation:
• Elicit common problem statements and needs from Members to facilitate FTP roadmap creation
• Craft out workstreams of further FTP projects for co-development between members

Technological areas and members co-development interest facilitate FTP roadmapping
Motivation / Objective

Motivation: Take the success of Robotic Middleware Framework (RMF) developed for Healthcare to address additional areas and move towards a solution that is ready to be commercialized for manufacturing industry. By deploying platform technologies with industry partners, fully autonomous operations using robots that work seamlessly together with scalable and flexible solutions are made possible.

Objective:
– Expending RMF with generic sensor interfacing
– Enhancing capabilities in RMF for manufacturing/warehousing use cases with simulation demonstration
– Physical testbedding of RMF for Members access and interoperability testing

Status:
– Target to launch in mid of 2021
ROS 2 Training Update
A 3-day training workshop was curated and delivered to ROS-I AP consortium members on ROS 2 basics and the applications of EPD and EMD. This training workshop will be open to public in 3rd quarter of 2021.

- Conducted ROS 2 basics, EPD & EMD training for 13 participants from 7 companies, provided participants with in depth technical explanation of the working principles for each of the packages.

- Created a valuable opportunity to acquire feedback on features which our members faced in deploying their robotic solutions.

- Participants identified potential use cases include mobile manipulators, depalletizing and easy pick and place configuration set up.

**Easy_Perception_Depolyment**
Object detection, classification, tracking and accurate positioning module.

**Easy_Manipulation_Depolyment**
Flexible and fast grasping library for multiple types of end effectors with integrated collision avoidance capability.
Easy Perception Deployment
Easy Perception Deployment

A ROS2 package that accelerates the **training** and **deployment** of custom-trained Computer Vision model for industries.

https://github.com/ros-industrial/easy_perception_deployment
What is EPD - Features

- **Permissively Licensed** and Open Source.

- **Reduces time** needed in training and deploying robotic vision systems by use of **transfer-learning**.

- Reduces knowledge barrier with the use of **GUI** to guide users. Targeted at **users with no programming background**.

- Relies on **open-standard ONNX AI models**. Removes overreliance on any one given Machine Learning library (Eg. Tensorflow, PyTorch, MXNet).

Image courtesy of icons8.com and onnx.com
What is EPD?

Model Training

.jpgs/.pngs Image Dataset of custom objects.

.txt Class Labels List

.onnx trained AI model

Model Deployment

.onnx trained AI model

.txt Class Labels List

A ROS2 package that runs inference using the model and classifies images provided by a video stream from a camera.
Built-In Use Case Configurations

EPD runs a deep-learning model as a ROS2 inference engine.

It outputs the following object information in the form of custom ROS2 messages that caters to common Computer Vision demands.

1. What is the object? (Object Classification)
2. Where is the object? (Object Localization)
EPD can be configured to run at **3 different Precision Levels**.

<table>
<thead>
<tr>
<th>Precision Level</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Model</strong>: squeezeNet</td>
<td>Determines presence and identity of objects in the scene,</td>
</tr>
<tr>
<td></td>
<td><strong>Label List</strong>: Imagenet</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Classes</strong></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><strong>Model</strong>: FasterRCNN</td>
<td>Determines presence and identity of objects in the scene, as well as</td>
</tr>
<tr>
<td></td>
<td><strong>Label List</strong>: CoCo</td>
<td>the bounding boxes around the identified object</td>
</tr>
<tr>
<td></td>
<td><strong>Dataset classes</strong></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td><strong>Model</strong>: maskRCNN</td>
<td>Determines presence and identity of objects in the scene, as well as</td>
</tr>
<tr>
<td></td>
<td><strong>Label List</strong>: CoCo</td>
<td>the bounding boxes around the identified object as well as the</td>
</tr>
<tr>
<td></td>
<td><strong>Dataset classes</strong></td>
<td>segmented masks of the scene</td>
</tr>
</tbody>
</table>
Tested for Industrial Use

**EPD Configuration:** ROS2 Foxy, Precision Level 3, Object Localization, operating at 2 FPS

**Use Case Description:** Industrial Conveyor Tracking and Automated Picking.
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

[https://github.com/ros-industrial/easy_manipulation_deployment](https://github.com/ros-industrial/easy_manipulation_deployment)
Easy Manipulation Deployment Features

**Workcell Builder**
Quick and Intuitive GUI for users to create a representation of the elements in a pick and place workcell

**Grasp Planner**
Modular and Flexible Grasp Planner that generates an end effector specific pose from the from a perception output

**Grasp Execution**
Robust Path planning process to navigate robot to the object for grasp, accounting for dynamic safety
Problem Statement:
For new users to ROS and to robotic workcell generation, it is **knowledge and time intensive** to generate the required files (URDFs, description packages) 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.
EMD Grasp Planner

Problem Statement:
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 point cloud information to generate valid grasp poses, accounting for finger collision and stability (Assuming objects with centre 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

Images referenced from:
https://www.researchgate.net/figure/On-Cornell-Grasping-Dataset-each-object-has-multiple-labelled-grasps-These-grasps-are_fig5_300409289
https://jacquard.liris.cnrs.fr/
EMD Grasp Planner – Flexibility on the Fly

EMD Grasp Planner – Ease of Configuration

Easy to understand configuration file that is highly customizable depending on the task provided

Currently supports finger and suction cup end effectors

```
end_effectors:
  end_effector_names: [robotiq_2f]

robotiq_2f:
  type: finger
  num_fingers_side_1: 4
  num_fingers_side_2: 6
  distance_between_fingers_1: 0.06
  distance_between_fingers_2: 0.05
  finger_thickness: 0.01
  gripper_stroke: 0.15
  grasp_planning_params:
    grasp_plane_dist_limit: 0.007
    voxel_size: 0.01
    grasp_rank_weight_1: 1.5
    grasp_rank_weight_2: 1.0
    world_x_angle_threshold: 0.5
    world_y_angle_threshold: 0.5
    world_z_angle_threshold: 0.25

end_effectors:
  end_effector_names: [suction_cup]

suction_cup:
  type: suction
  num_cups_length: 2
  num_cups_breadth: 2
  dist_between_cups_length: 0.06
  dist_between_cups_breadth: 0.03
  cup_radius: 0.01
  cup_height: 0.01
  grasp_planning_params:
    num_sample_along_axis: 3
    search_resolution: 0.01
    search_angle_resolution: 4
    weights:
      curvature: 1.0
      grasp_distance_to_center: 1.0
      number_contact_points: 1.0
```
EMD Grasp Execution – Dynamic Collision Checking

**Movelt2**

**Update Arm1 / Arm2 joint states**

Update the robot joint transforms within the scene (planning_scene: PlanningScene) where all collisions are stored.

After the update, collision checker will use the latest poses from the scene.

**Prediction**

Based on the current joint states of the Arm2, predict where it will be after one collision checking cycle. The register both the current and the future collision to the scene (planning_scene: PlanningScene) before collision checking.

**Check Safety Zone**

Check Arm1 robot trajectory collision with the environment and Arm2. This will decide whether emergency stop, slow-down-stop-and-replan or dynamically replan.

**Next Point / Local Planner**

Send the next command to the robot. It could be position or velocity command based on robot’s hardware interface.

In the future, this part can also be a local planner with other algorithm to leverage different control interface like force control or more robust control interface.
EMD Grasp Execution – Dynamic Safety Zones

Blind Zone
Collision detected even before the collision check is complete. **Robot will be stopped immediately**

Trajectory timeline

Current robot state

Emergency Zone
Collision detected but not enough time to slow down and stop safely. **Robot will be stopped immediately**

Slow down and Re-plan zone
Collision detected but re-planning is possible. **Robot trajectory will slow down, and re-planning occurs**

Dynamic Re-plan Zone
Collision detected, re-planning is possible, and robot is not required to slow down. **Robot Trajectory will continue as intended, while re-planning occurs simultaneously.**
EMD Grasp Execution – Dynamic Safety Zones

Slow Down and Re-planning

Re-planning after initial re-plan fails

Smooth Dynamic Replanning

Blind Zone

Emergency Zone

Slow down and Re-plan zone

Dynamic Re-plan Zone
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Thank you!