Industrial Manufacturing Automation Leveraging ROS

Agenda

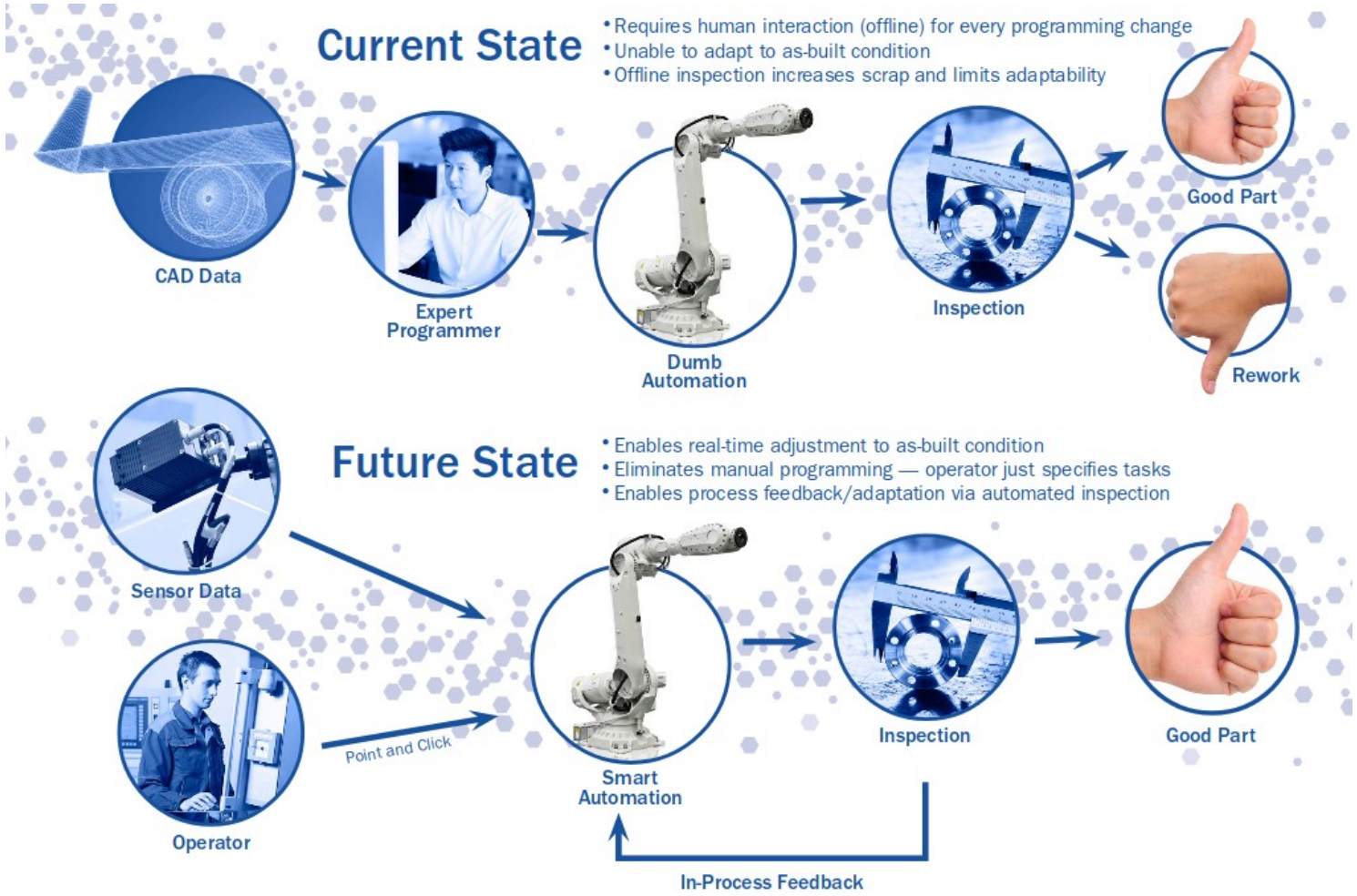
- Scan-N-Plan Evolution
  - Blending M1 – M4
  - Blending M4 (Demo)
  - Production System
- Production System
  - Overview
  - Challenges
  - Solutions
- Technology Leveraged
- Example Workcell
- Active Research

SwRI®

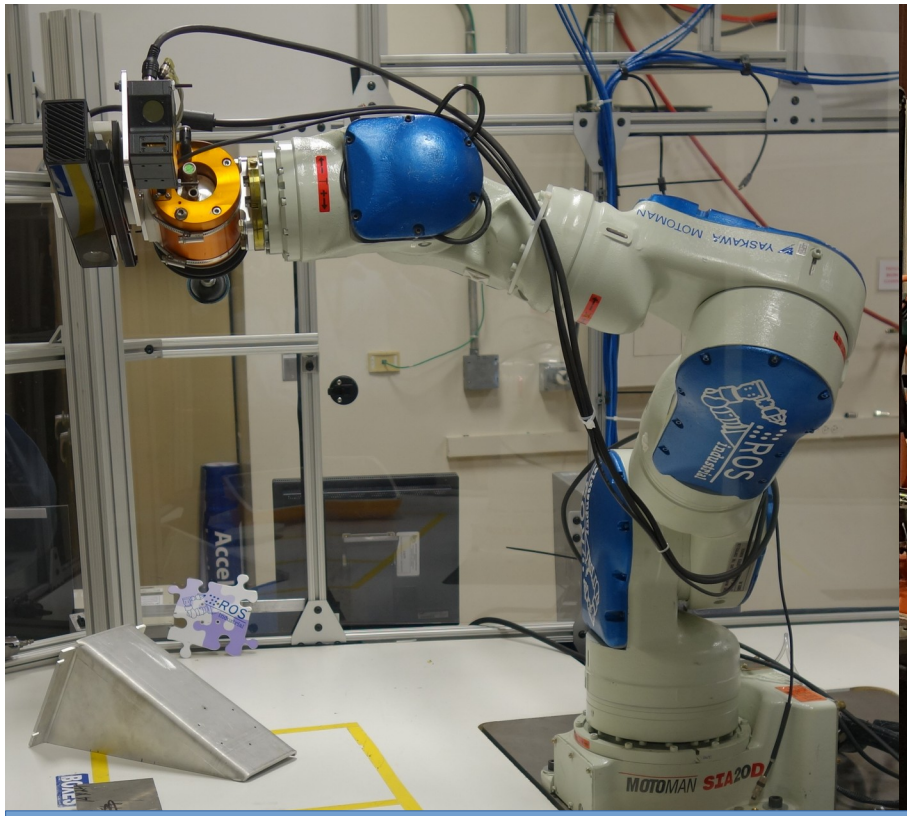
SOUTHWEST RESEARCH INSTITUTE

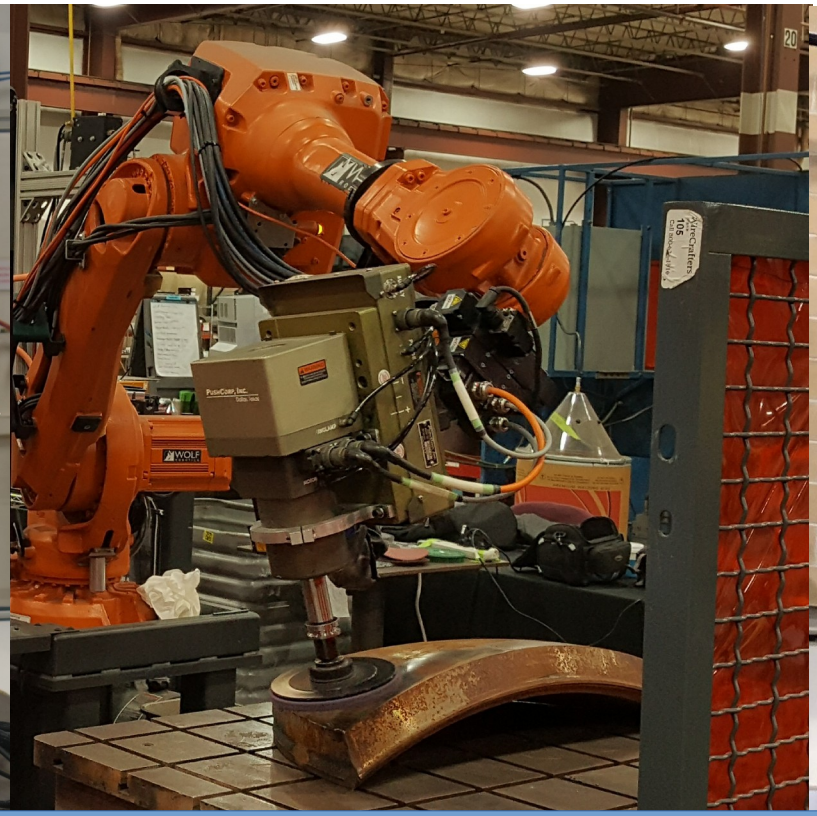
ROS® industrial

Scan-N-Plan


Current State
• Requires human interaction (offline) for every programming change
• Unable to adapt to as-built condition
• Offline inspection increases scrap and limits adaptability
CAD Data
Expert Programmer
Dumb Automation
Inspection
Good Part
Rework
Future State
• Enables real-time adjustment to as-built condition
• Eliminates manual programming — operator just specifies tasks
• Enables process feedback/adaptation via automated inspection
Sensor Data
Operator
Point and Click
Smart Automation
Inspection
Good Part
In-Process Feedback

Evolution





2014 → 2016 → 2019

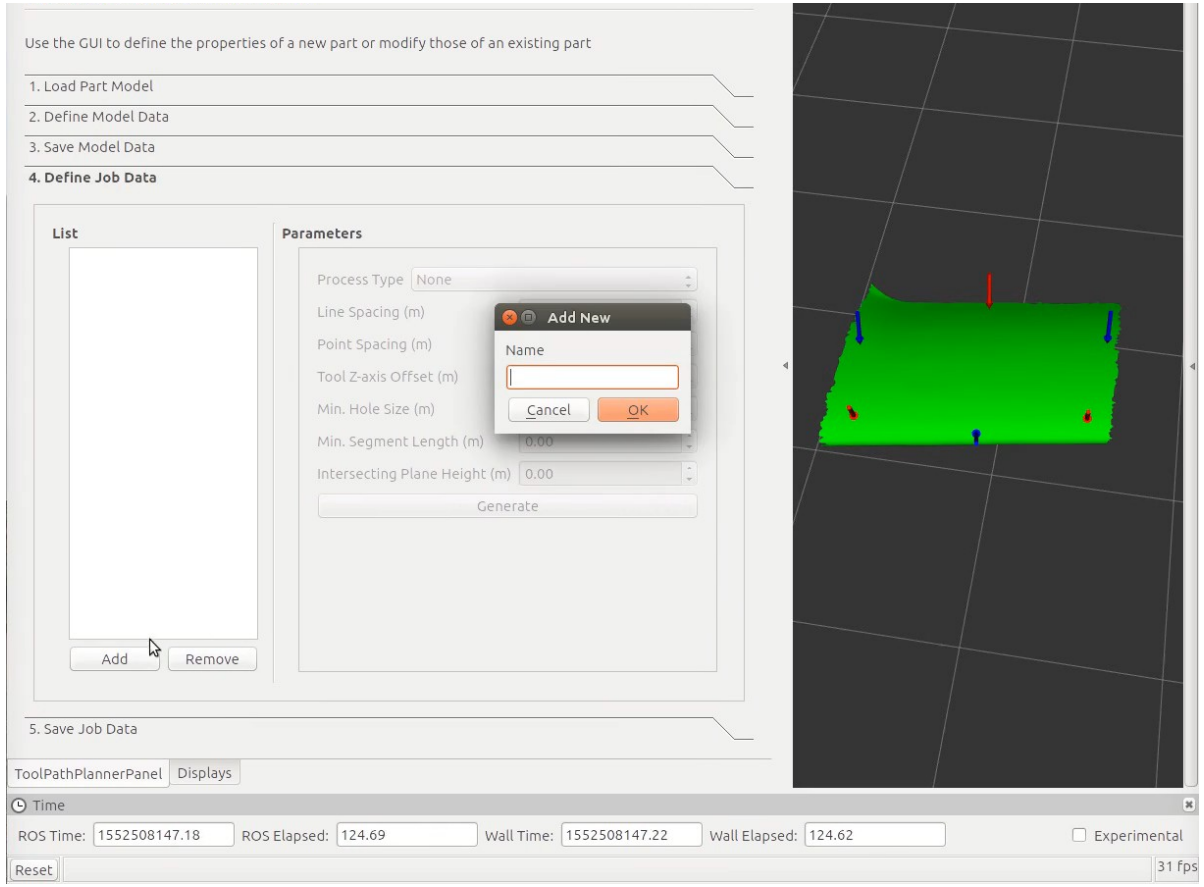
Production Systems

Production Systems

- Two axis gantry with 6DOF manipulator.
- Size: 6m x 4m
- Joint Effort with Integrator
  - Integrator design and built the system
  - SwRI developed the Scan-N-Plan solution
    - Offline
    - Online

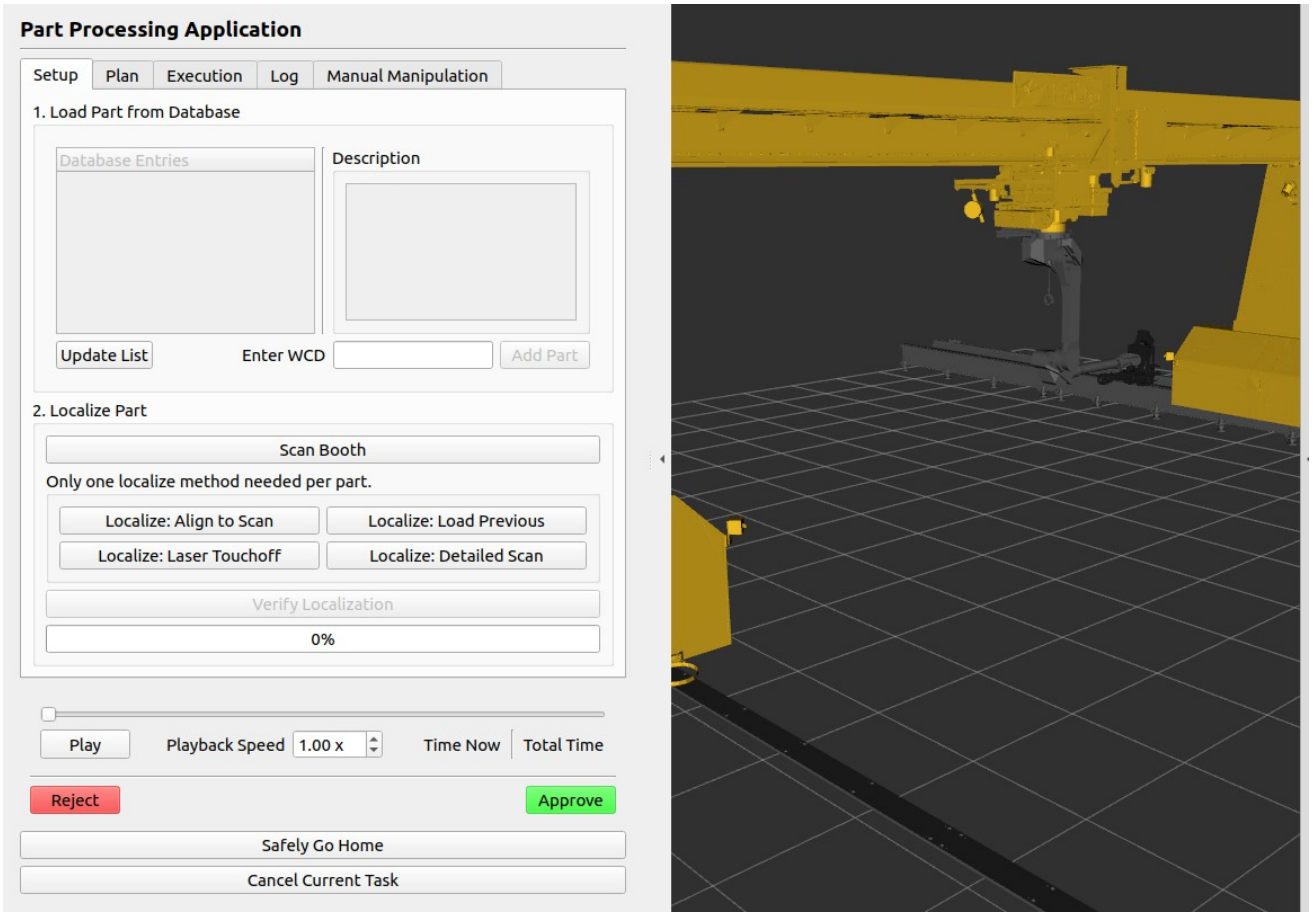
Production System Offline Component

- Add new parts
- Define model data
  - Localization features
  - Verification features
  - Save to database
- Define job data
  - Dynamically generate
    - Surface Tool Path
    - Edge Tool path
  - Save to database
- Ability to reload part and modify data



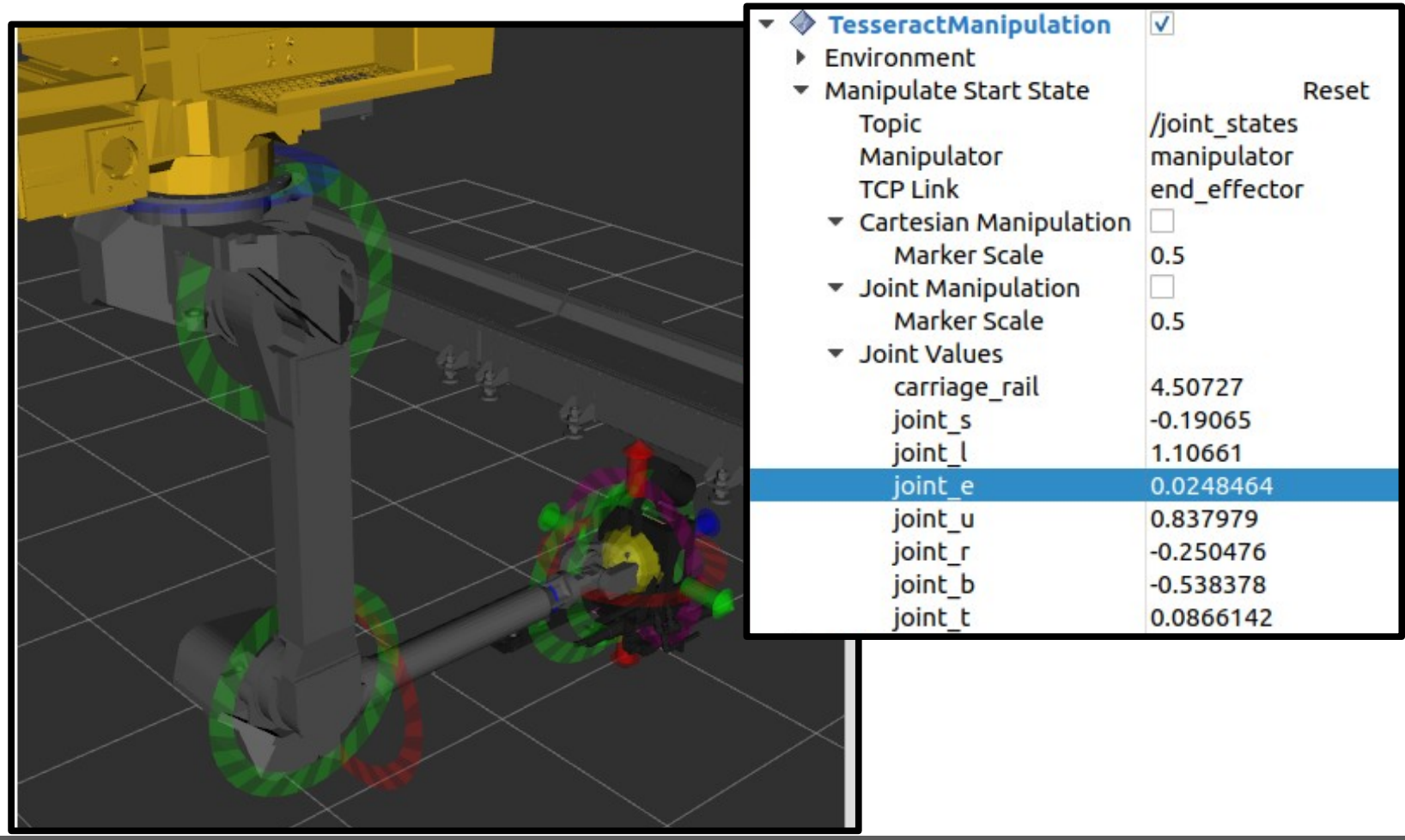
Production System Online Component

- Process
  - Select parts from database
  - Scan booth
  - Localize
  - Detailed Scan
  - Motion Planning
  - Preview and Approval
  - Execution
- Logging
- Manual Manipulation



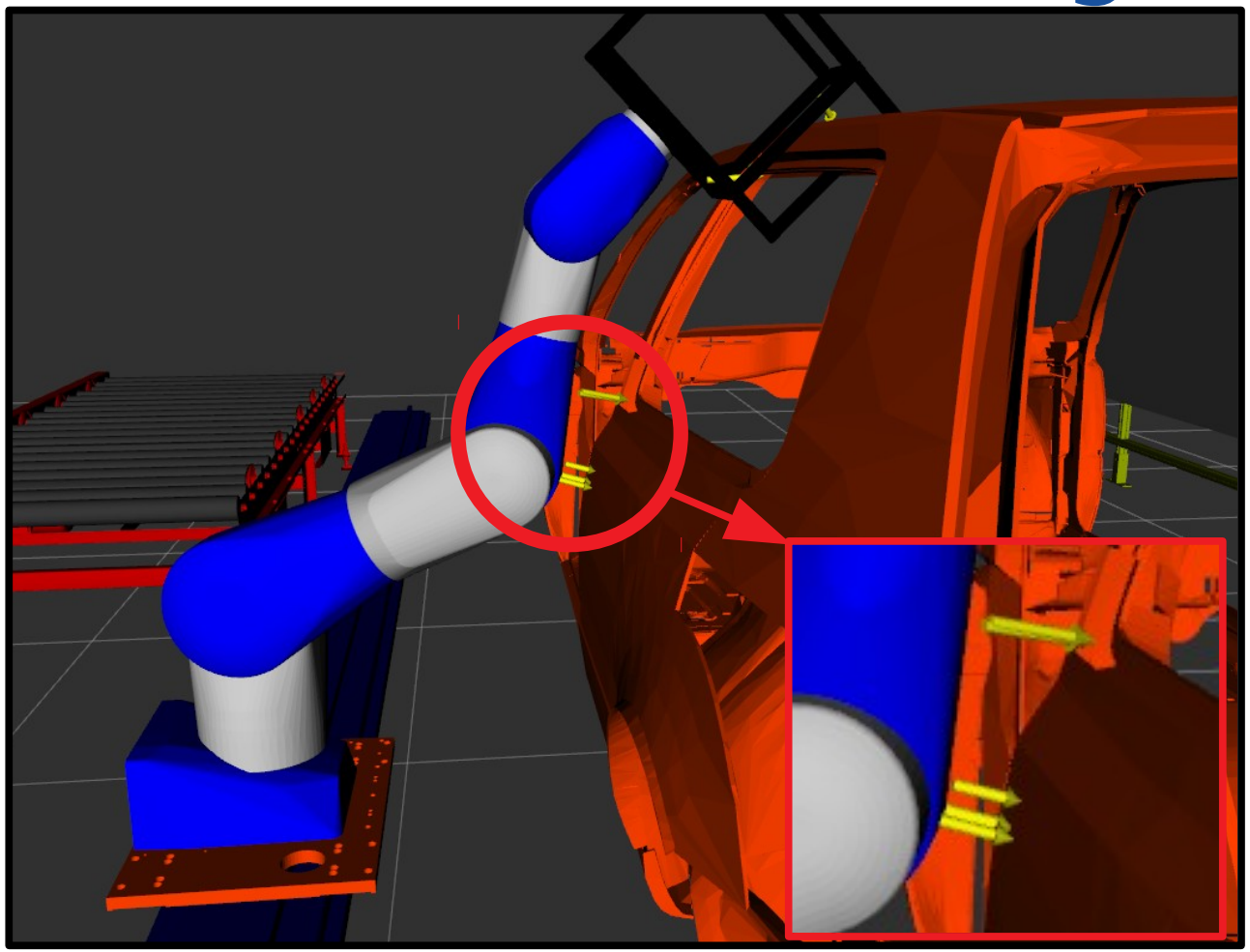
Production System Online Component

- Manual Manipulation
  - Open-Source
  - Group Selection
  - Joint and Cartesian Manipulation
  - Pkg: tesseract_rviz



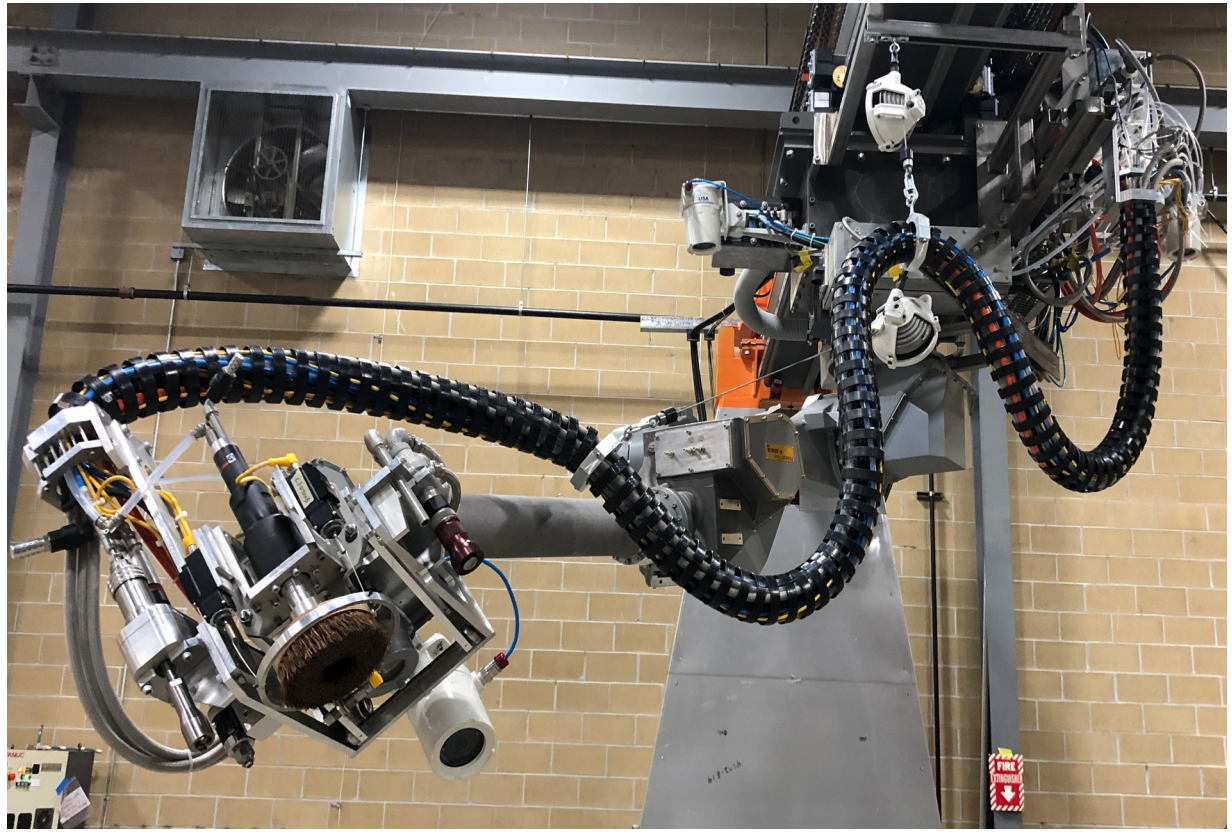
Production System Contact Monitoring

- In large system it is difficult for operators to see everything while manually operating the robot.
- Mitigate this risk active contact monitoring is leverage.
- It currently publishes the contact results at 80hz for the PLC to be able to execute a safe stop to prevent operator error.



Production System Challenges

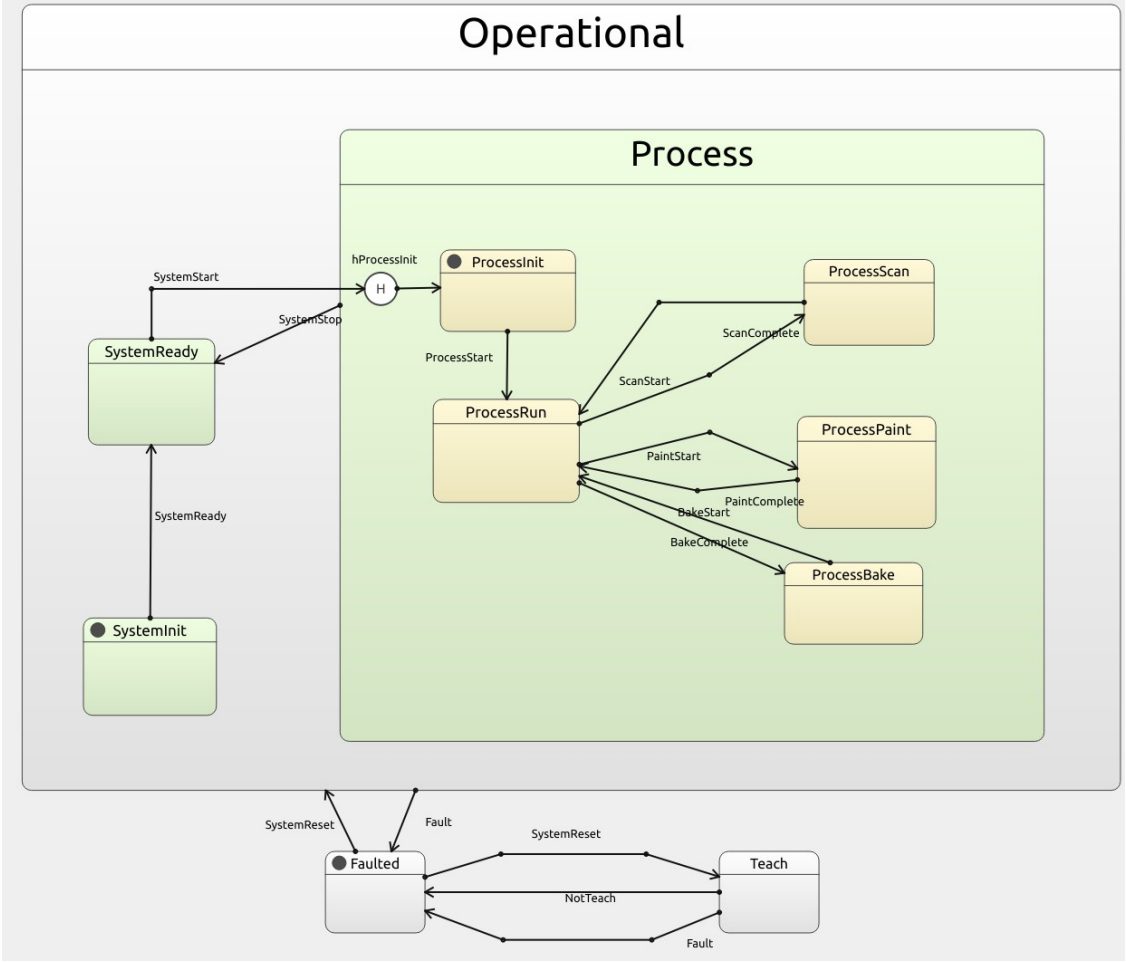
- Modeling System Constraints
  - Festooning
  - DCS Joint Exclusion Zones
    - If (J1 < 10 and J1 > -10) then
      - J2 > 60 and J2 < 80
      - J3 > -30 and J3 < 40
  - Configuration
  - Limit robot extension
  - Numerical rounding
    - Programs sent to Robot are at Joint limits or DCS Joint Limits cause robot faults
    - ROS Reading state at the same limits causing motion planning failures
  - Error Recovery



ROS-Industrial Technology Leveraged

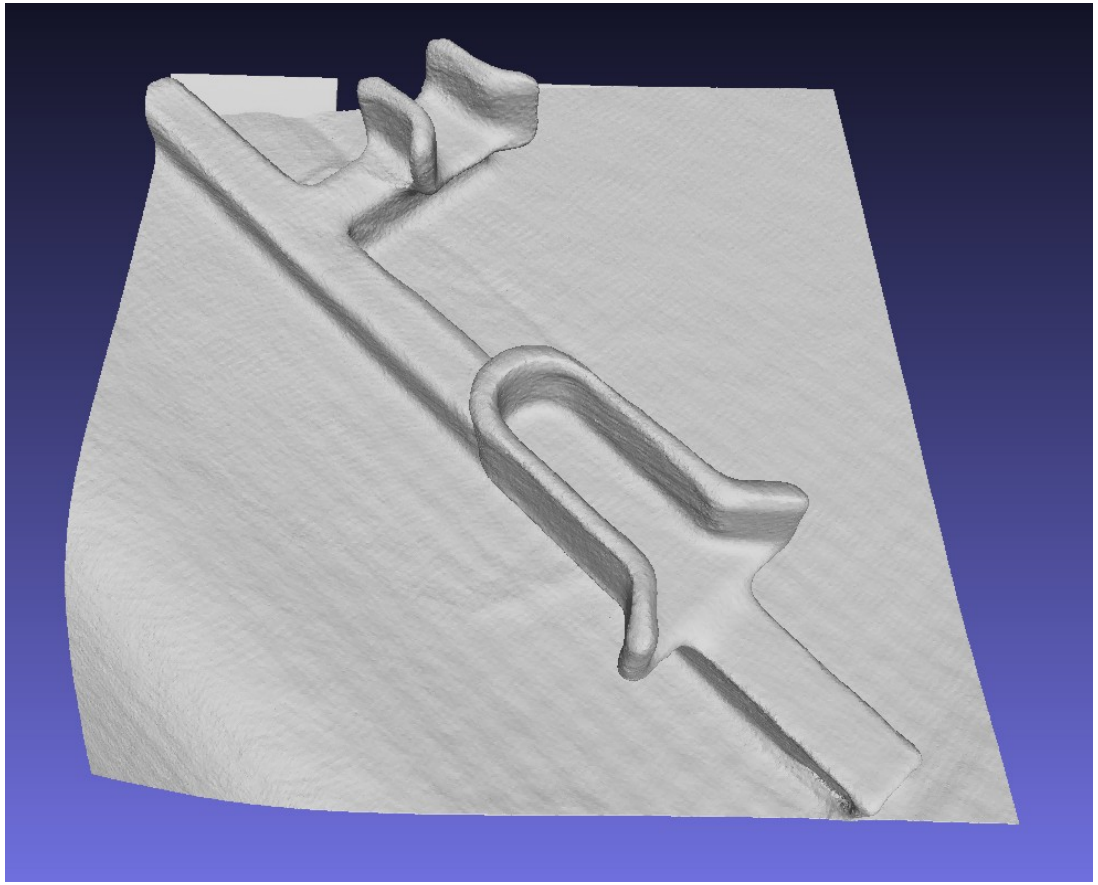
ROS_SCXML

- State machine library based on Qscxml that loads a scxml state machine file definition in order to run a FSM.
- It allows attaching custom c++ function callbacks to state events and can be embeded into a qt gui application
- Open sourced in the near future.



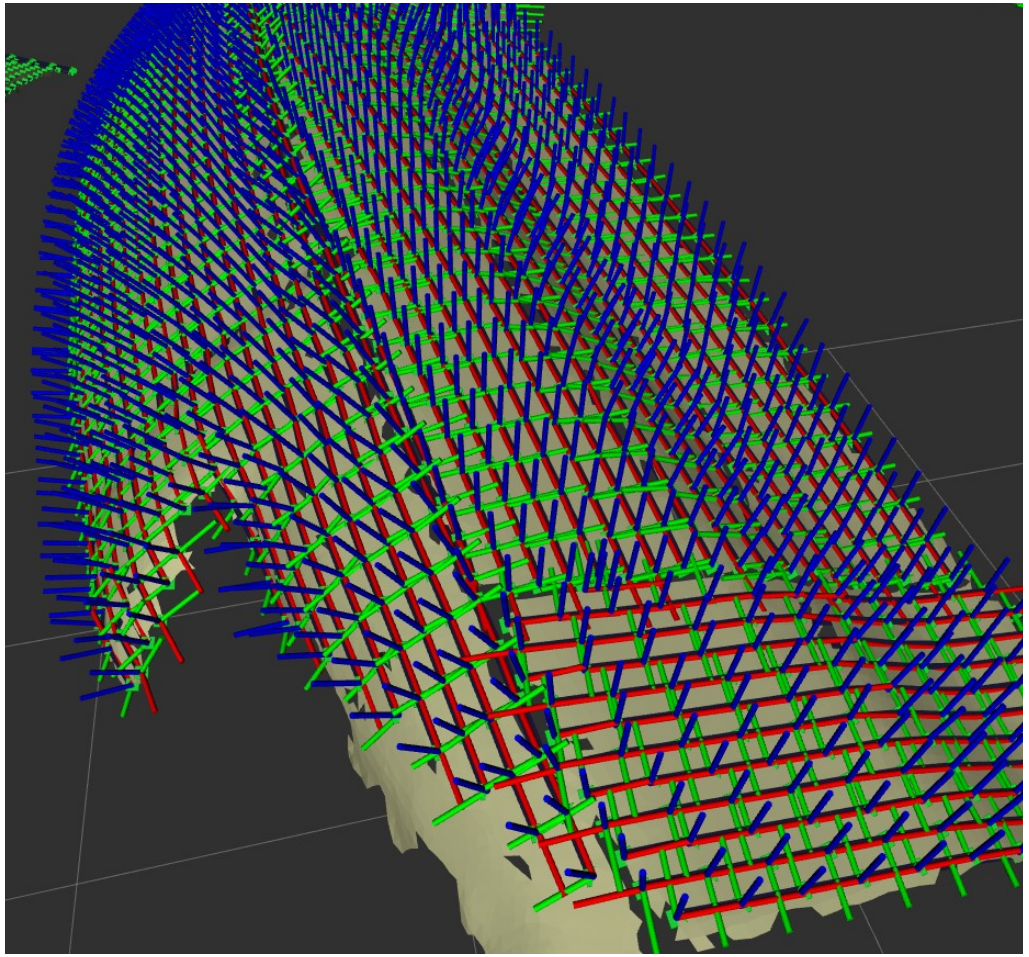
YAK (Yet Another Kinfu)

- Improvements
  - ROS Agnostic
    - Modern CMake
    - Upgraded Cmake version for better cuda support



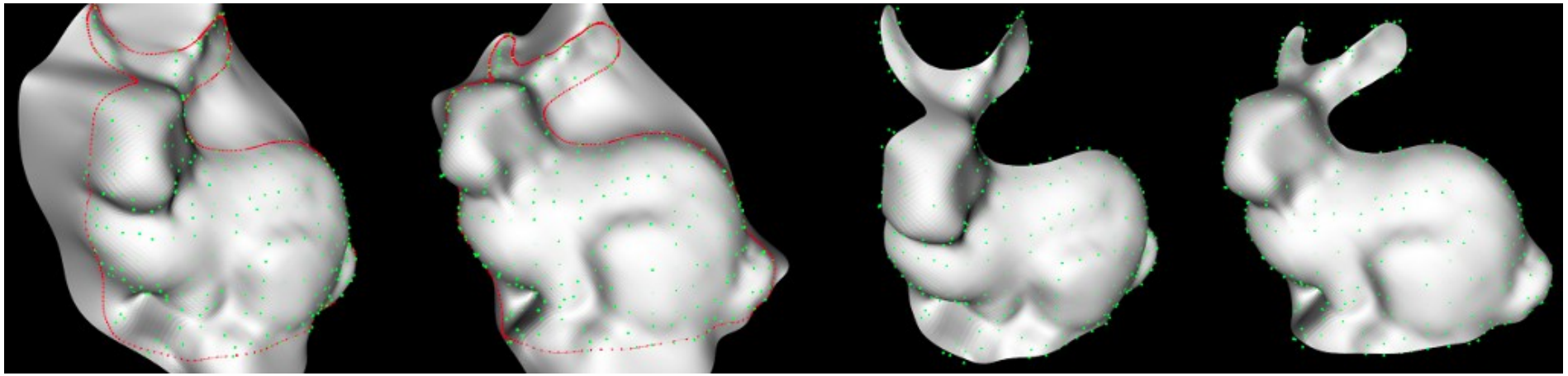
Noether

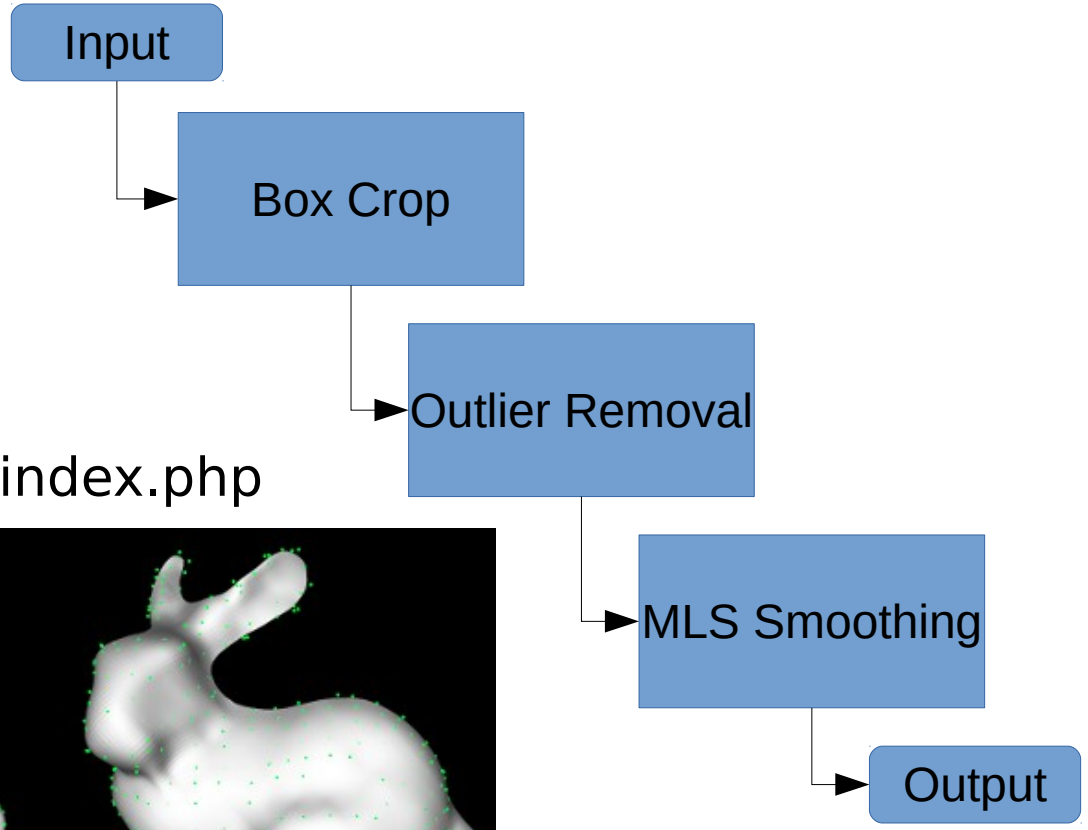
- Tool path generation on well behaved surface meshes (pictures above).
- All waypoints have their z axis normal to the surface.
- Surface segmentation: can divide a mesh into multiple sub-meshes based on local surface features such as average normal direction, curvature and distance.



Noether (New)

- Filter Pipeline (PointCloud & Meshes)
  - Yaml Configuration
- B-Spline Surface Reconstruction
  - PCL (Must build from source)
  - http://pointclouds.org/blog/trcs/moerwald/index.php



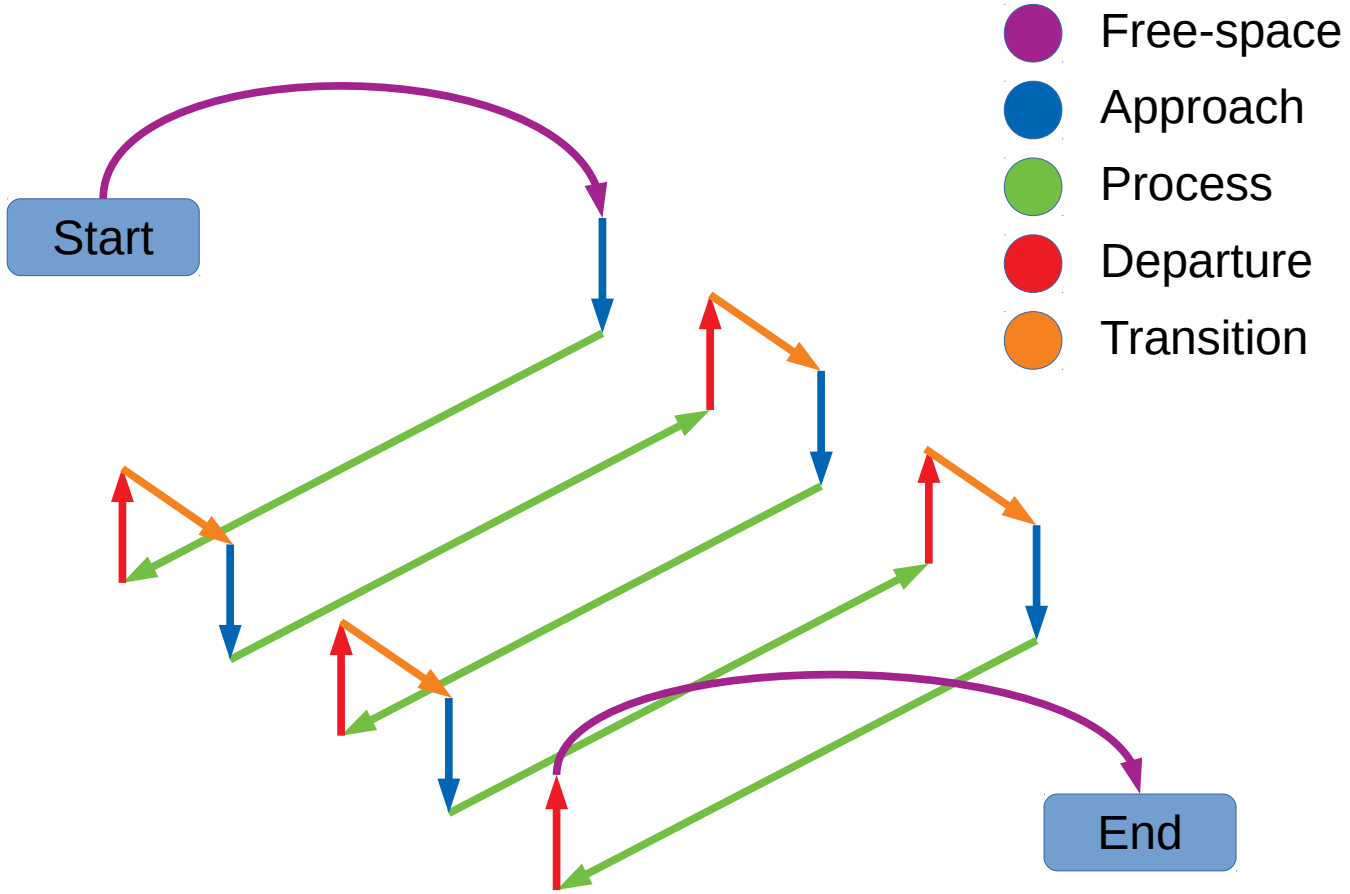


Tesseract (Planning Environment)

- **tesseract_geometry**
  - capsule, convex_mesh, sdf_mesh, octomap/PointCloud
- **tesseract_urdf**
  - Support new shape types & Quaternions
- **tesseract_kinematics** (Forward, Inverse, Jacobian)
  - IKFast & OPW Kinematics
- **tesseract_motion_planners**
  - TrajOpt, Descartes & OMPL Integration
- **tesseract_process_planners**
  - End-To-End Planners
- **tesseract_ros** (Full ROS support)
- **tesseract_ros2** (ROS2 support - Rviz pending)

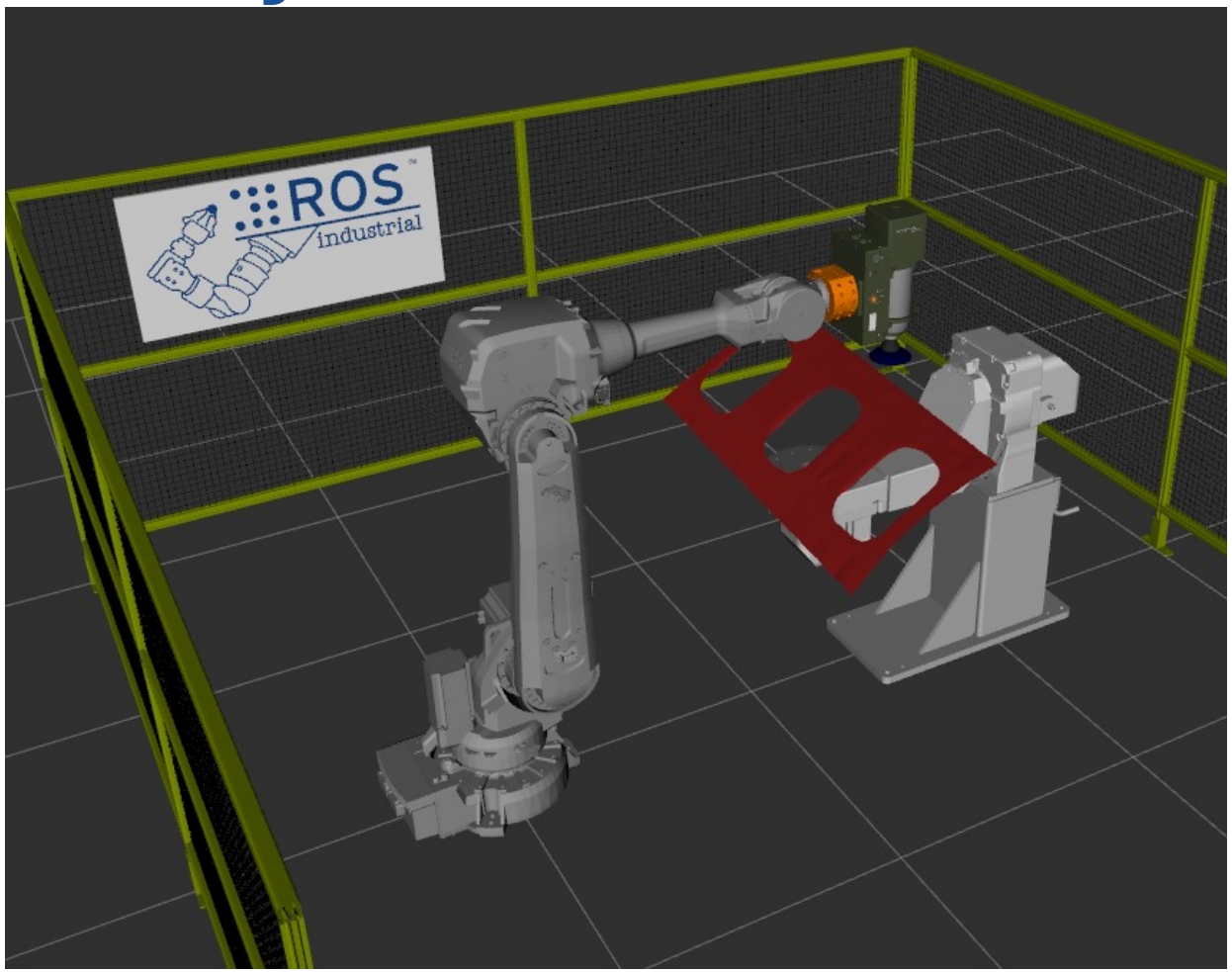
Tesseract (Planning Environment)

- **tesseract_process_planners**
  - Framework that take a tool path generated on a surface and constructs a process tool path.
  - Process Definition
    - Start
    - Segments
      - Segment (Approach, Process, Departure)
    - Transitions
      - From-End
      - From-Start
    - End

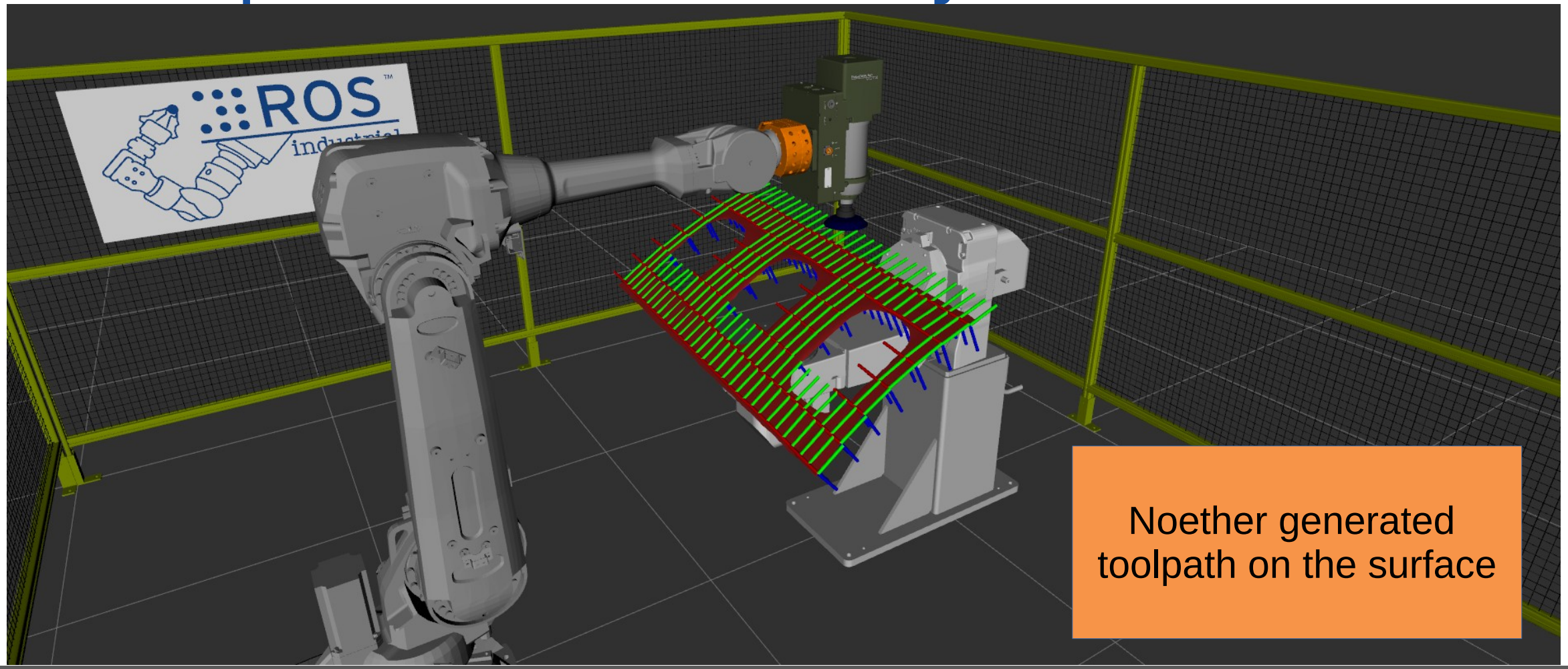


Example Scan-N-Plan Systems

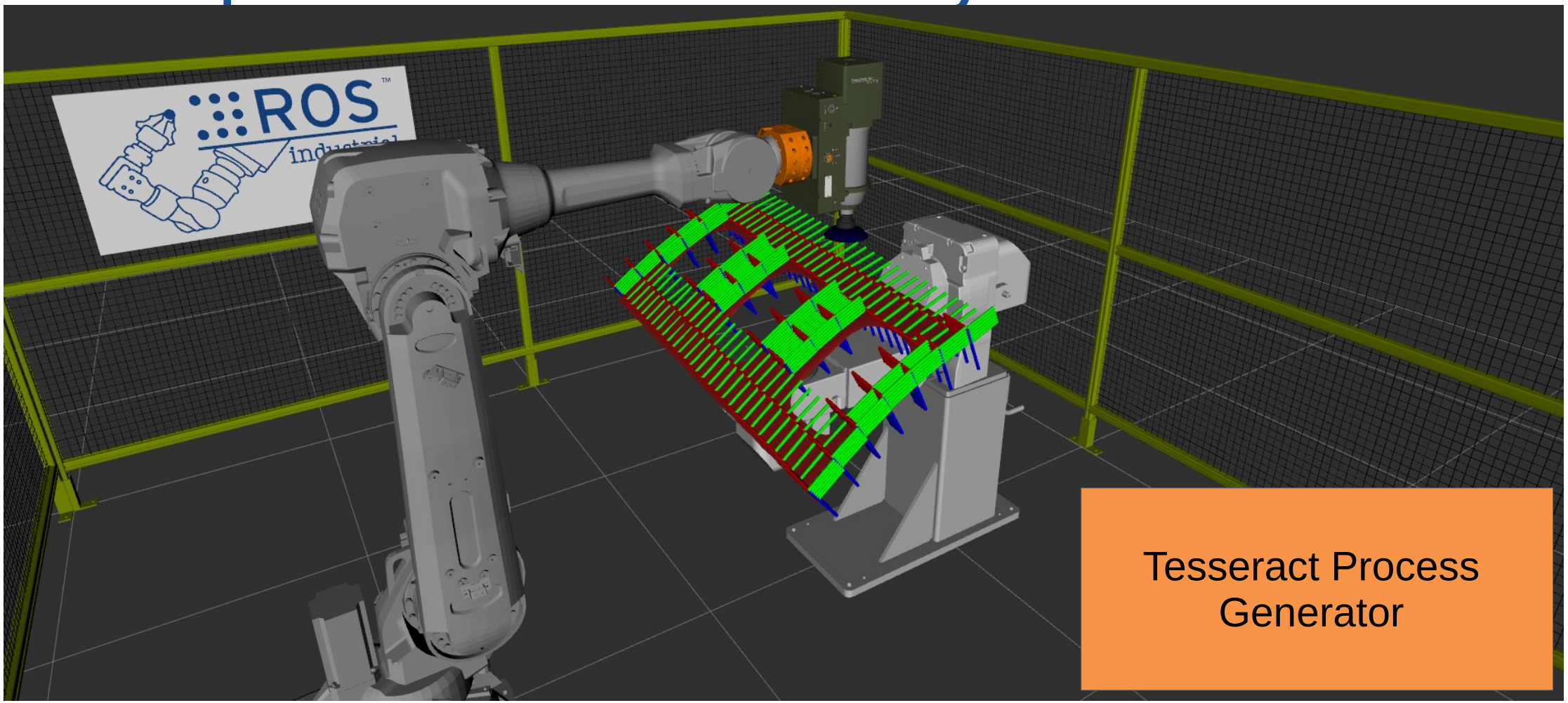
- Two axis external positioner with 6DOF manipulator.
- PushCorp Spindle with Compliance Device
- Panel to process



Example Scan-N-Plan Systems



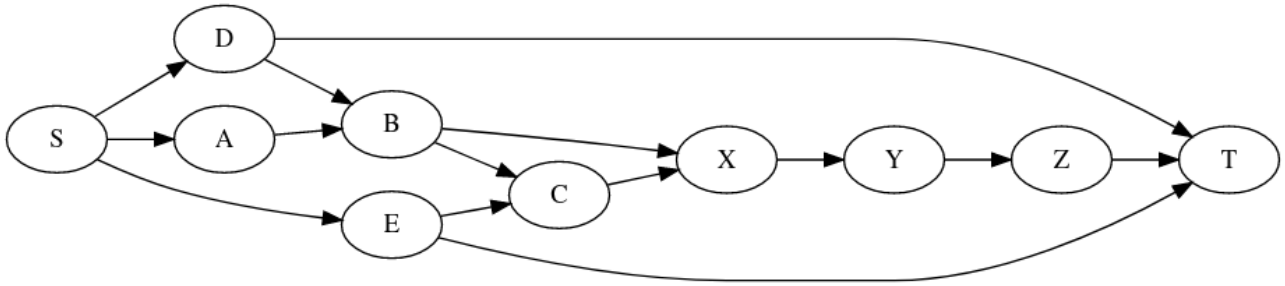
Example Scan-N-Plan Systems



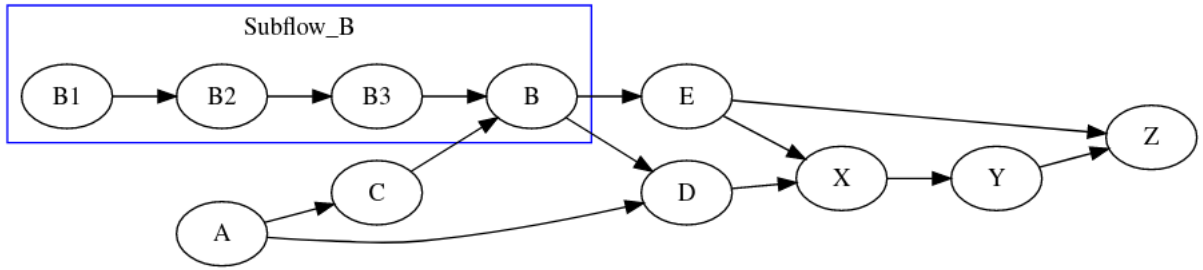
Example Scan-N-Plan Systems

In-Progress

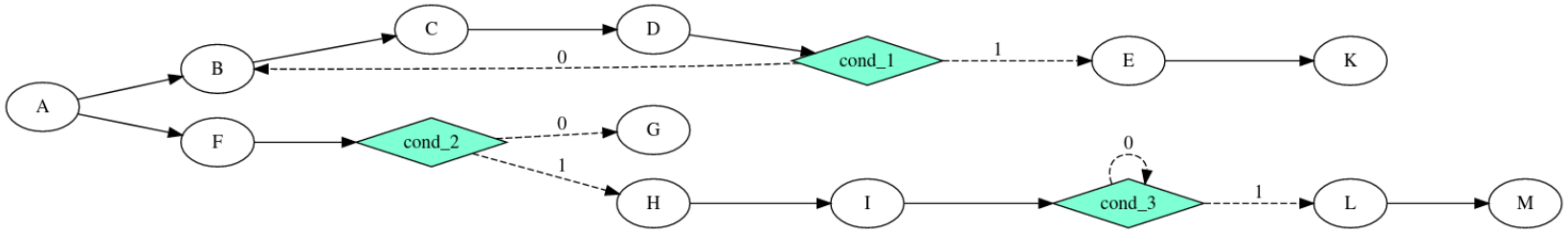
Static Tasking



Dynamic Tasking



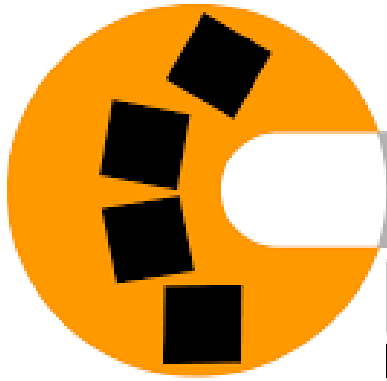
Conditional Tasking



Leveraging
cpp-taskflow

Current IR&D (Realtime Path Planning)

TensorFlow



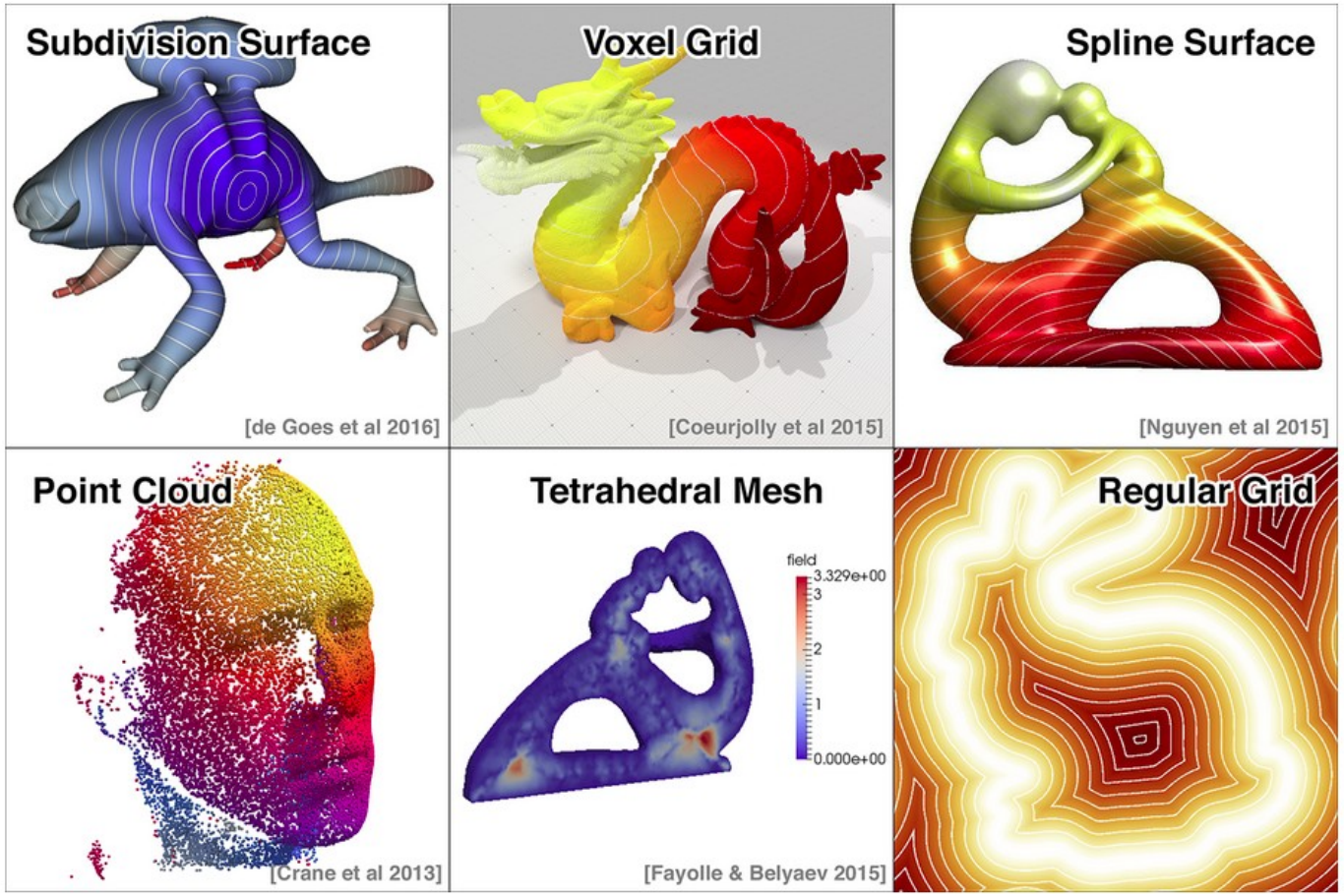
BULLET PHYSICS LIBRARY

Motion Planning
GPU Accelerated
Cost/Constraint

PyTorch

GPU Accelerated
Collision Checking

Current IR&D (Robust Toolpath Gen.)



The heat method is a general principle that can be applied to any geometric data structure, as long as one knows how to take the gradient of a scalar function. It has been implemented on a variety of data structures including subdivision surfaces [de Goes et al 2016], voxel grids [Coeurjolly et al 2015], spline surfaces [Nguyen et al 2015], point clouds [Crane et al 2013], tetrahedral meshes [Belyaev & Fayolle 2015], and regular grids (using standard finite differences).

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