Industrial Manufacturing Automation Leveraging ROS
Agenda

• Scan-N-Plan Evolution
  • Blending M1 – M4
  • Blending M4 (Demo)
  • Production System
• Production System
  • Overview
  • Challenges
  • Solutions
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

**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
Evolution

2014 2016 2019
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 currentlypublishes 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 \((J1 < 10 \text{ and } J1 > -10)\) then
      - \(J2 > 60 \text{ and } J2 < 80\)
      - \(J3 > -30 \text{ and } J3 < 40\)
  - 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_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)
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
  - Hybrid Planners
    - Descartes + TrajOpt
    - OMPL + TrajOpt

- **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

- Free-space
- Approach
- Process
- Departure
- Transition
Tesseract/TrajOpt

- **TrajOpt**
  - Dynamic Cartesian Cost and constraints Improvements
  - Evaluated to low level data structures for cost and constraints. Settled on IFOPT and Eigen AutoDiff
  - Next Steps Remove dependency on Tesseract leveraging TypeErasers
Descartes Light & OPW Kinematics

- Descartes Light
- IKFast Interface
- Gantry sampling
- ROS Agnostic
- OPW Kinematics
- ROS Agnostic
Agile System in Action...

Intuitive Process Application – Registration, Multi-Process Planning
Contact Information

- **Levi Armstrong**
  - Group Leader
- **Southwest Research Institute**
  - 6220 Culebra Road
  - San Antonio, Texas 78238
- Phone: (210) 522-3801
  Email: levi.armstrong@swri.org
- [www.swri.org](http://www.swri.org)
- [www.ros-i.org](http://www.ros-i.org)