Development of an Agile Platform for Aerospace Applications Leveraging Open-Source Tools

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Overview

- SwRI Introduction
- SwRI Robotics & ROS-Industrial
- Approaches to Automation
- Scan and Plan
- Automation for Aerospace
- A5 Program
- Results and Challenges
- Future Work
- Relevance
- Questions
SwRI: Deep Sea to Deep Space

Southwest Research Institute Characteristics
- Est. 1947
- San Antonio, Texas, USA
- Independent, Not for profit
- Applied RDT&E Services
- Natural Science and Eng.
- FY 2019 Revenue: $674M

Alvin submersible
SwRI & Advanced Robotics in Manufacturing
A Disruption in Software for Automation

ROS – Robot Operating System

- Open Source
- Established to prevent re-inventing the wheel
- Maintained by Open Robotics
- Reusable Software Components
- >1,000,000 user downloads/mo

Plumbing + Tools + Capabilities + Ecosystem
What is ROS-I?

- Industrial 3D Sensors
  - ROS Qt Creator Plugin: CAD to ROS
  - Intel® RealSense™
  - PM Pepperl & Fuchs
  - IDS	Envisics
  - Sick

- ROS/2:
  - ROS Qt Creator Plugin: CAD to ROS
  - Mobile Manipulator Sorting
  - Scan N Plan

- Hardware Interfaces:
  - Industrial Robots
  - Universal Robots

- Human Interfaces:
  - CALS

- Calibration

- Bridges
  - CANopen™
  - EtherCAT™
  - PROFINET™

Featuring ROS-I.

aerodefevent.com
Technical Vision Supported by Industry
Automation for Aerospace

• Why?
  • Improved human safety
  • Improved quality for manufacturing processes
  • Improved productivity
  • Cost reduction

• Challenges
  • Large-scale components or assembled aircraft
  • Purpose-built automation is too expensive
  • High mix, low volume
  • Limited CAD and as-built model data
Continue to Evolve Automation

- Enables real-time adjustment to as-built condition
- Eliminates manual programming – operator just specifies tasks
- Enables process feedback and adaption via automated inspection
- “Smart” Automation

- Increased agility – able to do new things quickly
- Improved autonomy
- Intelligence that is adaptable
- Adjust in real-time to changing and/or perceived changes to the operational condition
A5 Program

- Advanced Automation for Agile Aerospace Applications
- Funded by Air Force Research Laboratory (AFRL)
- Team
  - National Center for Defense Manufacturing and Machining (prime)
  - Boeing
  - Southwest Research Institute
  - Robins AFB (end-user, technology champion)
- Key goals
  - Take the automation to the part
  - No a-priori knowledge about the part or environment necessary
  - No need for expert robot programmers
  - Easily reconfigurable for new manufacturing processes
A5 Program

- Targeted towards aircraft sustainment
  - Platforms: C17, F15
- Tasks
  - Robotic system development
  - Development and demonstration of closed-loop sanding
  - Development of X-ray inspection and demonstration on in-service aircraft
  - Development and demonstration of third manufacturing process
  - Process improvement
  - Technology transfer to integrator
A5 Hardware

- Vetex mobile platform
  - Stability outriggers
- Yaskawa manipulator
  - 4m reach, 120kg payload
- Gudel rail
- 23’ (L) x 7.5’ (W) x 12.5’ (H)
- 22,500 lbs.
- Sensors
  - Wrist-mounted 3D sensor and color camera
  - Articulated LiDAR scanners with color cameras
  - Safety LiDAR scanners and bumper switches
- Operator HMI
A5 Software

- Built on ROS
- Leverages many open-source tools
  - Surface reconstruction
  - Automated tool path planning
  - Automated collision-free motion planning
  - Communication to equipment, sensors, and robot
- Runs on a standard industrial PC
- Released as open-source*
  - [https://github.com/orgs/a5-robotics](https://github.com/orgs/a5-robotics)
  - *Currently available only to ROS-Industrial Consortium members
A5 System Operations

- Mobile Mode
- Scanning Mode
- Process Planning Mode
- Execution Mode
Mobile Mode

- Operator manually positions platform
- Visual reachability feedback from GUI
- Collection of coarse data for environment representation
- Colorized point cloud data
- Turn point cloud scan into collision object
- Extend outriggers for process stability
Scanning Mode

- Interactive robot instruction using GUI
- Surface reconstruction
- Automated tool path planning
- Automated motion planning
- Trajectory preview and operator approval
- Collection of higher accuracy data using wrist-mounted 3D sensor
- Surface reconstruction
- Collision environment update
Process Planning Mode

- Interactive robot instruction
  - Colorized mesh
  - Selection cursor is tool model
- Operator specifies key process parameters
  - Feeds, speeds, offsets, pressure, force, etc.
- Automated tool path planning
- Automated motion planning
- Trajectory preview and operator approval
Execution Mode

• Robot performs specified process
• Collection of process data
• Communication with tool and auxiliary equipment
• Process feedback to operator
Results
Results

• A5 Phase II (on-going)
  - X-ray NDI for F-15 inlet duct inspection
  - Updating to facilitate new process and workflow
  - Adding new capabilities
    - Constrained motion planning
    - CAD model alignment to sensor data
    - Support for new motion planners/frameworks
A5 – X Ray Inspection
Extensibility Results

- Leveraged A5 software as platform for paint applications
  - ARM Institute
    - [https://arminstitute.org/project-highlight-mobile-autonomous-coating-application-for-aircraft-sustainment/](https://arminstitute.org/project-highlight-mobile-autonomous-coating-application-for-aircraft-sustainment/)
- Demonstrated adaptability to new hardware
- Improved existing tools and developed new capabilities
Extensibility Results
Future Work

• Continue additional phases of A5 program
  • X-Ray NDI Physical Demonstration
  • Process Improvement & Solution Hardening
  • Technology transfer

• Leveraging A5 software framework for other applications
• Integration of new tools for surface reconstruction, tool path planning, and motion planning
Challenges

• Develop trust that the robot will behave “sanely” around valuable aircraft
• Surface reconstruction
• Operator Usability
• Wide-area sensor package calibration
• Cable management
• Production hardening
  • Overall processing time
  • Error logging/recovery
Conclusions

• Feasible agile automation strategy for aerospace applications
  • Take the automation to the part
  • No a-priori knowledge about the part or environment necessary
  • Can utilize CAD data
• No need for expert robot programmers
• Easily reconfigurable for new manufacturing processes
• Easily adaptable for different robot configurations
• Open-source software can be effectively leveraged for industrial applications
Questions?