Distributed Robotic Architecture

Using Actin and DDS

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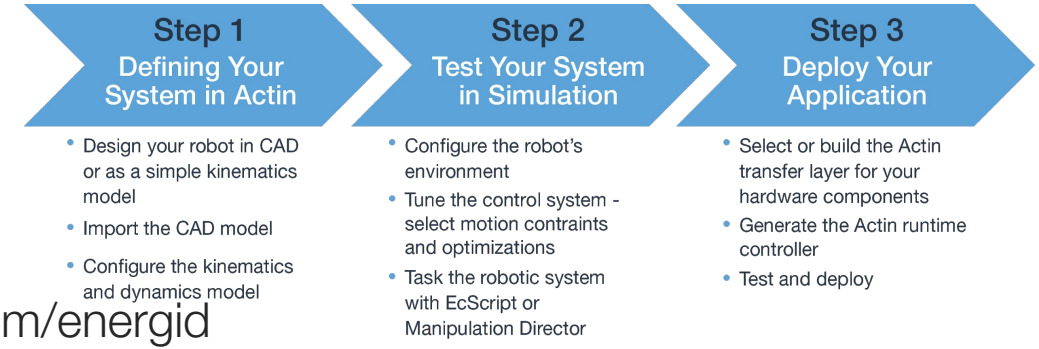
Overview

- Who is Energid?
- What is Actin?
- Actin with DDS
- Tasking with DDS
- Projects using DDS
- Live demo

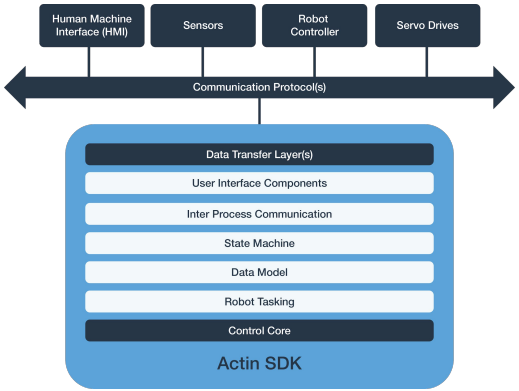
Energid Technologies

- Develops software for simulation and control of any robotic system
- Actin software is at the core of our business
  - Actin SDK
  - Actin applications
  - Integration services
- Now a Teradyne company
- Cool videos: https://vimeo.com/energid



Actin Software

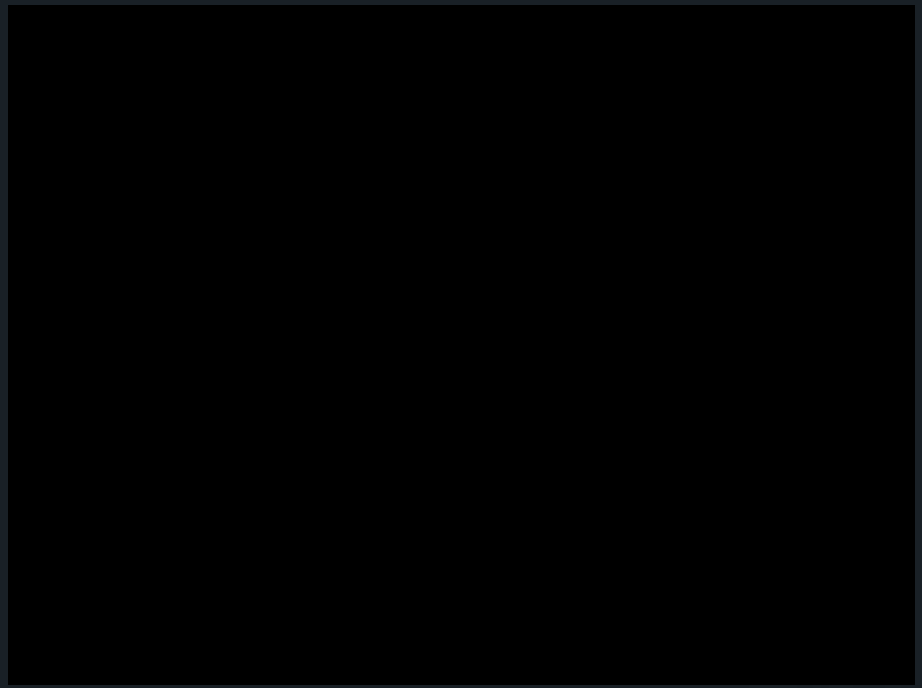
- General kinematics and dynamics model
  - Inverse and forward kinematics and dynamics
  - Kinematically redundant mechanisms
  - Fixed and mobile base manipulators
- General motion constraint and optimization framework
  - Dynamic collision avoidance
  - Joint limit and singularity avoidance
  - Strength optimization
  - Dynamic response to sensor data
- Adaptive tasking
  - Global path planning
  - Complex tool path motion control (EcScript)
  - Coordination of many robots and axes (Manipulation Director)
- General platform support
  - Easy integration with sensors and actuators
  - Kinematic model generation from CAD
  - Desktop applications for Windows, Linux, OS X
  - Real-time control on VxWorks, RT Linux, RTOS32, RTX64



Constraint Optimization

- End effector constraints
- Collision avoidance
- Joint limit avoidance
- Singularity avoidance
- Center of gravity

- Video
  - 3 HEBI Actuator Arms
  - 21 DOF Total
  - Frame end effector



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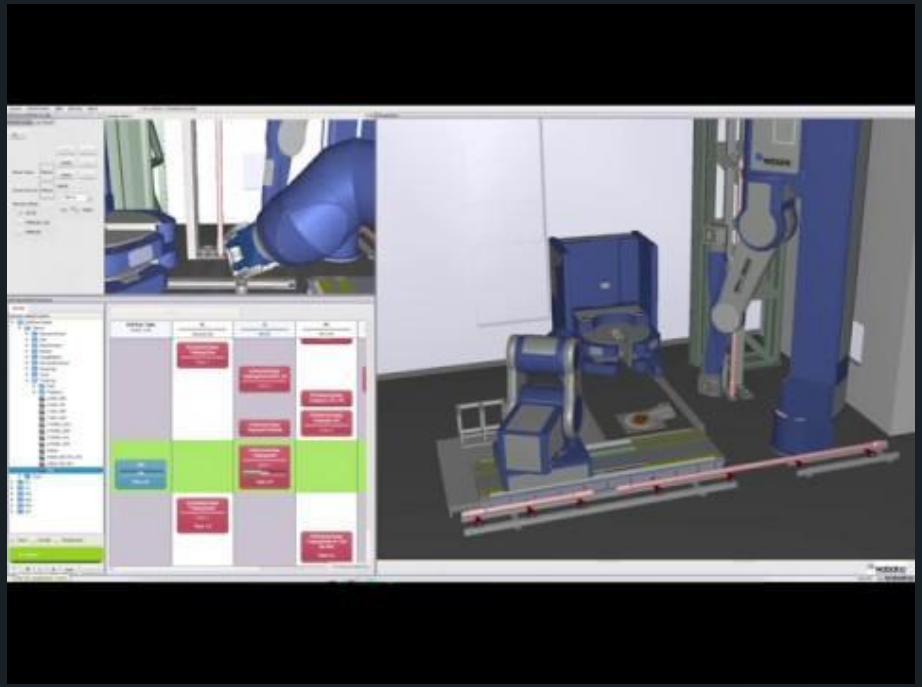
Multi-Robot Coordination

- 5 Machines
  - Robot
  - Pipe Handler
  - Roughneck
  - Elevator/Lift
  - Slips

- Manipulation Director
  - Hierarchical tasking
  - Machine coordination



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Collision Avoidance

- Collision exclusion maps
  - Self collision exclusion candidates
  - Static collision exclusion candidates
  - Dynamic collision exclusion candidates

- Video
  - UR5 (6-DOF)
  - Adaptive tasking
  - Dynamic collision avoidance

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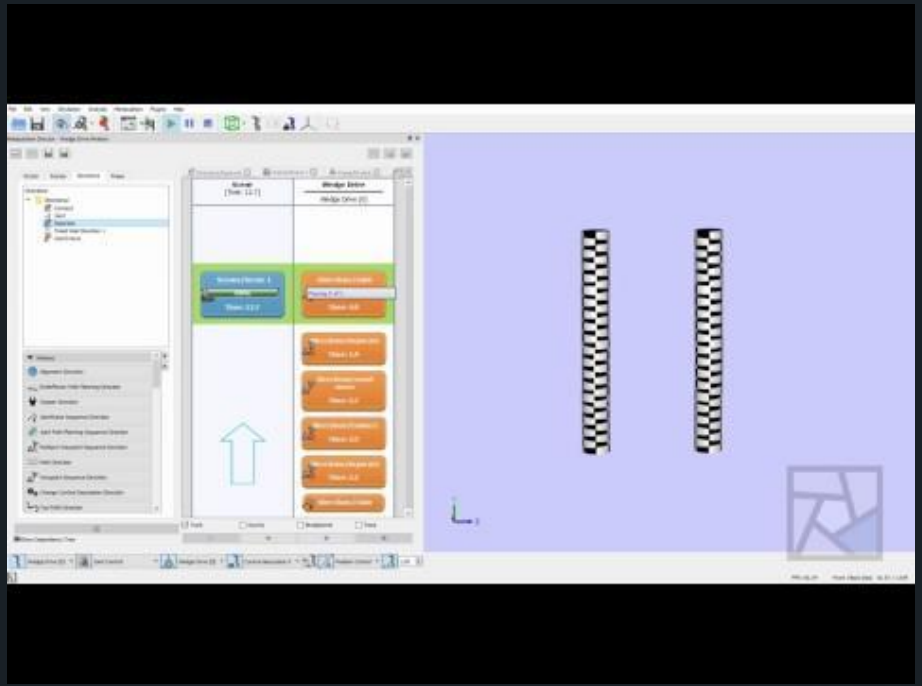
Kinematically Redundant Mechanisms

- Extra degrees of freedom allows optimizing for other constraints

- Video
  - 2 Theoretical 36-DOF “wedge actuator” arms



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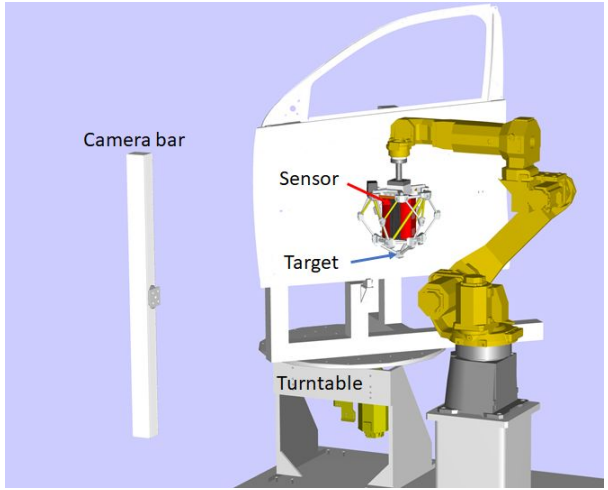
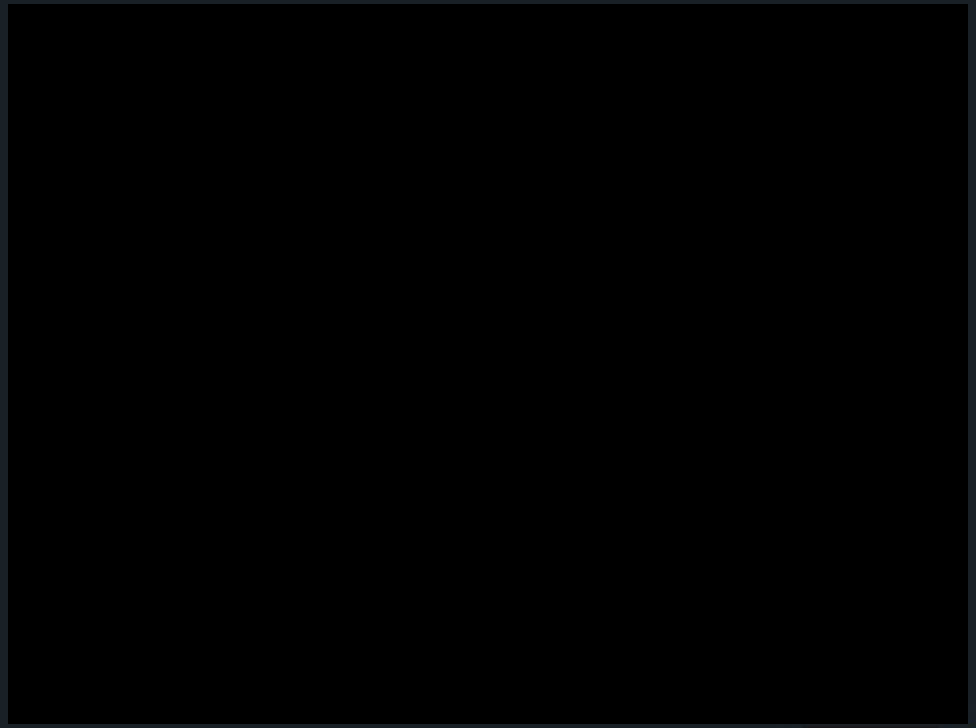
Global Path Planning

- Fanuc M-10iA/12 6 DOF arm
- Added turntable DOF
- Complex part inspection
  - 41 inspection points
  - Travelling salesman problem
- Additional constraints
  - Target has 36 LED emitters
  - Camera bar has 3 cameras
  - At least 4 LEDs visible to all 3 cameras





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Real Time

- Video
  - HM Elfin 5 Robot (6-DOF)
  - Added linear rail
  - EcScript motion control
  - 1 ms Updates

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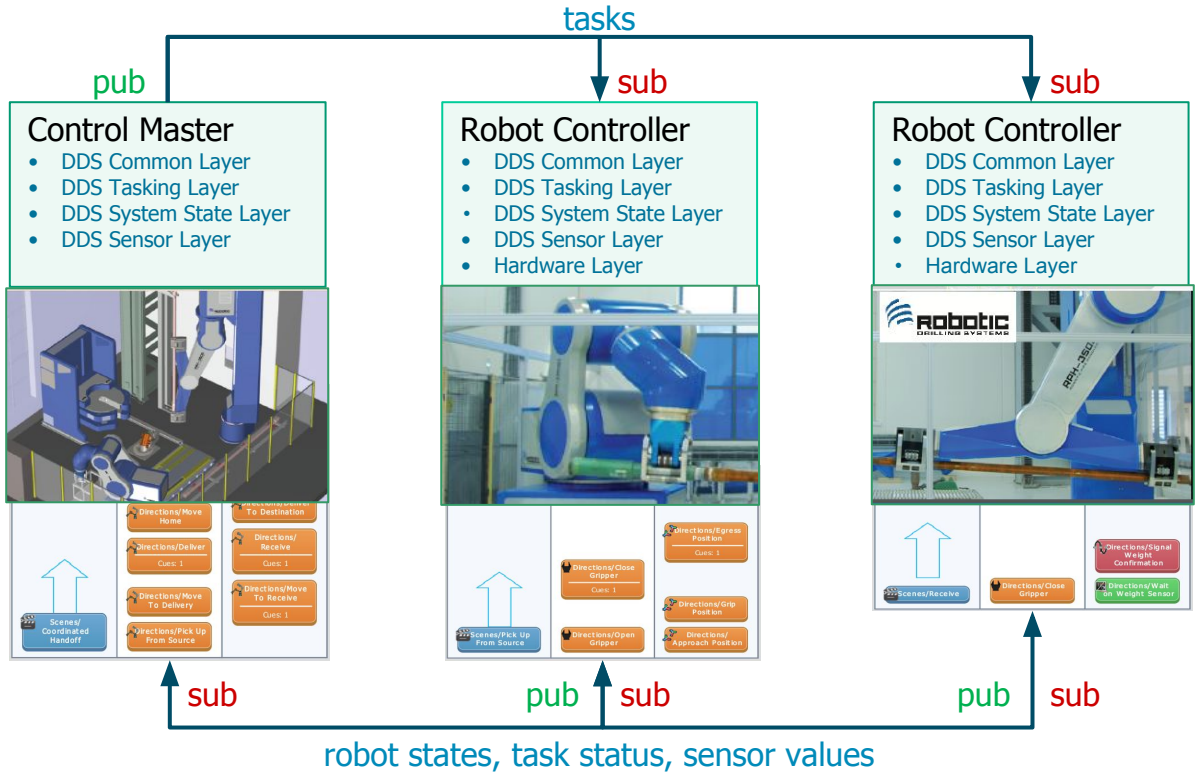
Actin with DDS

- Started using DDS early 2013
  - Government customer required us to integrate Actin with their tools using DDS
  - Early RDS work indicated DDS would be a perfect fit
- Single-robot deployments
  - Increased demand for teleoperation
- Multi-robot deployments
  - One robot controller machine per robot
  - Communication between controllers
    - Commands, state synchronization, sensor feedback, hardware status
  - Scalable architecture

DDS Enables

- Flexible system architectures
  - Add new sensors, actuators, etc
  - Swap out components
  - Scalability
  - Redundancy
- Simplified communication between teams
  - Send the IDL, topic names, and QOS
- High degree of tunability through QOS
- Reduced development time!

Distributed Robot Control Architecture

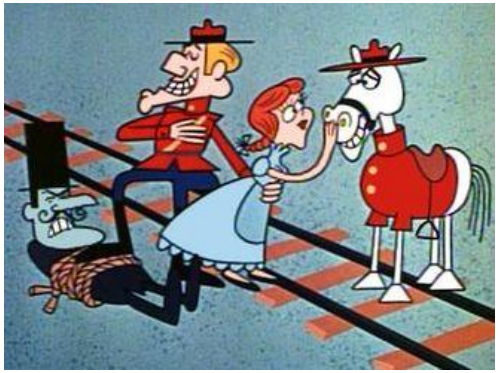


Tasking With DDS

- Manipulation Director
- DDS Tasking Implementation
  - Fundamentals
  - Topics
  - Sequence Diagram
  - Implementation Specifics
- Hierarchical Tasking

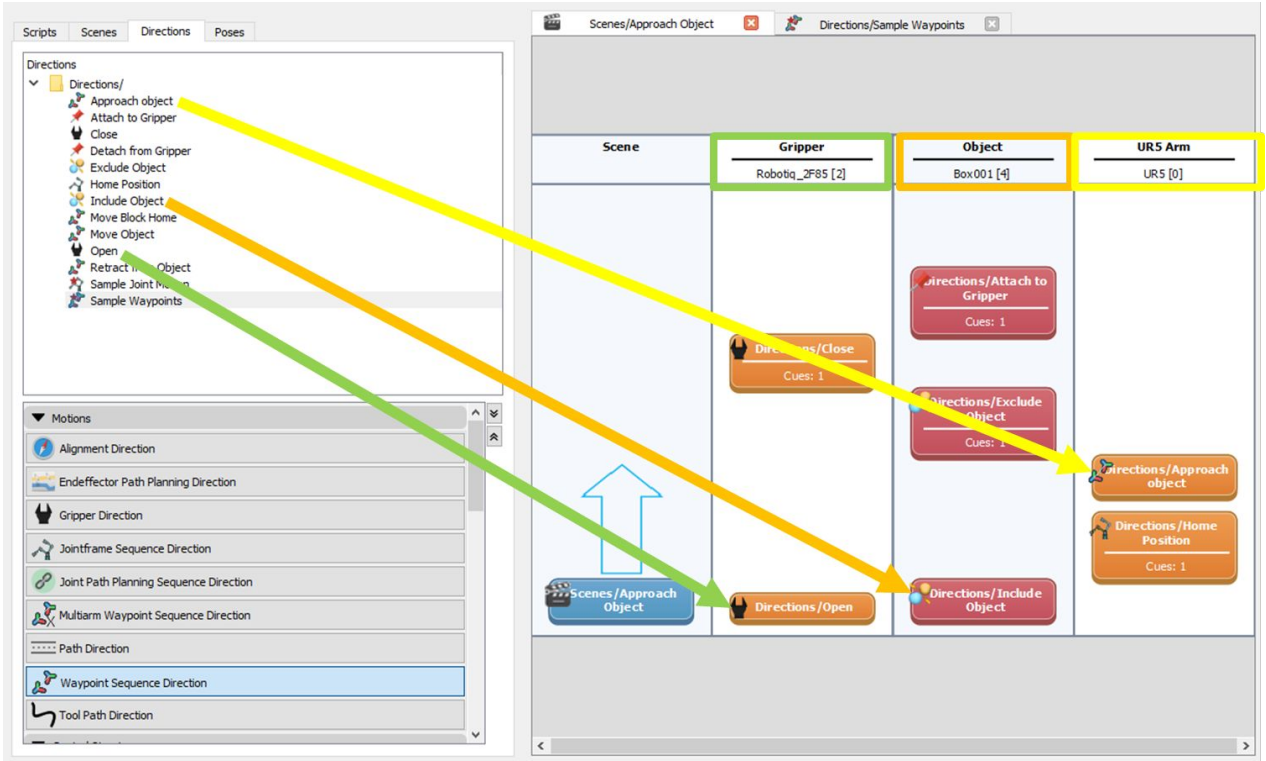
Manipulation Director

- Library of manipulation tasks
  - Low-level blocks used to build higher-level blocks
  - All blocks are reusable
  - Write to and read from XML
  - Extensible architecture
- Theater terminology
  - Director - directs the execution of a script
  - Cast - Assigns actors (robots) to play roles in the script
  - Scripts - Composed of scenes
  - Scenes - Composed of directions for the actors
  - Directions
    - Stage Directions - Non “speaking” instructions to actors
    - Manipulation Directions - The “speaking” lines … For a robot, this means “movement”
  - Poses
    - Reusable transformations
    - Can be fixed or relative
    - Used inside directions for defining positions and orientations
  - Cues



At some point, we lost the “plot” (of theater terminology)

Manipulation Director GUI



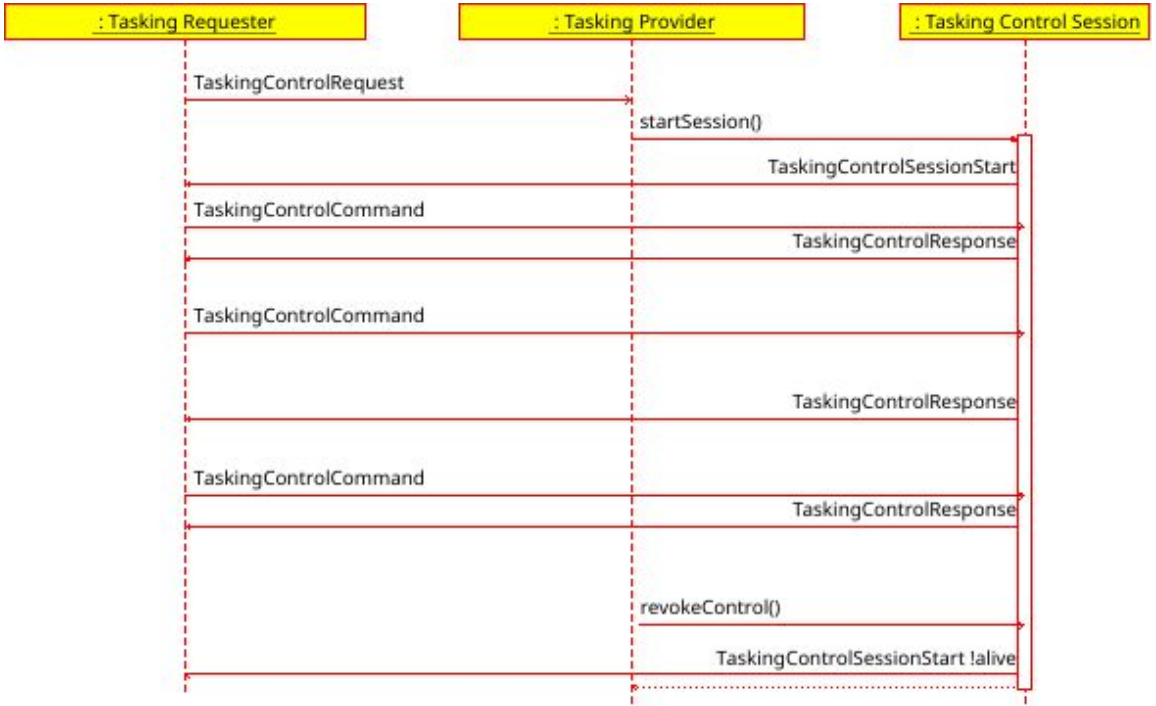
Tasking Fundamentals

- Tasking provider “provides” a resource to be tasked
- Tasking requester “requests” control of a resource
- Only one requester can have control of provider at a time
- Control is granted or revoked by the provider
- Control takes into account
  - Machine state (Manual vs. Auto)
  - Continuity of control
- Purpose
  - Manage objects in the manipulation director library
  - Manage task execution of manipulation director objects
- Not so “secret” sauce
  - Multiple keys
  - Content filtered topics

Tasking Topics

- TaskingControlRequest
  - Request control of a particular role
  - Keyed by role and UUID of the requester
- TaskingControlSessionStart
  - Informs a provider when control has been granted
  - When the instance is no longer alive, the requester no longer has control
  - Keyed by role and UUID of the requester
- TaskingControlCommand
  - Send a command to the role
  - Commands manage manipulation director library and execution
  - Keyed by role and UUID of the requester
- TaskingControlResponse
  - Send a response from the role to the requester
  - Responses indicate the success or failure of commands
  - Keyed by role and UUID of the requester

Tasking Sequence Diagram



Tasking Implementation Specifics

- Tasking Requester
  - Generates UUID
  - Publishes
    - TaskingControlRequest uuid=UUID
    - TaskingControlCommand uuid=UUID
  - Subscribes
    - TaskingControlSessionStart (role = 'roleName' AND uuid = 'requesterUuid')
    - TaskingControlResponse (role = 'roleName' AND uuid = 'requesterUuid')
- Tasking Provider
  - Starts tasking control session to grant control
  - Stops tasking control session to revoke control
  - Subscribes
    - TaskingControlRequest (role = 'roleName')
- Tasking Control Session
  - Direct connection to requester UUID
  - Publishes
    - TaskingControlSessionStart uuid=UUID
    - TaskingControlResponse uuid=UUID
  - Subscribes
    - TaskingControlCommand (role = 'roleName' AND uuid = 'requesterUuid')

Hierarchical Tasking

- Lower-level tasking provider
  - Provides lower-level manipulation director library
  - Single machine tasks
  - Single machine does not mean single role

- Higher-level tasking provider
  - Requests control of lower-level tasking providers
  - Provides higher-level manipulation director library
  - Direction sends tasking commands to lower-level providers
  - Multi-machine tasks

- How many levels are needed?

Projects Using DDS

- CANRIG Robotics
- URCaps Integration

CANRIG Robotics

- Formerly Robotic Drilling Systems
  - Acquired by NABORS in 2017
- Manual operations dominate global rig fleet
  - Remove people from the rig floor
  - Save lives
  - Save time
- Tripping is the biggest time consumer
- CANRIG Robots
  - Next-generation
  - Fully electric
  - Maintenance free
  - Design life = 10 years
  - Beautiful design!

CANRIG
DRILLING TECHNOLOGY

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CANRIG
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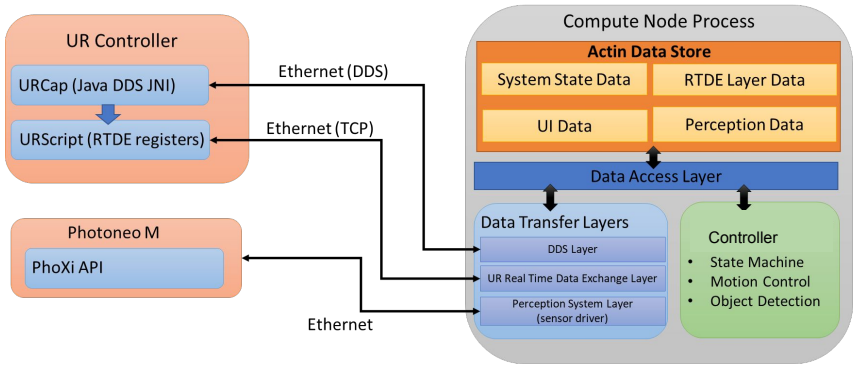
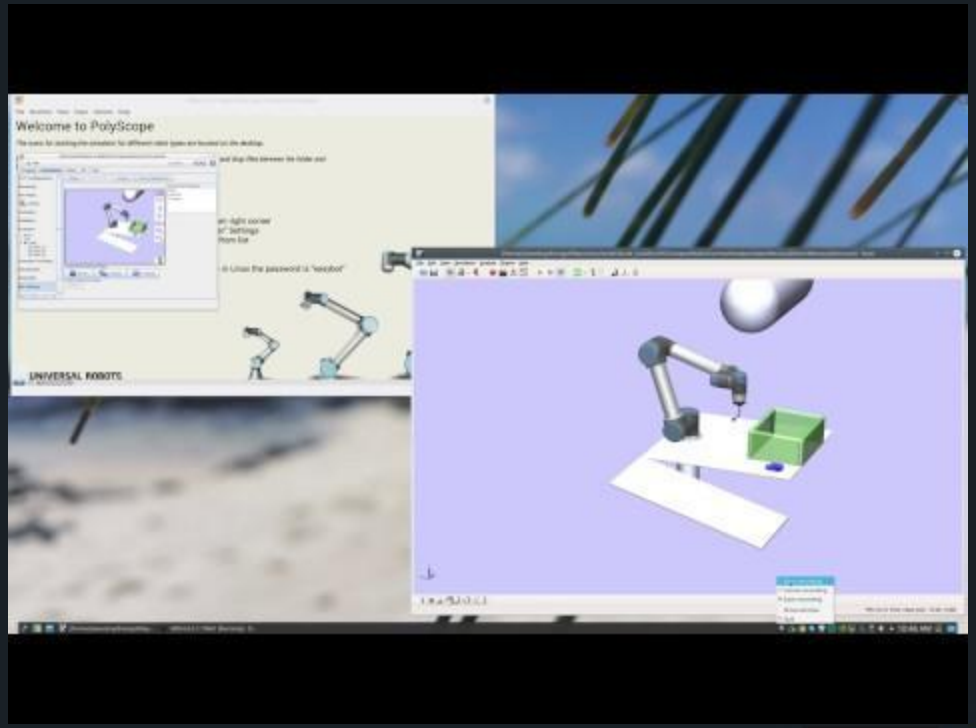
URCaps Integration

- 6 DOF UR3, UR5, or UR10
- Compute node separate from robot controller
  - Runs Actin
  - Provides 3D rendered images





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Live Demo

- User interface process (Actin Viewer)
- Robot simulation process (Actin Viewer)
- User interface process 2 (Actin Viewer)