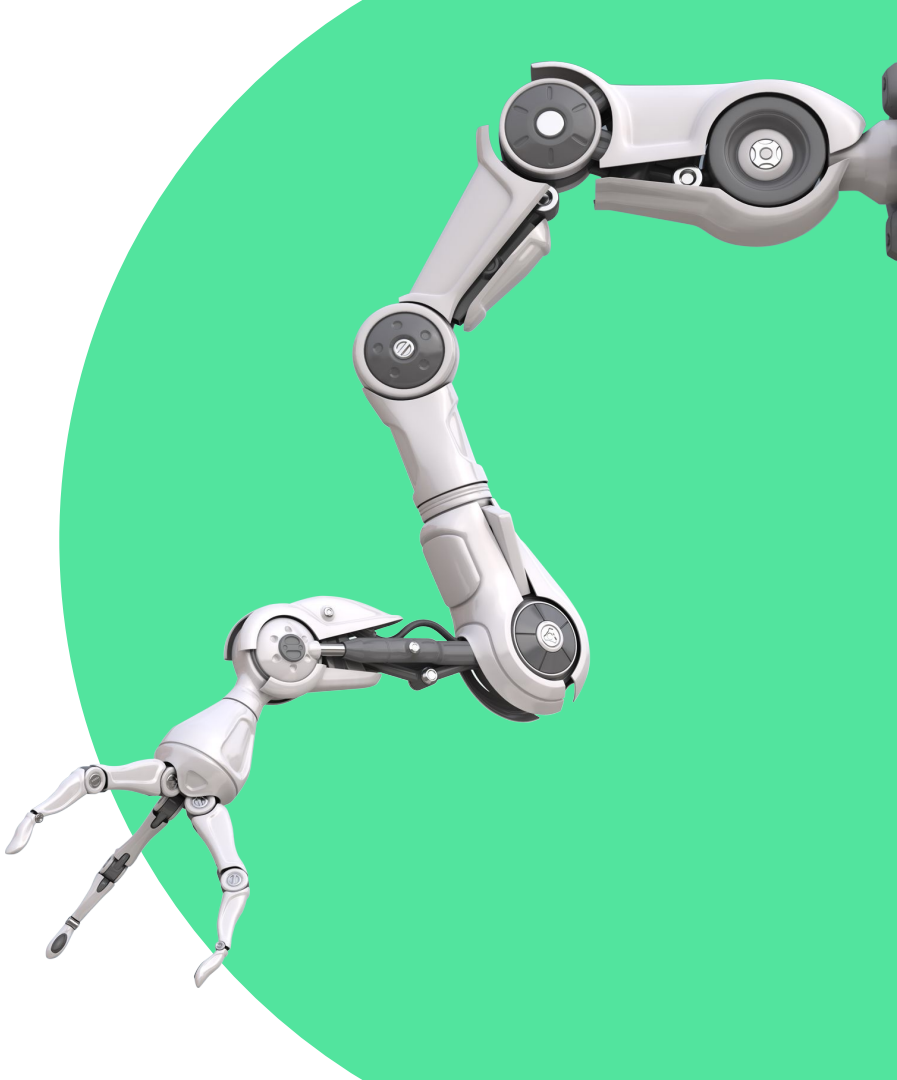
MoveIt for ROS2 - Update

ROS-I Community Meeting - June 2020



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MoveIt: Evolution of a Motion Planning Platform

arm_navigation

Version 1.0

2010

MoveIt!

Beta

2013

MoveIt!

Version 1.0

2019

MoveIt2

Version 2.0

2020

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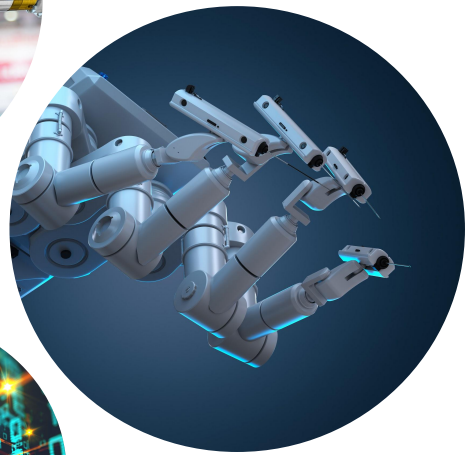
MoveIt Capabilities

- Motion Planning
  - Generate high-degree of freedom trajectories through cluttered environments and avoid local minimums
- Manipulation
  - Analyze and interact with your environment with grasp generation
- Inverse Kinematics
  - Solve for joint positions for a given pose, even in over-actuated arms
- Control
  - Execute time-parameterized joint trajectories to low level hardware controllers through common interfaces
- 3D Perception
  - Connect to depth sensors and point clouds with Octomaps
- Collision Checking
  - Avoid obstacles using geometric primitives, meshes, or point clouds



A Feature-Rich Ecosystem

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Global Planners
- OMPL
- SBPL
- TrajOpt
- STOMP
- CHOMP

Cartesian Planners
- RobotState
- Descartes
- JogArm
- PilzMotion

Inverse Kinematics
- KDL
- IKFast
- TracIK
- LMA
- BioIK

Grasping Libraries
- MoveIt Grasps
- Grasp Pose Detection (GPD)
- Intel OpenVino GPD

Collision Checking
- Fast Collision Library (FCL)
- Bullet

Perception / Octomap
- Depth Images
- Point Clouds

Why ROS2 vs ROS1?

- Realtime capabilities now available
- Designed for production - same support for R&D
- Multi-platform: Linux, Windows, macOS

MoveIt2

Milestone 1

Straight Port to ROS 2

Fully migrate existing MoveIt packages to ROS 2
- Wrap up Acutronic's work porting core MoveIt functionality

Leverage ROS 2:
- Build system (ament), middleware, logging, parameters

Cleanup MoveIt 2 codebase

Milestone 2

Realtime Support

Reactive, closed-loop control to sensor input
- Visual servoing, octomap updates
- Preempt motion if new collision detected

Seperate global and local planner (hybrid planning)
- Global planner (full collision checking): 30hz
- Local planner (IK-based, field-based): 300hz

Zero-memory copy integration to controllers (ros_control)
- Tighter integration to ros_control

Integrate pilz_industrial_motion

MoveIt Survey Results

91% most excited about ROS 2 realtime control

55% reactive planning and closed loop control

48% better integration with lower level realtime control

48% planning with dynamics

Milestone 3

Fully Leverage ROS 2

Lifecycle management of MoveIt nodes
- Deterministic startup, reset, & shutdown sequences

Leverage ROS2 component nodes
- Ability to run MoveIt as single or multi-process
- Replace pluginlib with components

Cleanup API
- More generic and standalone interfaces

MoveIt Survey Results

47% excited about component nodes

Future Milestones

Determinism

Out of box / default planners return reliable paths
- Tune or replace OMPL, BIT*

Further optimize / smooth paths
- Default use TOTG, TOPP time parameterization
- Use post-processing optimization (STOMP, TrajOpt)

Fully featured Cartesian Planner
- Like Descartes but better and fully integrated

Force-torque control

Improved Interfaces / State Machines

Deprecate the Pick and Place pipeline
- Fully support the MoveIt Task Constructor

First class support of state machines

Non-ROS C++ API
- Similar to MoveGroup but without middleware

Machine Learning

Neural-network based motion planning - new plugins
- General near-optimal heuristics for path planning
- e.g. MPNet

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Update

- Migration Progress: **~85.5%** - 53 of 62 total targets ported
  - We're in last phase of Milestone 1

    (see progress at https://github.com/ros-planning/moveit2/projects/4)
- Full plan/execution pipeline supported via MoveItCpp
- GSoC-project: JogArm port and improvements
- Preparing **Foxy 2.1 Beta** release for July 2020
- Milestones 1-3 are supported by ROSin

  (see https://www.rosin-project.eu/ftp/moveit-realtime-control-and-ros2-migration)
- Contributors from Intel and OSRF

Google Summer of Code

ROSin

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MoveIt 2 & Realtime

Why care about realtime motion planning?

Realtime-safety is required for online robot manipulations:

- Complex interactions with environment with forces, torques
- Dragging, pushing, smoothing, wiping, scraping
- Enables:
  - Reactive Closed-loop control
  - High rate joint command streaming (e.g. >1 kHz)
  - Low latency and reliable sensor->control pipeline

Milestone 2 - Realtime Support

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Goal: Use ROS 2 real-time features for robust and dynamic motions

- Feature 1: Adaptive & Reactive Closed-loop control
- Feature 2: Dynamic trajectory execution using hybrid planning
- Feature 3: Zero-memory copy integration with ROS controllers

Feature 1: Reactive Closed-loop control

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Goal: Execute simple motions based on dynamic goal or path constraints

Examples:

- Vision-based: Picking a detected item off a moving conveyor belt
- Force-based: Pulling a lever, tighten up a screw

Possible approach:

- Compute JogArm position control based on vision/force input

Problem: Only works locally, gets stuck in local minima

Feature 1: Reactive Closed-loop control

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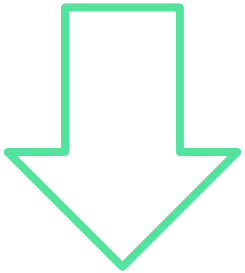
Problem: Only works locally, gets stuck in local minima



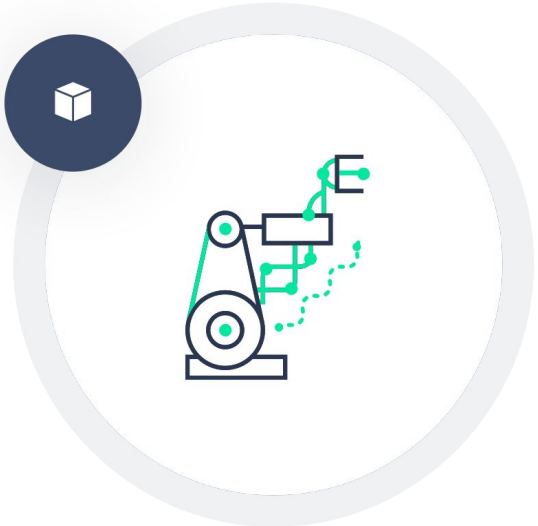
Proposal: Use hybrid planning to always include global solution (*Feature 2*)

Proposed: Hybrid Planning

- Simultaneously plan globally and locally
- Plan at different speeds (separate threads)
  - Global planner (full collision checking): ~30Hz
  - Local Planner (IK-based, field-based): >300Hz
- Support force-based planning

Example Applications:

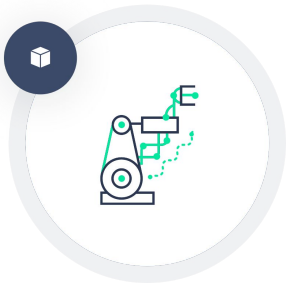
- Human-robot collaboration
- Painting a wall
- Filling a dishwasher
- Balancing a tray while placing on table



Global Planning

i.e. Sampling based

- Pros:
  - Plan around complex obstacles
  - Avoid getting stuck in local minimum
  - Complete: will find solution if exists
- Cons:
  - Slower computation time
  - Not realtime
  - Not deterministic



Local Planning

i.e. Jacobian based

- Pros:
  - Fast / Reactive
  - Deterministic
  - Well suited for visual servoing
- Cons:
  - Gets stuck in local minimum
  - Fewer collision safety guarantees

Feature 2: Dynamic trajectories using hybrid planning

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Goal: Execute adaptive and reactive motions using global/local planning

Adaptive Motion - *Drawing on a chalkboard*

- Global planner defines the motion required for drawing the letters
- Local planner follows motion while controlling for force, smoothness, etc..

Reactive Motion - *Steering around a new collision object in the scene*

- Global planner used for fixing invalidated trajectories
- Local planner allows “keeping clear” from objects using field-based distance minimization

Feature 2: Dynamic trajectories using hybrid planning

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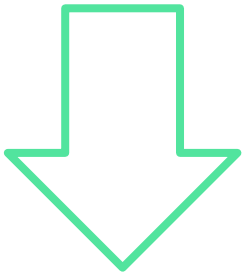
Problem: ROS controller and node communication latency



Proposal:

- Implement zero-memory copying with ROS controllers (*Feature 3*)
- Composable nodes (*Milestone 3 - Fully Leverage ROS 2*)

Improving MoveIt 1 with MoveItCpp

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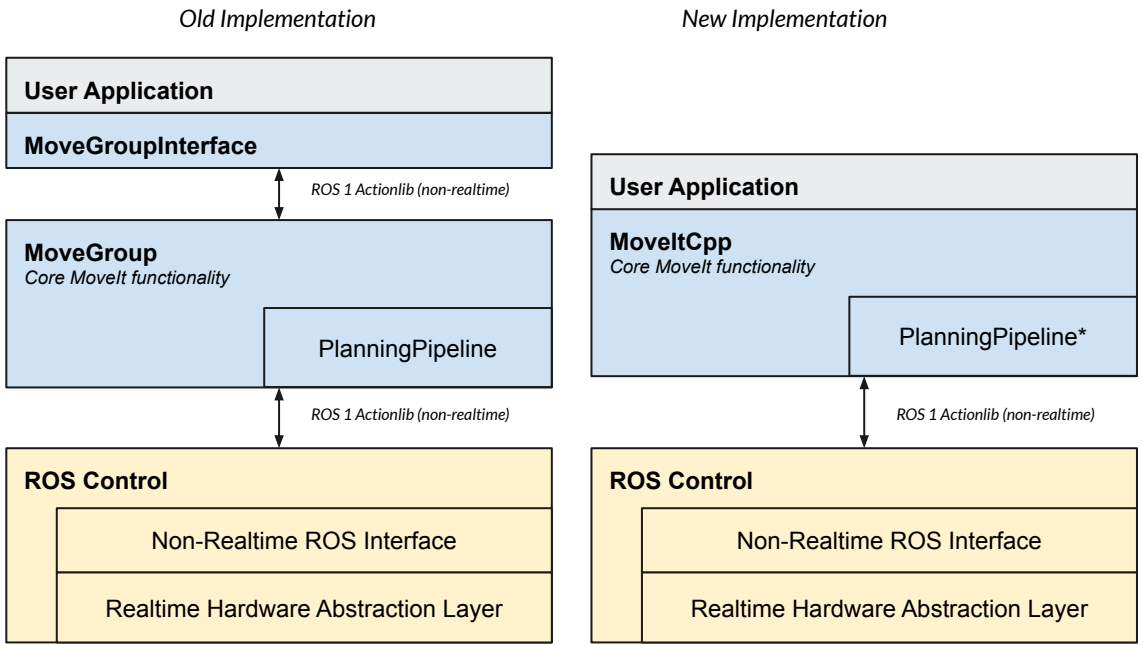
- Direct access to core MoveIt components
- Support for multiple planning pipelines
- Support for running multiple robots
    - More flexible configuration



MoveIt 2 Architecture

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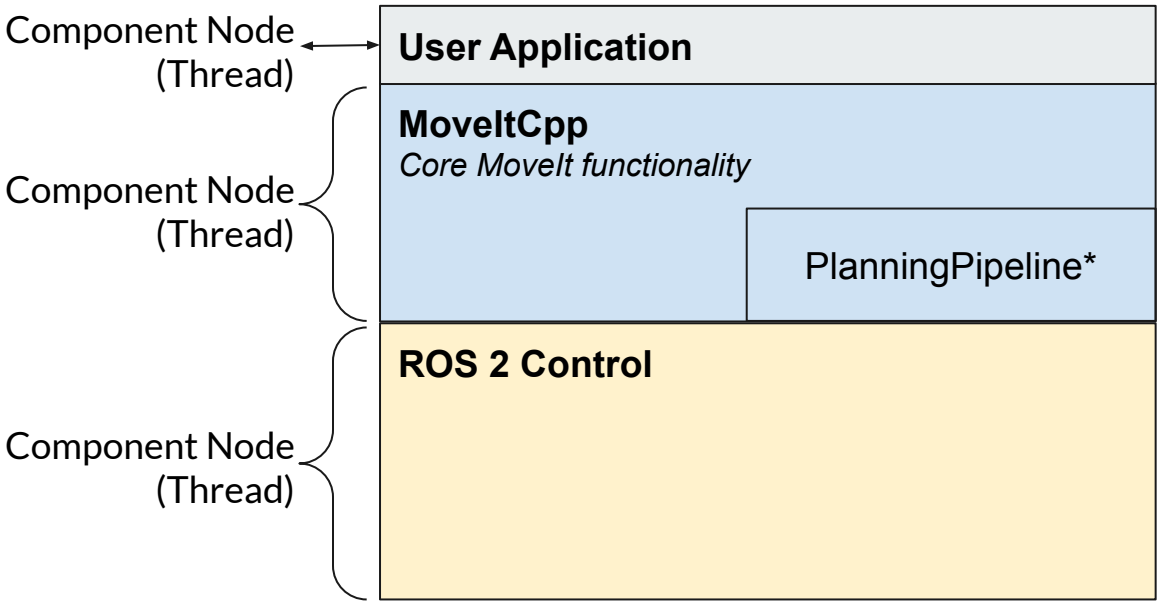
- Leverage ROS2 component nodes for better performance (Milestone 3)



MoveIt 2 Architecture

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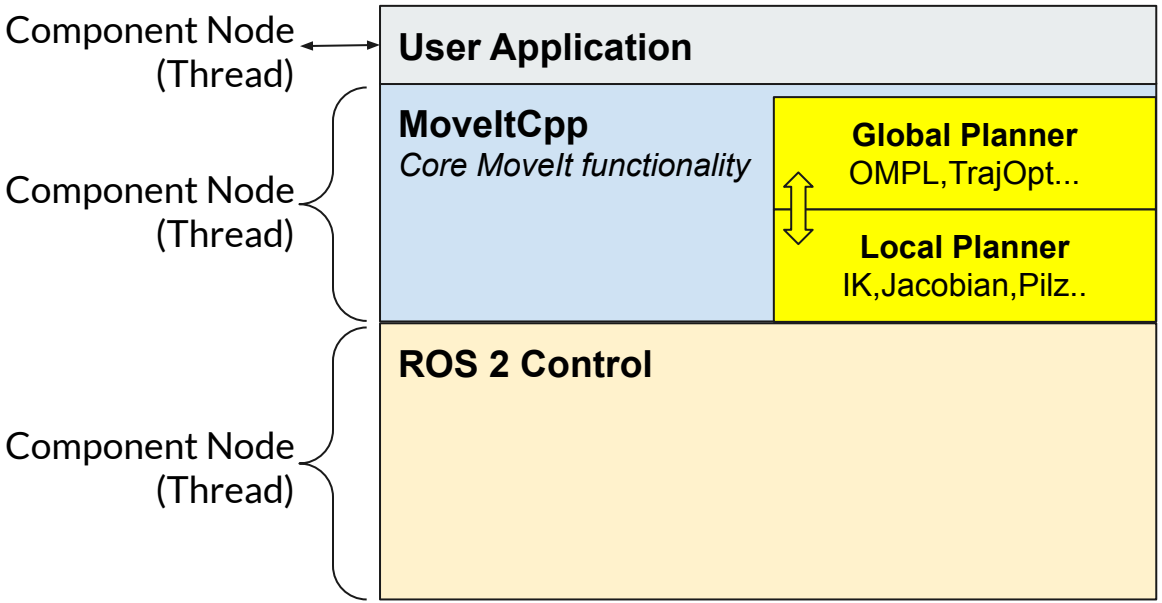
- Hybrid motion planning



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Getting Involved

Open Discussions

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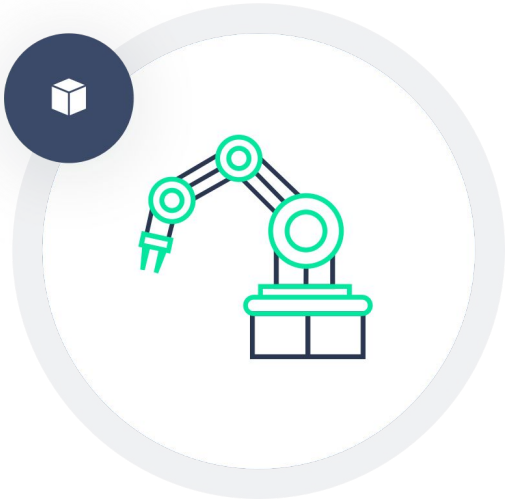
- Launch configuration and node lifecycle management
- Best practices for parameter declaration, lookup and sharing
- MoveIt ROS1 legacy support (bridges) and migration guide
- Branch/repo syncs and release strategies
- Support for dynamic robot model description
- Composable node architecture and component interfaces
- Enhanced ros2_control integration
- Native support for state machine integration
- MTC-enabled pick&place pipeline
- ...



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Get Involved

https://github.com/ros-planning/moveit2

Many approaches:

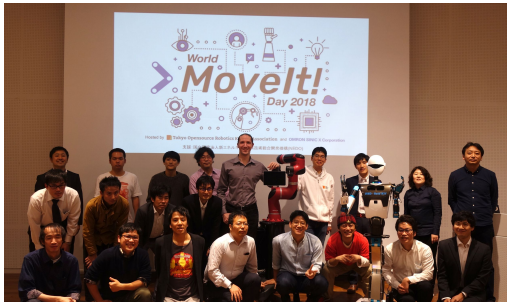
- Adding New Features
- Helping with MoveIt 2 Port
- Financial contributions via code sprints and grants
- Enhancing Documentation
- Reporting & Fixing Bugs

MoveIt2

Upcoming Events

MoveItCon

November 17th, 2020



More event info: moveit.ros.org

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Thanks!

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