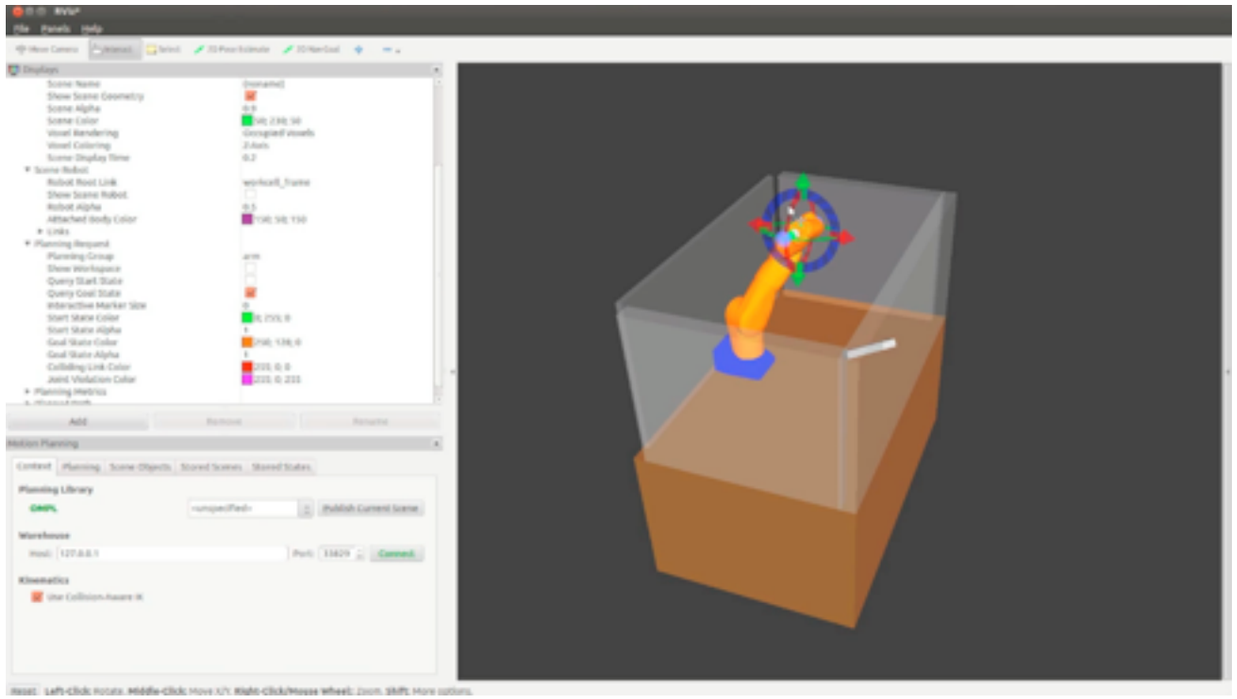
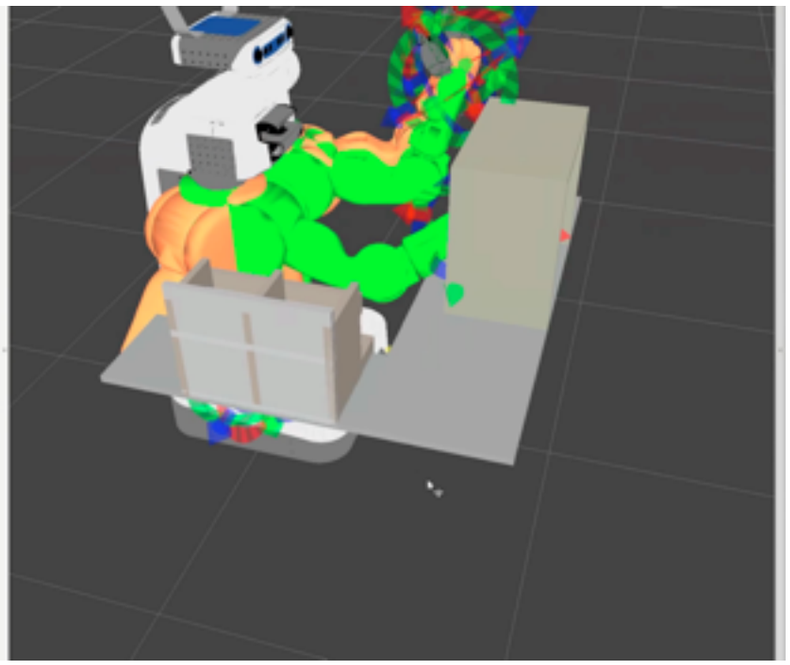

Sachin Chitta, Ioan Sucan, Acorn Pooley

with contributions from: Dave Coleman, Suat Gedikli, Mario Prats, Matei Ciocarlie, Kaijen Hsiao, Jon Binney, Adam Leeper, Julius Kammerl, David Gossow, Vincent Rabaud, Dave Hershberger and the ROS and PR2 communities

# What is MoveIt!

- MoveIt!- Software for building mobile manipulation applications
    - ❖ Motion Planning, Kinematics, Collision Checking integrated with Perception, Grasping, Control and Navigation for Mobile Manipulation





# Motivation

- Build state of the art software platform for robotics applications and research
- “Simple things should be easy”
  - Provide out-of-the-box experience
    - easy to setup with new robots - Setup Assistant
    - Easy to use APIs - C++ and Python
- “Allow users to dive deeper to address harder problems”
  - Flexible platform - easy to add new components
- Performance
  - design for high performance

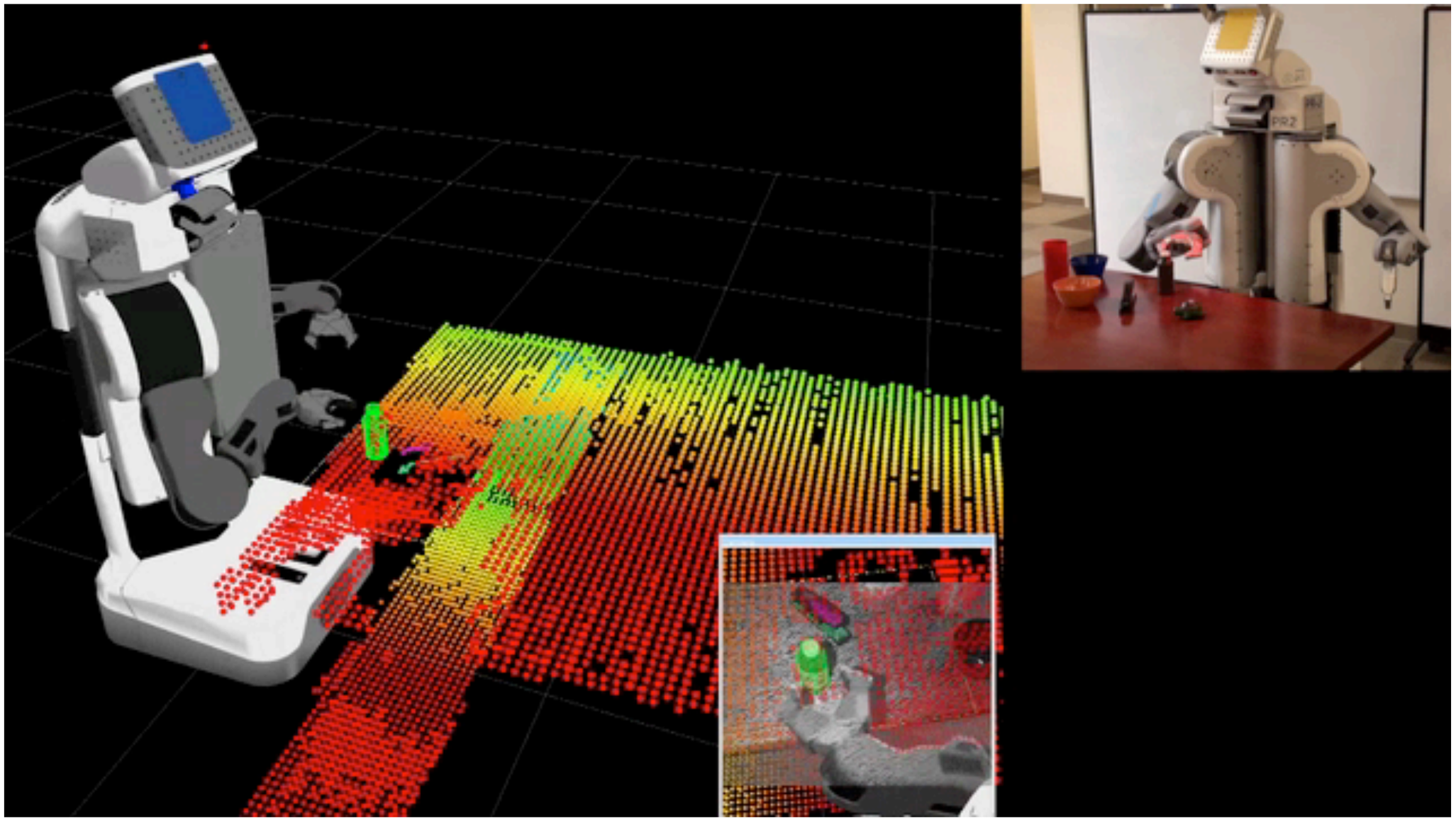
# Motivation

- Developing new higher-level capabilities is time-consuming
  - building every capability from scratch is a waste of effort
- Environment awareness critical for new applications
  - Integrated 3D perception can provide situational awareness, improving safety, especially in human-robot collaborative tasks
- Motion Planning important for dynamic changing environments
  - essential for maintaining safety and performance in human-robot collaborative tasks
- Constrained manipulation tasks are hard to solve
  - increasingly complex types of constraints need to be handled

# MoveIt!: Evolution

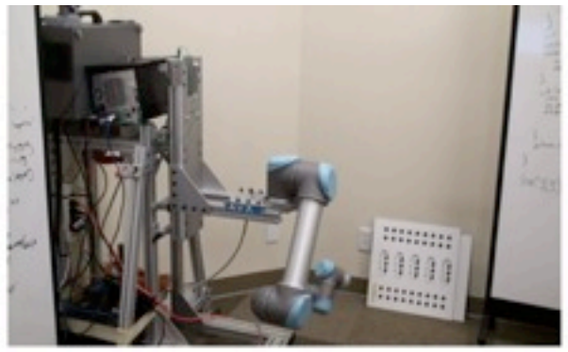
- MoveIt! has evolved from the arm_navigation and grasping pipeline set of stacks
  - essentially a rewrite from scratch
  - ROS API almost the same
  - incorporates lessons learnt

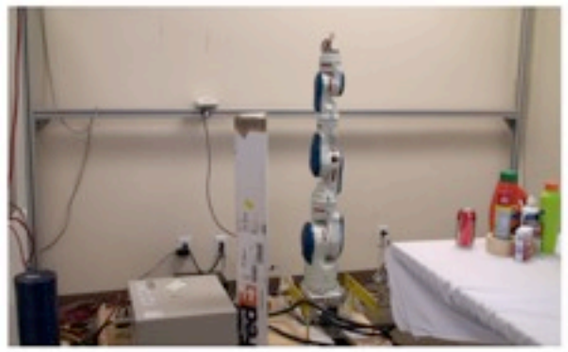
# Mobile Manipulation: State of the art

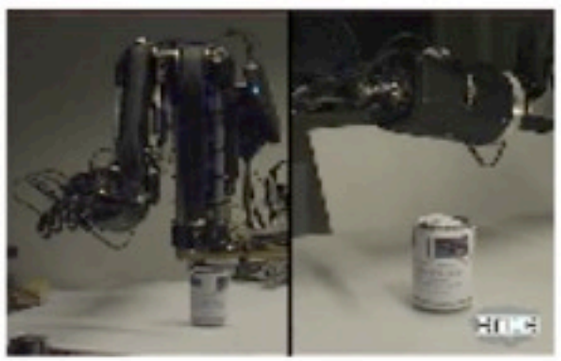


Chitta, Jones, Ciocarlie, Hsiao, Sucan, 2011

# Robots Using Our Software



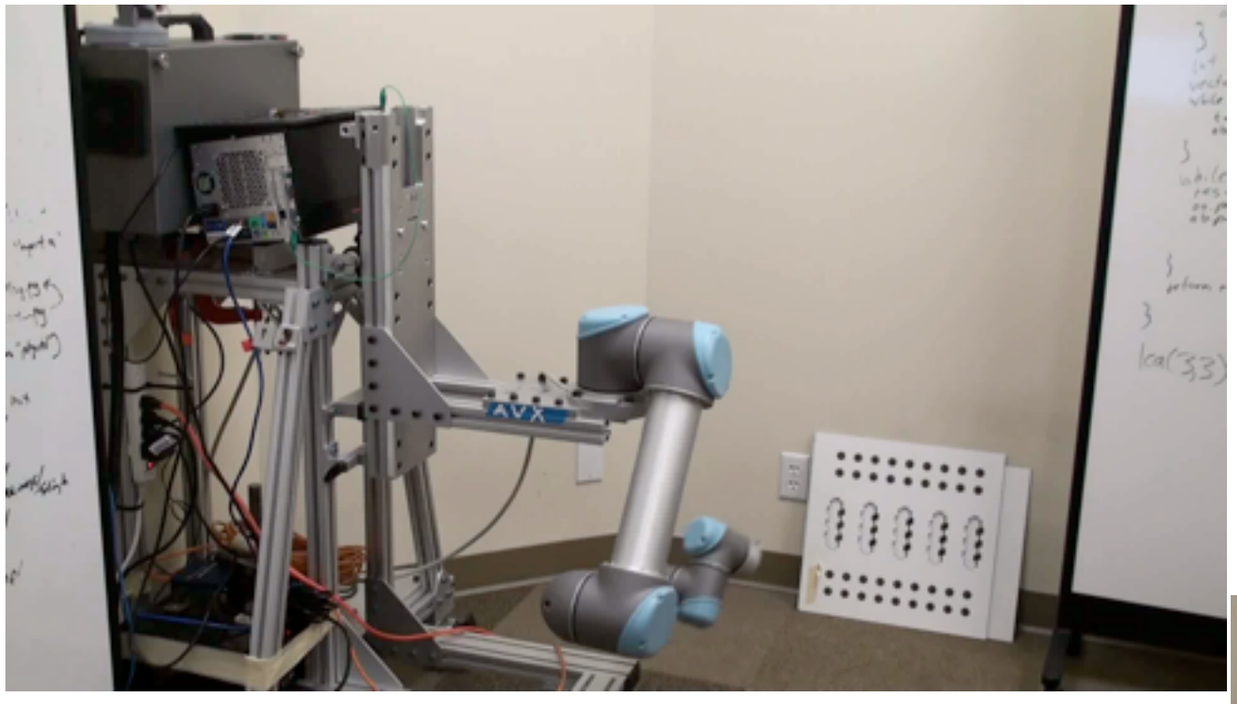


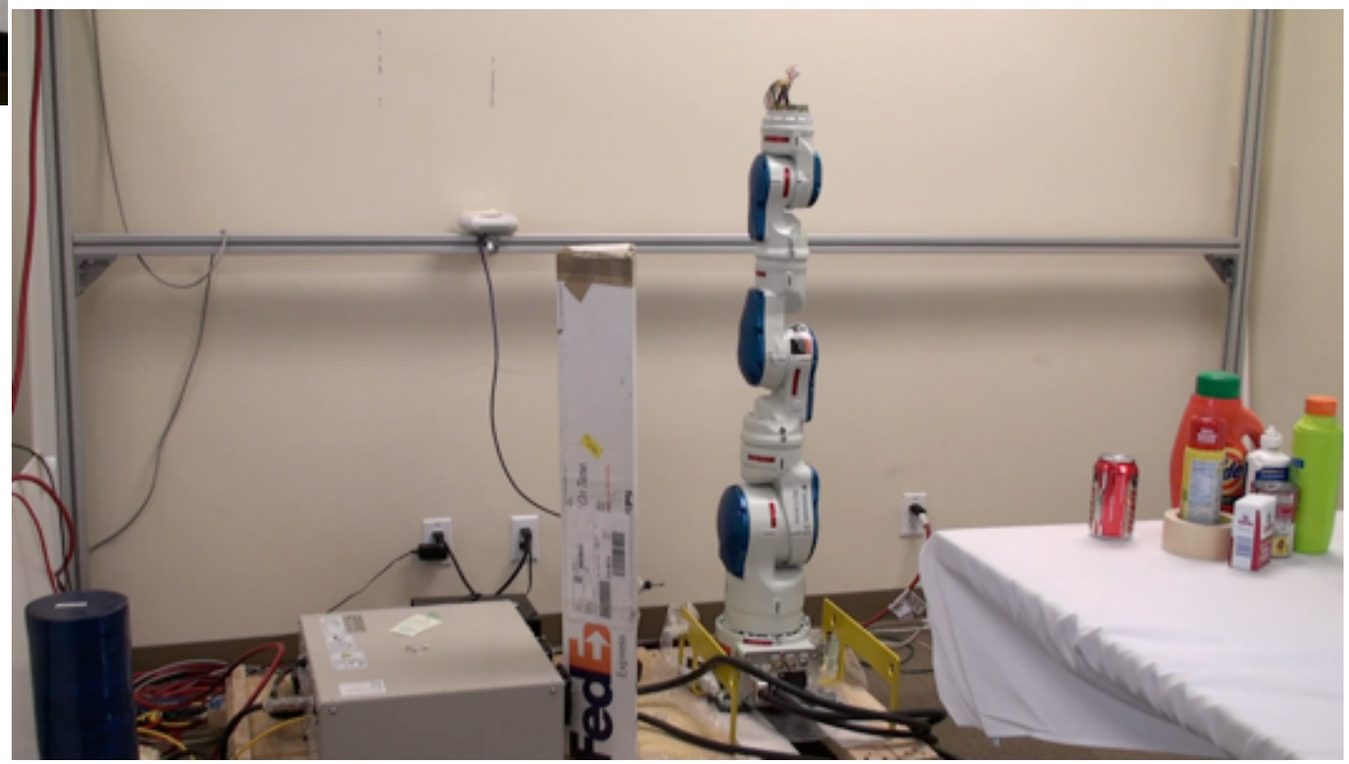


# Application - ROS-Industrial

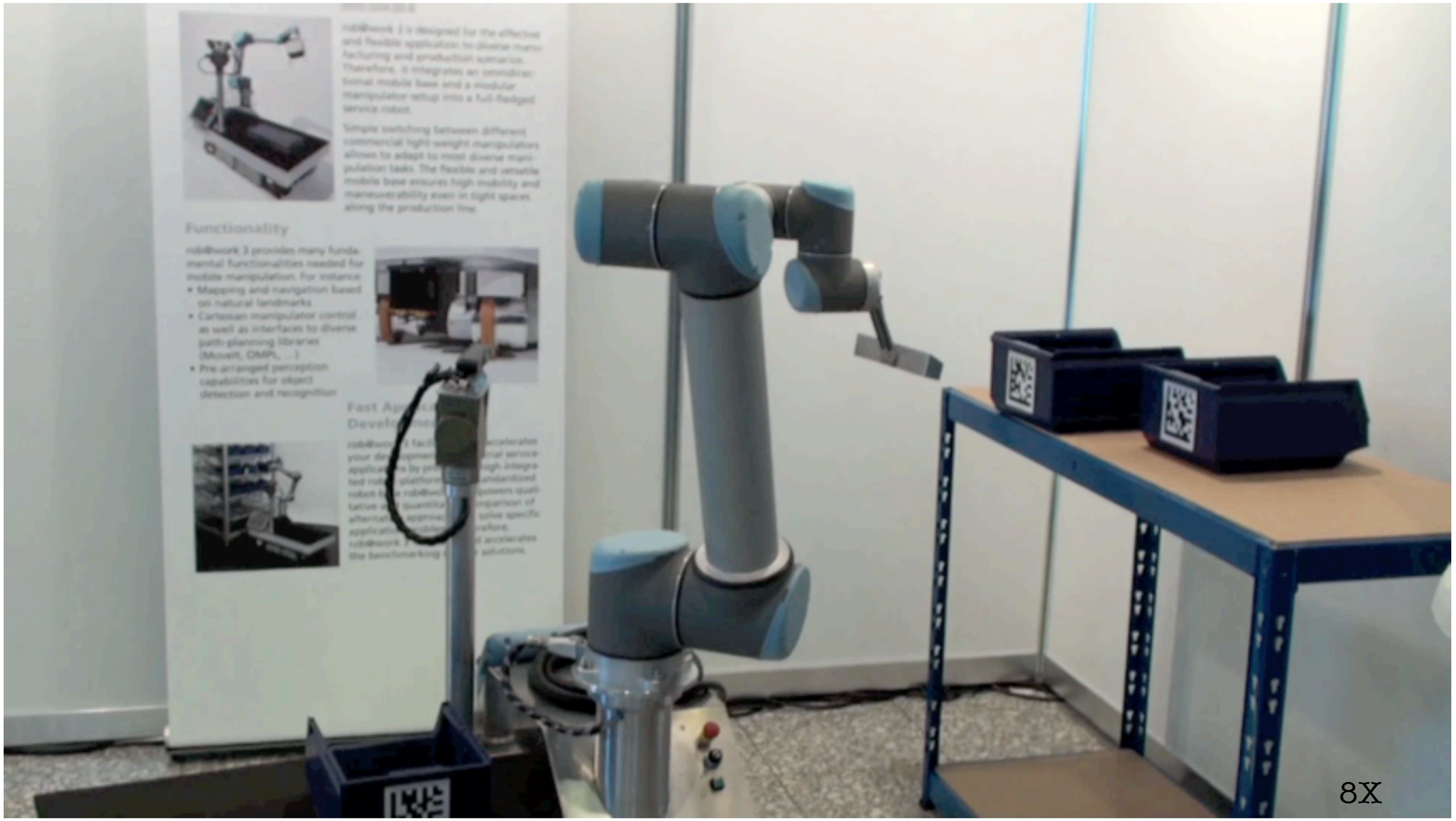

*collaboration between Willow Garage, SWRI and Yaskawa
http://www.rosindustrial.org

# MoveIt!





# Application - ROS-Industrial

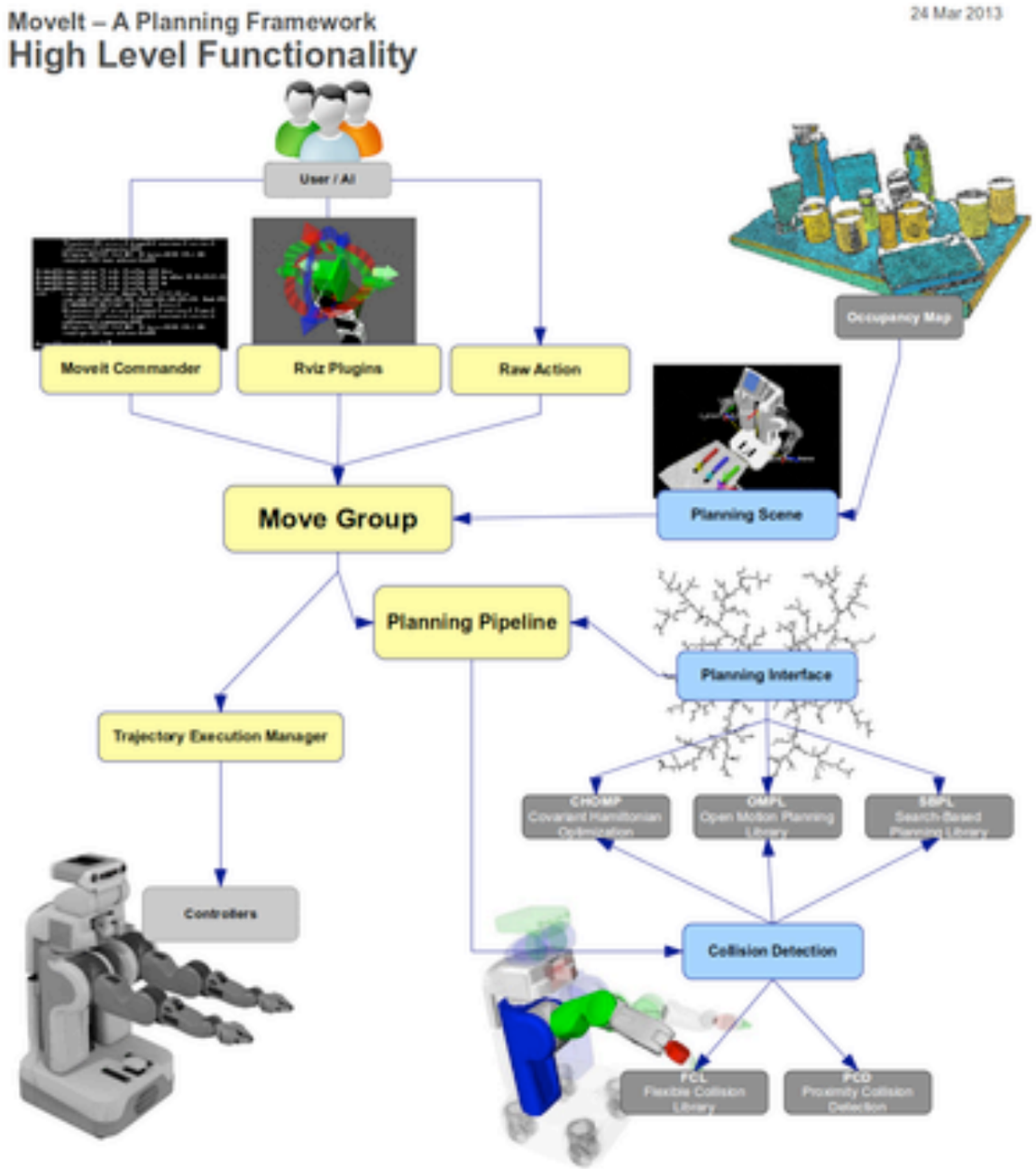



Rob@Work running MoveIt!

# MoveIt!

- Technical Capabilities
  - ❖ Collision Checking: fast and flexible
  - ❖ Integrated Kinematics
  - ❖ Motion Planning
    - fast, good quality paths
    - kinematic constraints
  - ❖ Integrated Perception for Environment Representation
  - ❖ Standardized Interfaces to Controllers
  - ❖ Execution and Monitoring
  - ❖ Kinematic Analysis

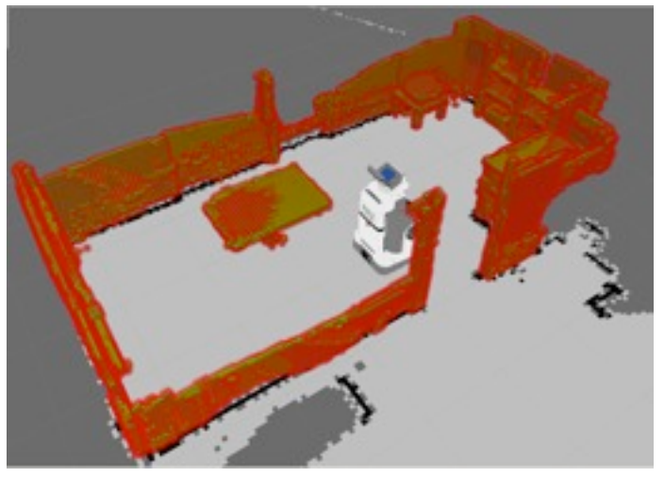
# MoveIt!


MoveIt – A Planning Framework
High Level Functionality
24 Mar 2013
User / AI
MoveIt Commander
Rviz Plugins
Raw Action
Occupancy Map
Move Group
Planning Scene
Planning Pipeline
Planning Interface
Trajectory Execution Manager
Controllers
CHOMP
Covariant Hamiltonian Optimization
OMPL
Open Motion Planning Library
SBPL
Search-Based Planning Library
Collision Detection
FCL
Flexible Collision Library
PCD
Proximity Collision Detection

# Collision Checking

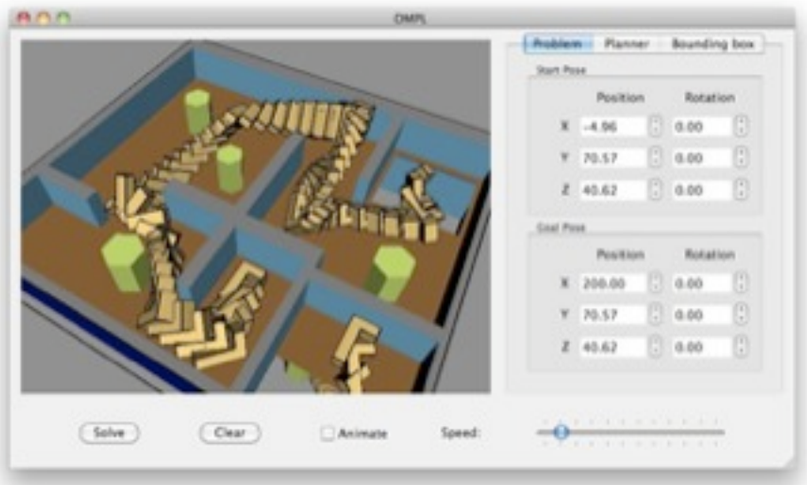
- FCL - Flexible Collision Library*
  - ❖ parallelizable collision checking
  - ❖ Maximum about 2-3,000 full body collision checks for the PR2 per second
    - ✓ with realtime sensor data
    - ❖ + high fidelity mesh model
- Proximity Collision Detection

  - ❖ Uses 3D distance transform to determine distance to nearest obstacle and gradient
  - ❖ + very fast - 40 to 80,000 collision checks per second for the full body of the PR2
  - ❖ - not as accurate



*Pan, Sucan, Chitta, Manocha - 2012

# Motion Planning

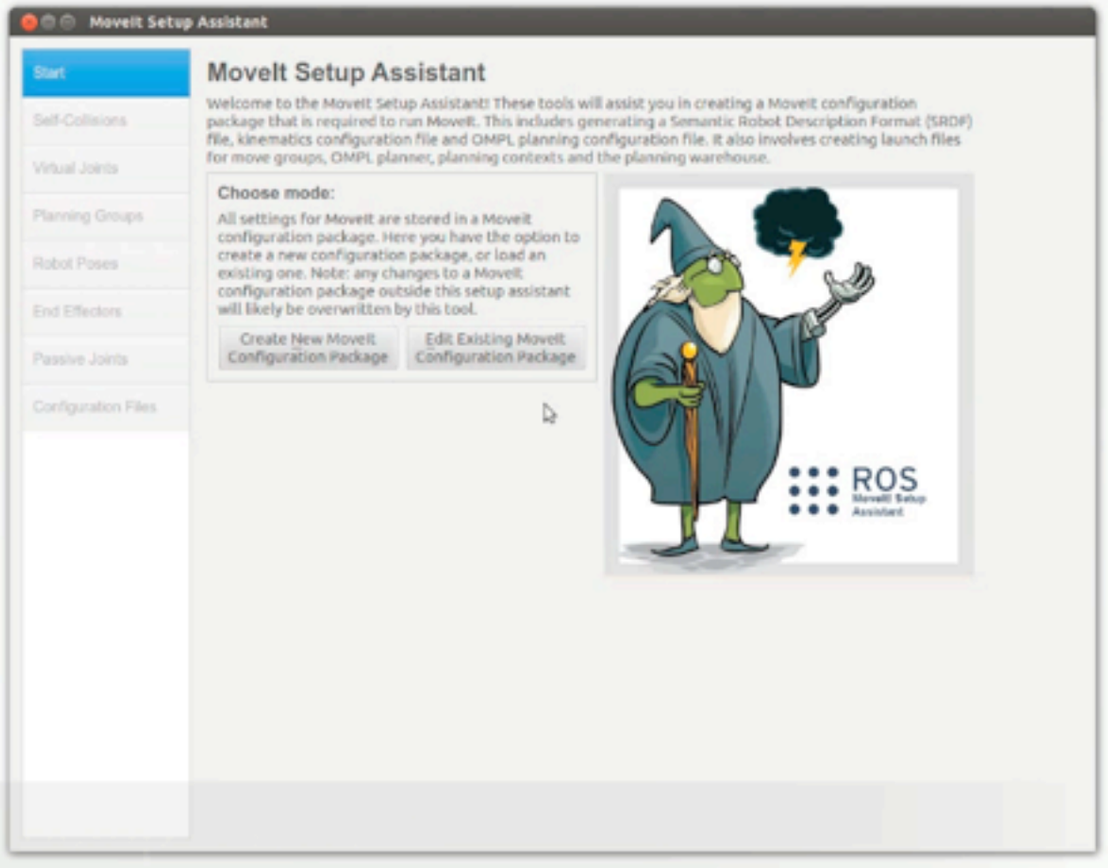



- Plugin interface for planners
- Integration with robots through MoveIt!
- Automatically configured using the MoveIt! Setup Assistant
  - Sampling based planners (OMPL) *http://ompl.kavrakilab.org
  - Search Based Planning Library (SBPL) *http://www.ros.org/wiki/sbpl



*OMPL - Sucan, Moll, Kavraki (Rice University), SBPL - Max Likhachev (CMU)

# Easy Setup and Configuration



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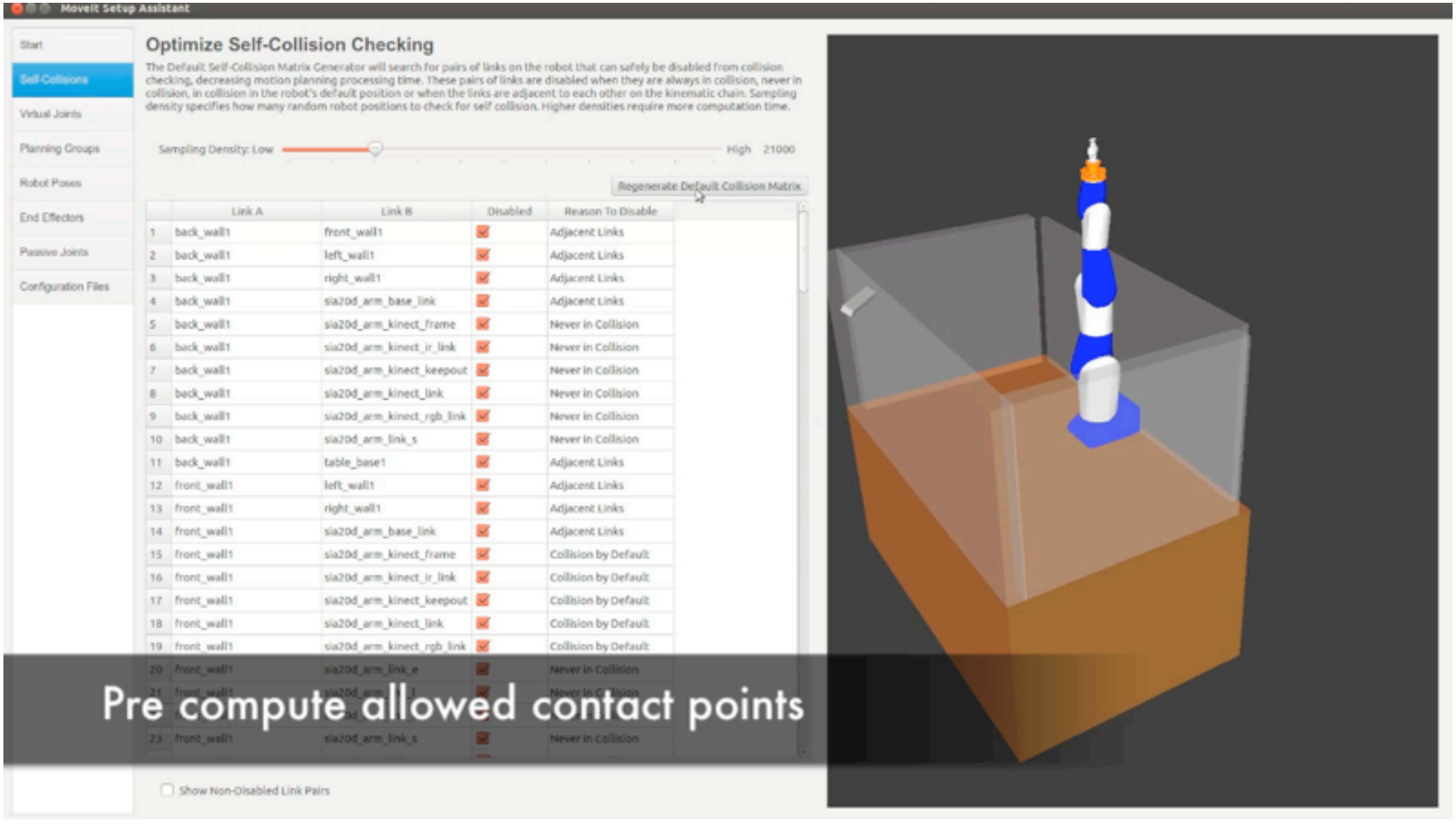

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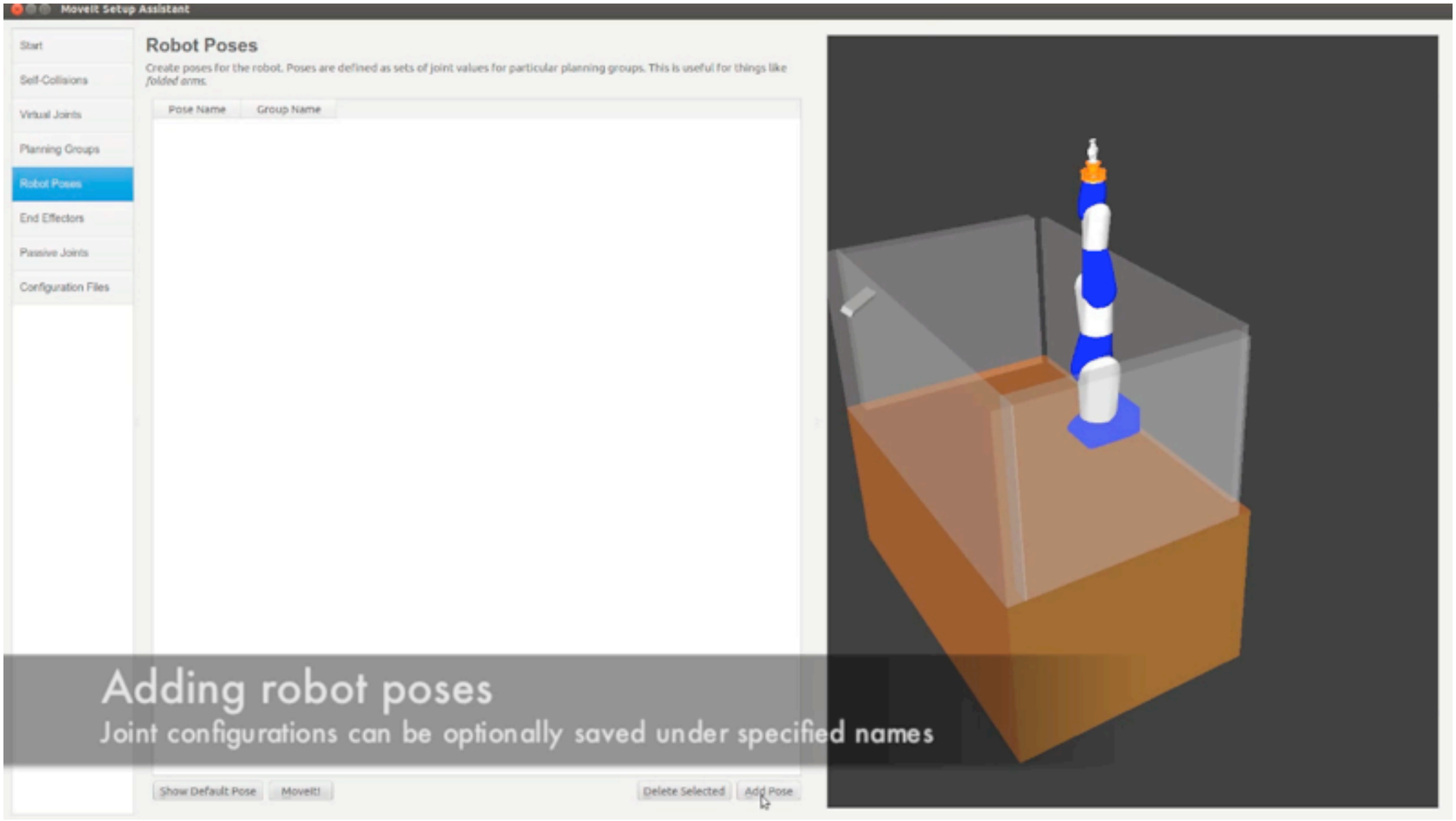

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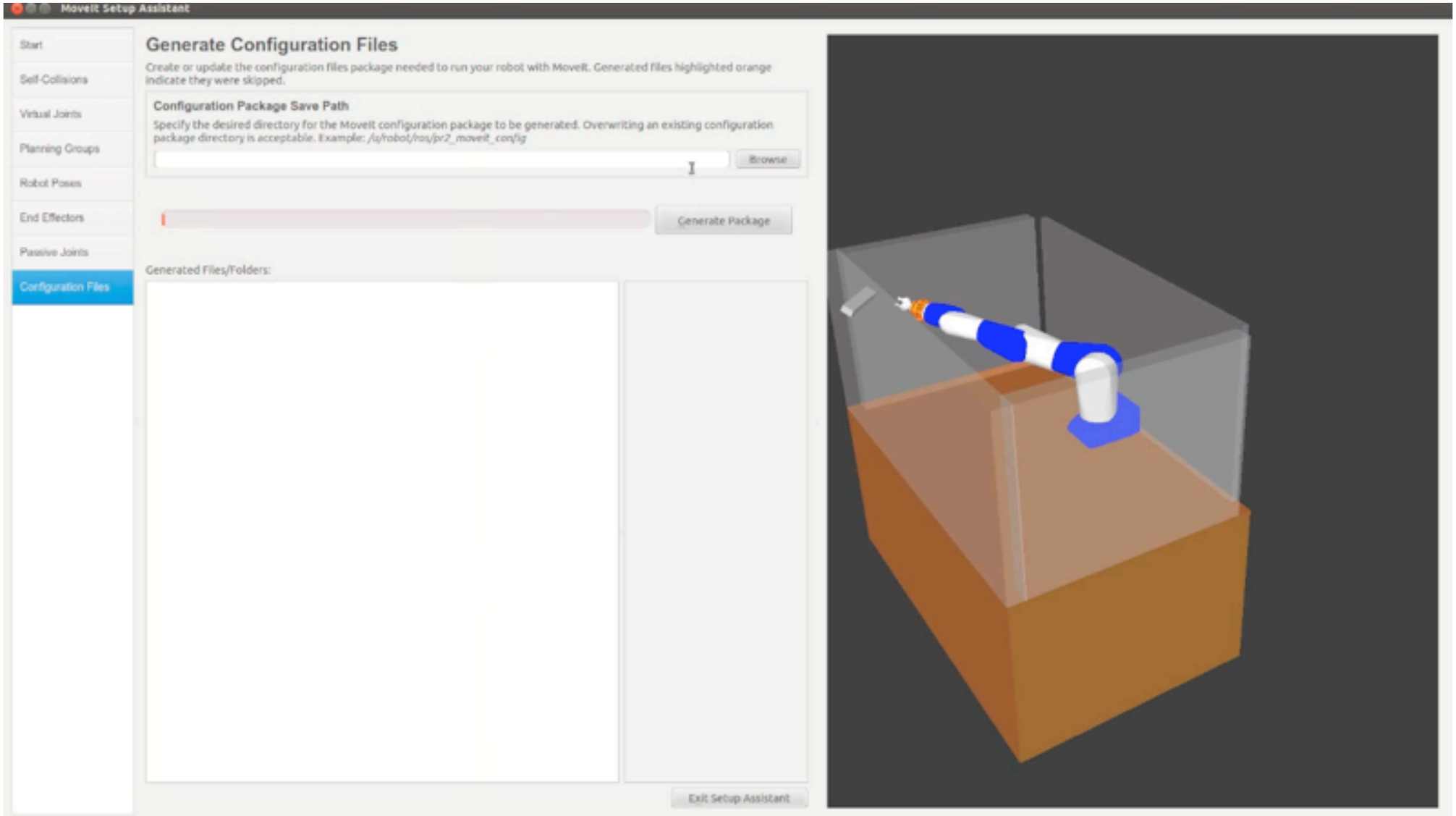

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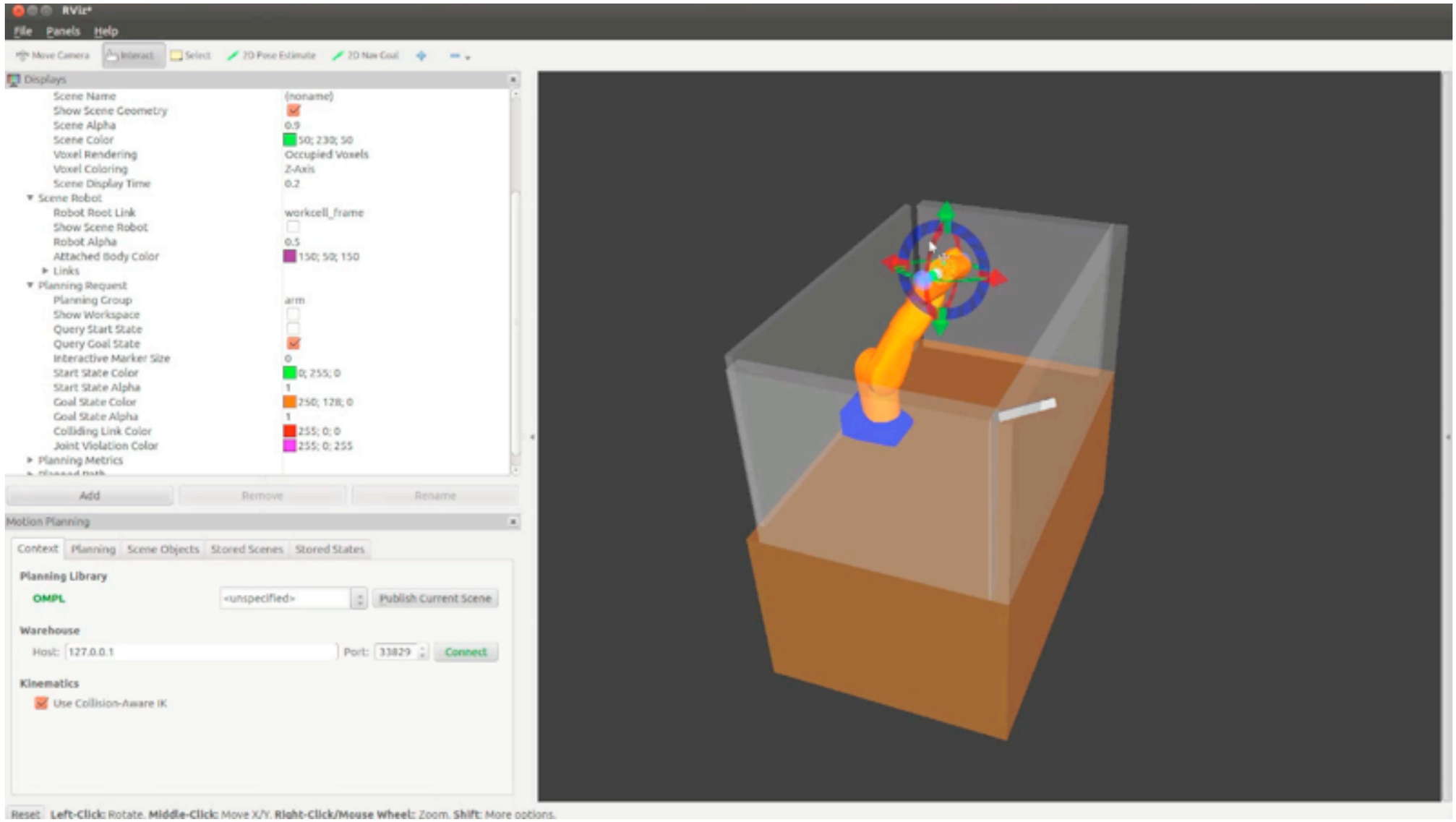
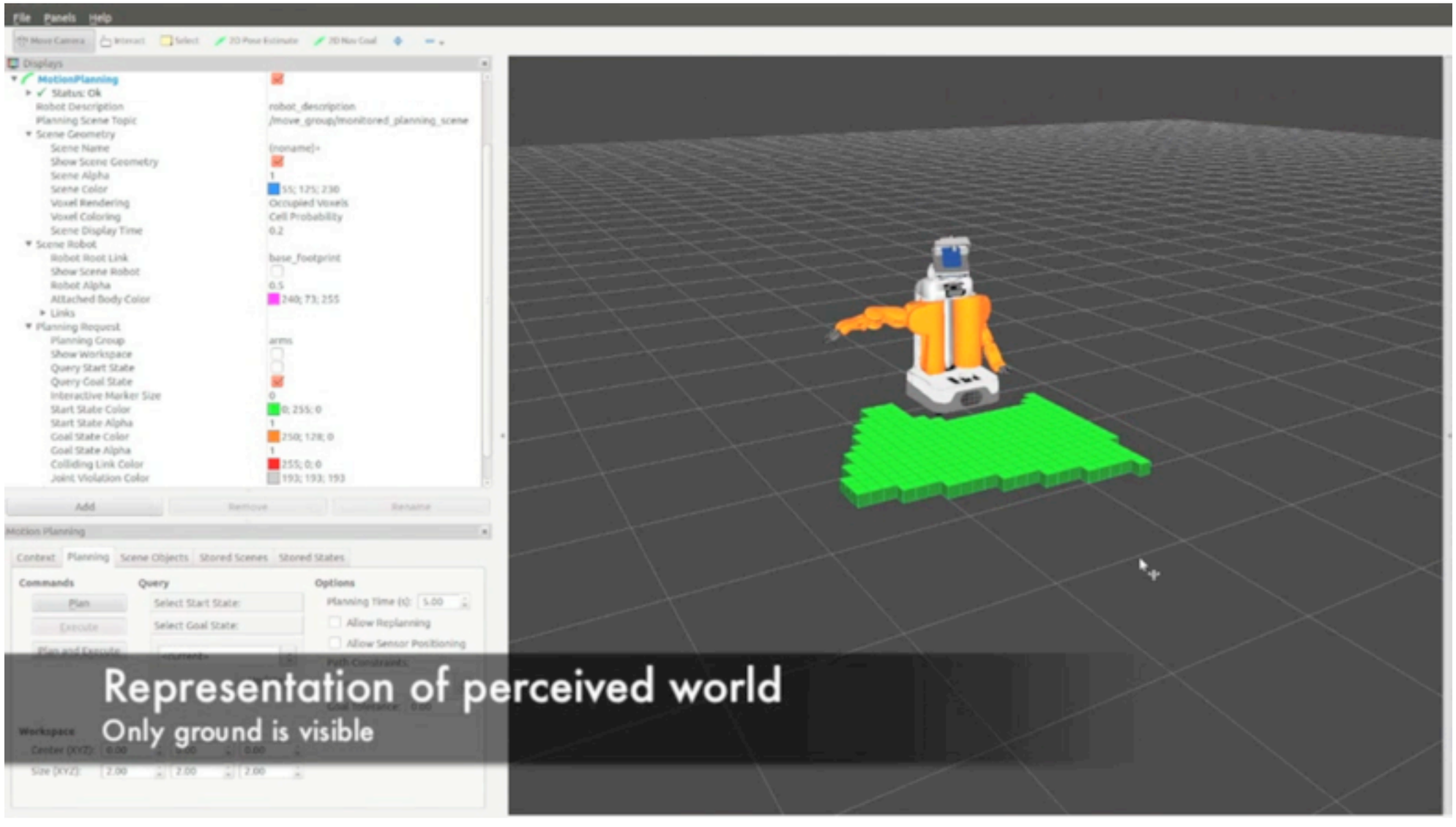


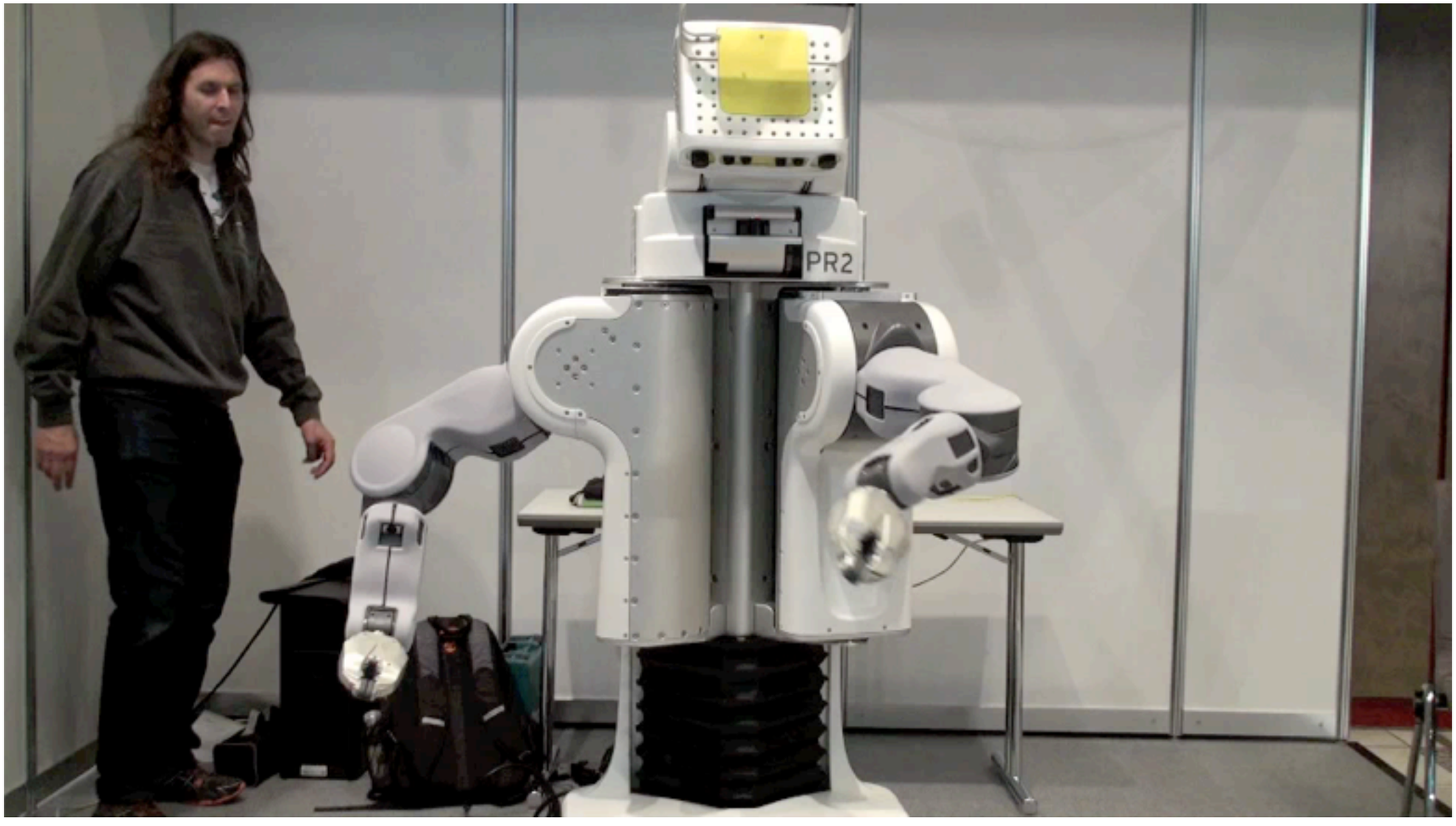

Live Demo by Dave Coleman later today!!

# Integrating Perception



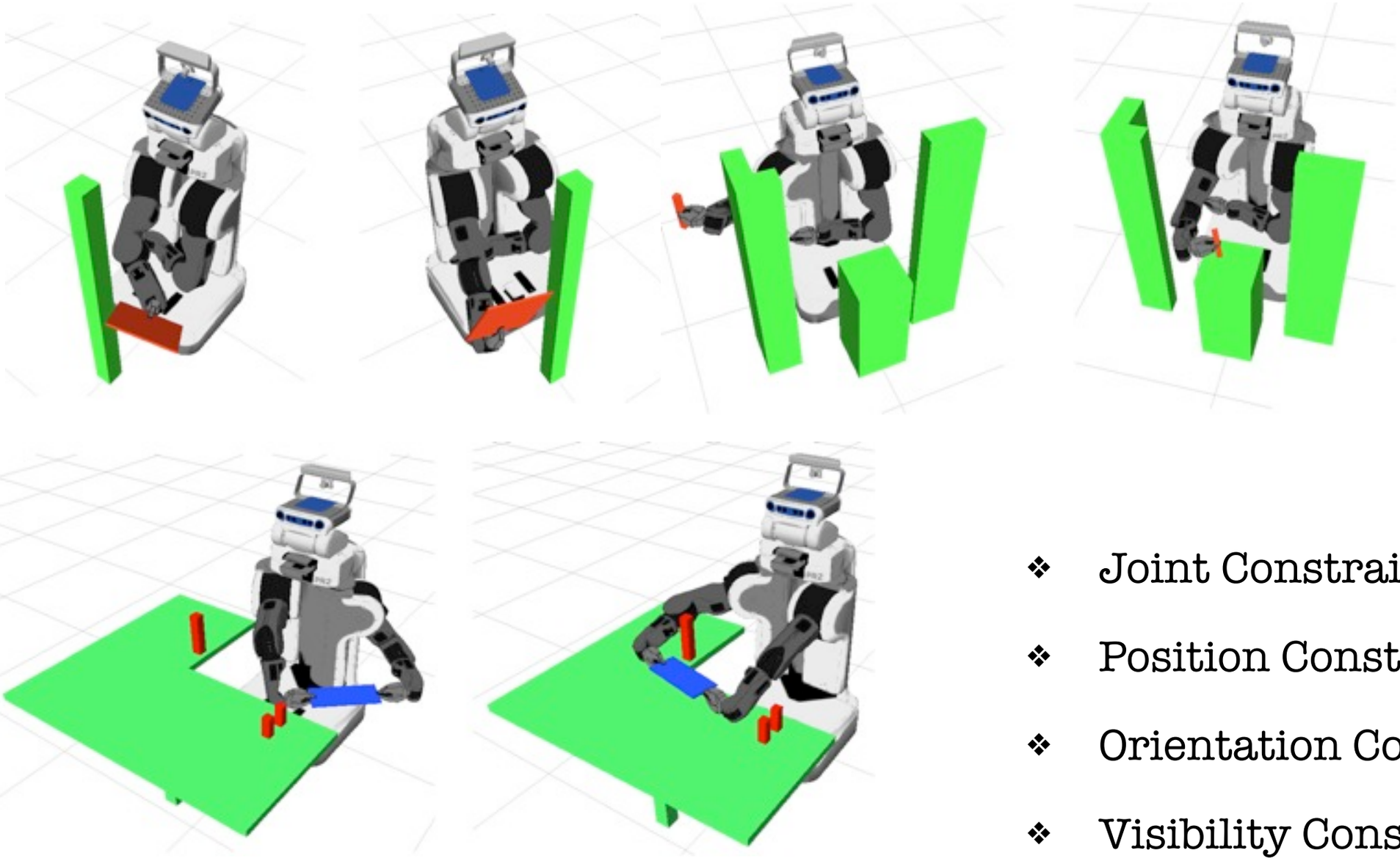

Octomap: octomap.sf.net
Point Cloud Library: pointclouds.org

# Reactive Motion



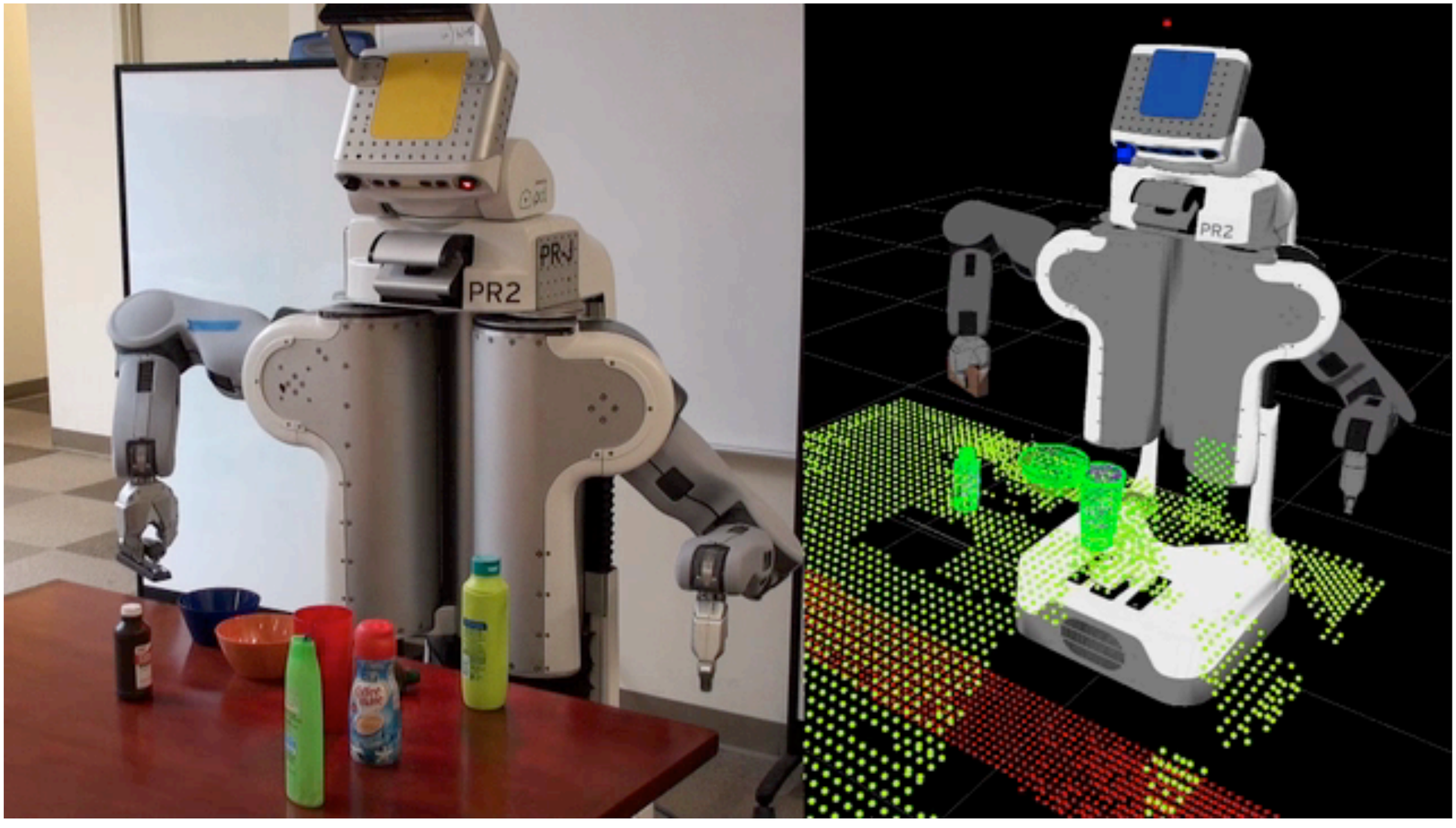

* Live Demo later!!

# Constraint Representation

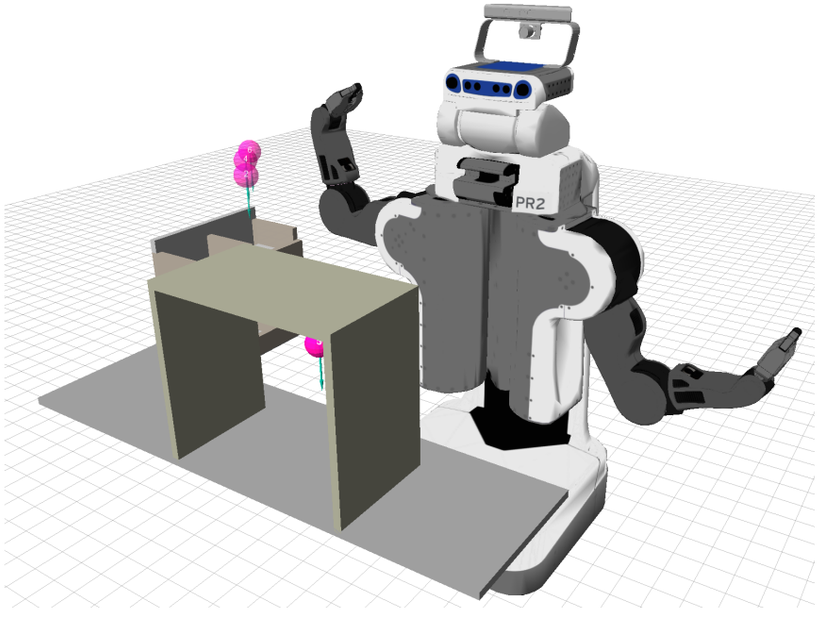


- Joint Constraints
- Position Constraints
- Orientation Constraints
- Visibility Constraints

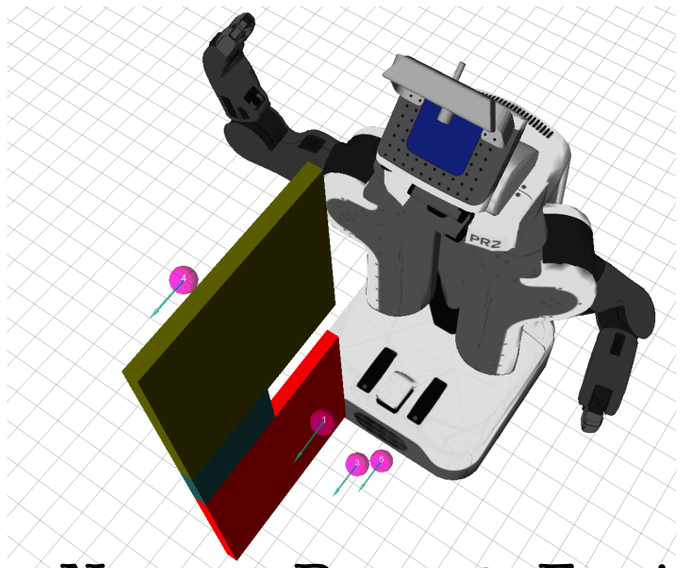
# Orientation Constraints



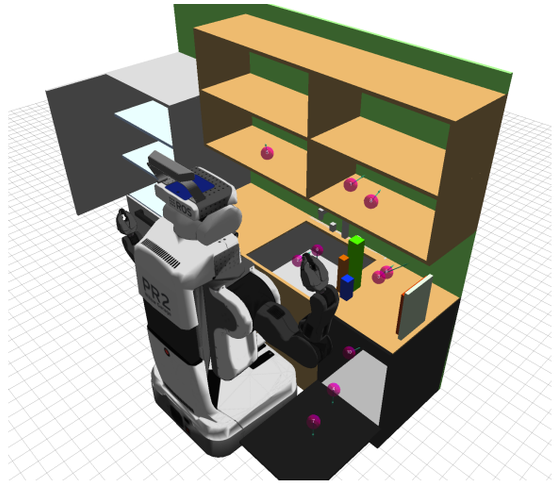
# Applications: Benchmarking



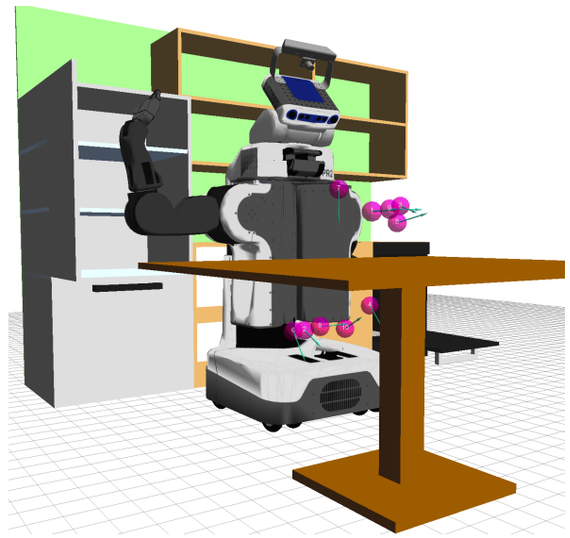
- Industrial Environment



- Narrow Passage Environment



- Kitchen Environment

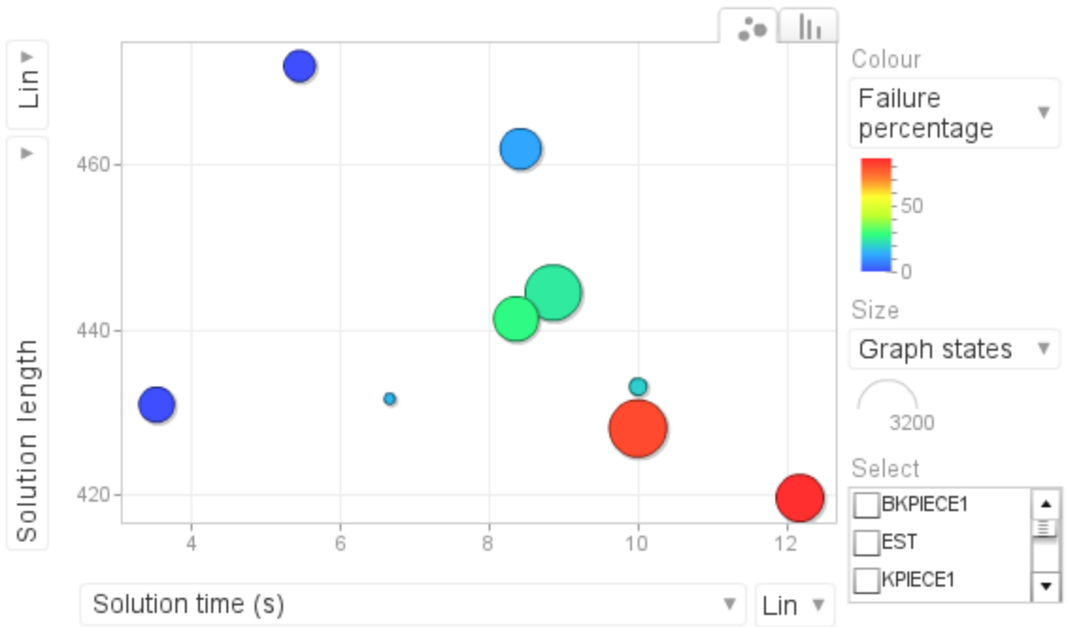


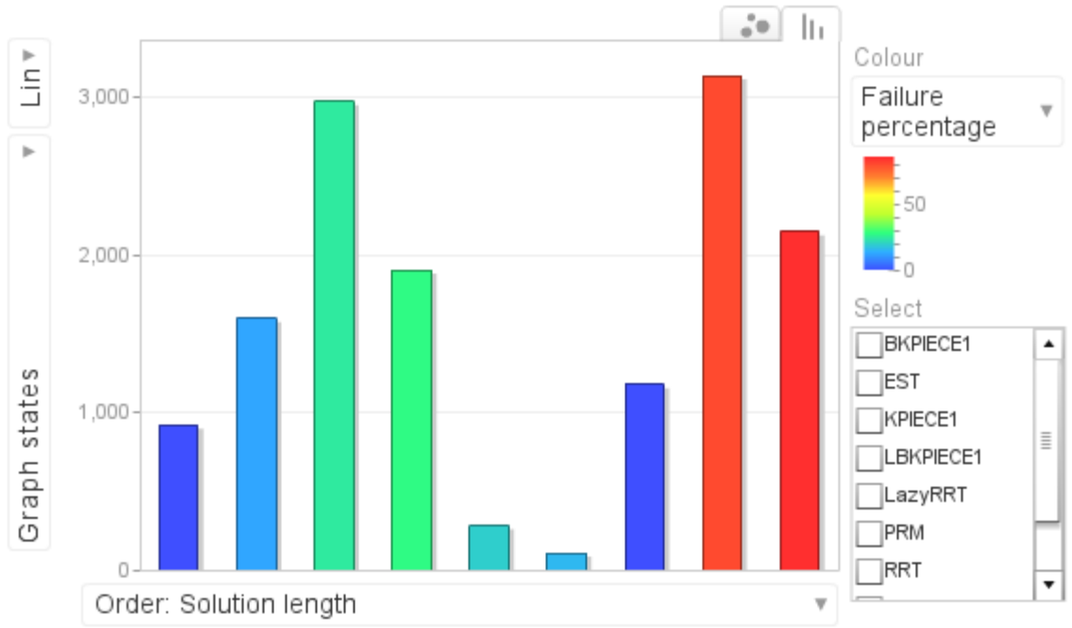
- Tabletop Environment



* Cohen, Sucan, Chitta, “A Generic Infrastructure for Benchmarking Motion Planners”, IROS 2012, Portugal

# Benchmarking



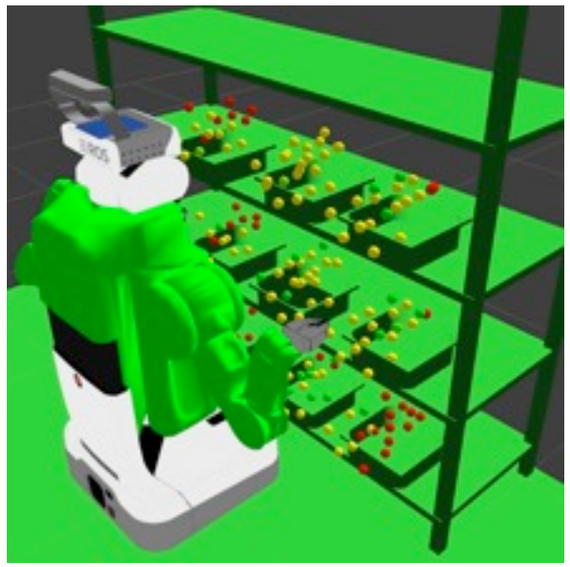



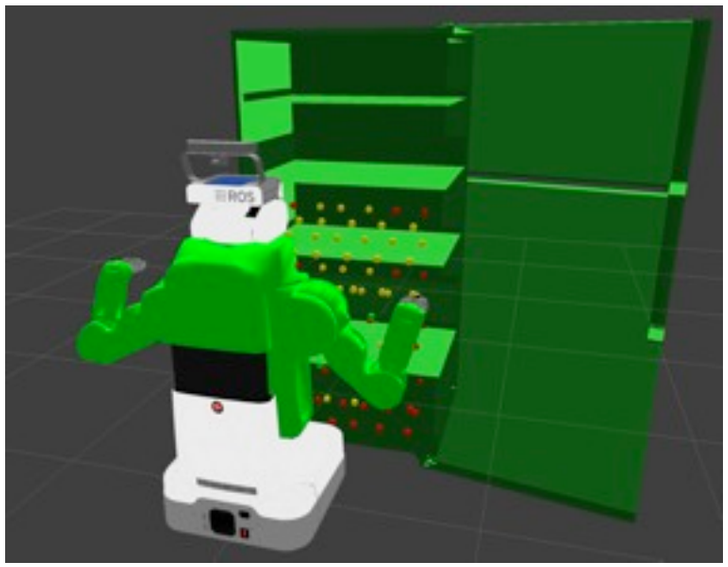

More in Talk by Ryan Luna and Ioan Sucan (later today)

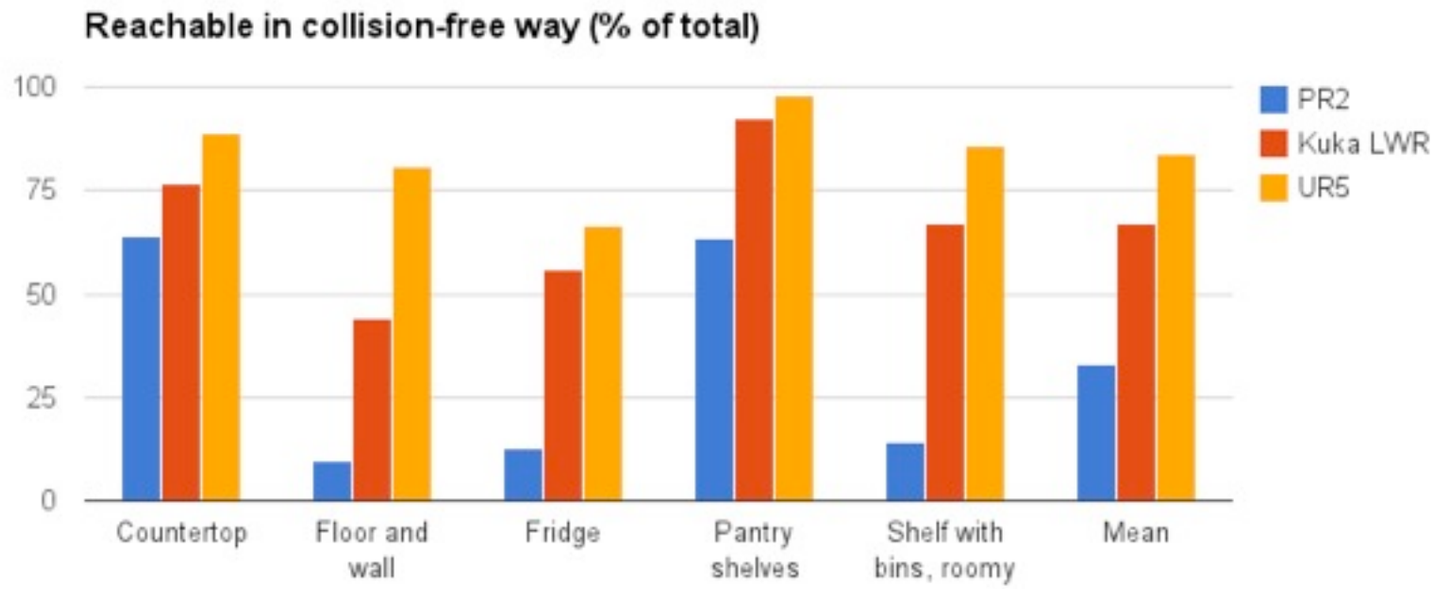
# Applications: Kinematic Workspace Analysis

- Robot Design Evaluation
- Robot Workspace Placement

# Kinematic Workspace Analysis

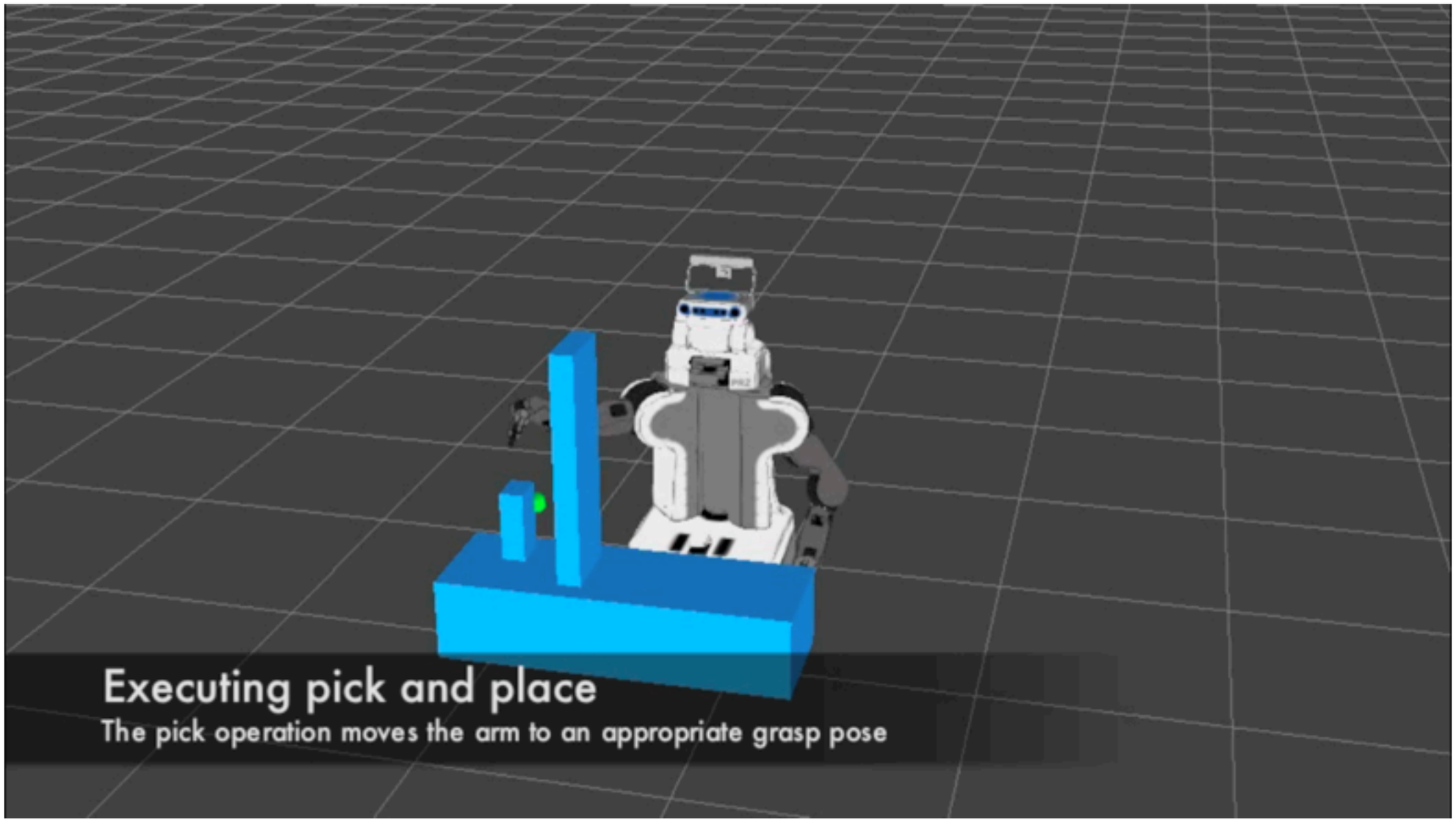






# MoveIt!

- Applications - Pick and Place
  - Integrated Grasping, Planning, Perception and Execution



# User API

- Really simple API (e.g. moving an arm):

```
move_group_interface::MoveGroup group("arm");
group.setRandomTarget();
group.move();
```

# MoveIt!

- New Architecture (different from arm navigation)
  - ✓ Minimize transport and messaging overhead - Single process for planning and perception, shares environment representation (planning scene) vs. multiple ROS nodes each performing individual functions
  - ❖ Computation - Core capabilities (e.g. motion planning, kinematics, etc.) are setup in C++ libraries
  - ❖ Communication and Configuration through ROS
  - ❖ Emphasis on speed and efficiency – parallelize collision checking, kinematics, etc.

# MoveIt!

- Capabilities (differences to arm navigation)
  - ❖ Collision Checking
    - ✓ Parallelizable
    - ✓ can switch between different types of collision checkers
    - ✓ cleaner C++ interface
  - ❖ Motion Planning
    - ✓ plugin based C++ interface (in addition to ROS interface)
    - ✓ Parallelizable
    - ✓ planning pipeline includes trajectory smoothing

# Highlights

- Technical
  - Performance
    - Single process sharing environment representation
    - Parallelizable collision checking and kinematics
    - Parallelizable pick and place (upcoming capability)
  - Integrated Perception for Environment Representation
    - Can incorporate  any source of point clouds
    - Fast self-filtering and environment representation
  - Reactive Motion Planning
    - Safer operation in collaborative environments

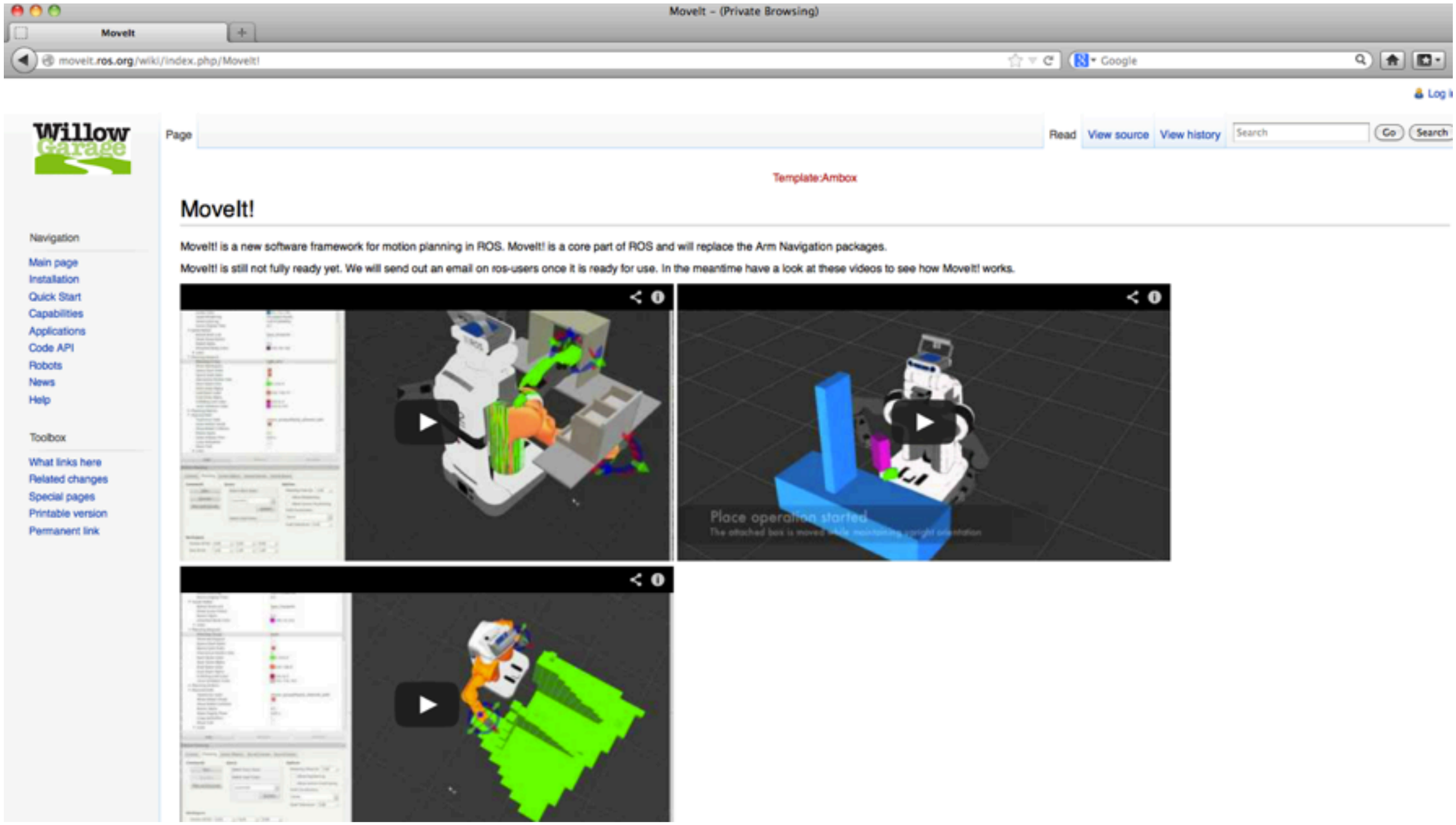
# Highlights

- User Friendly
  - Easy configuration for new robots
  - Graphical User Interfaces
  - Better Visualization and Introspection
  - Easy to use C++ API
  - Python bindings

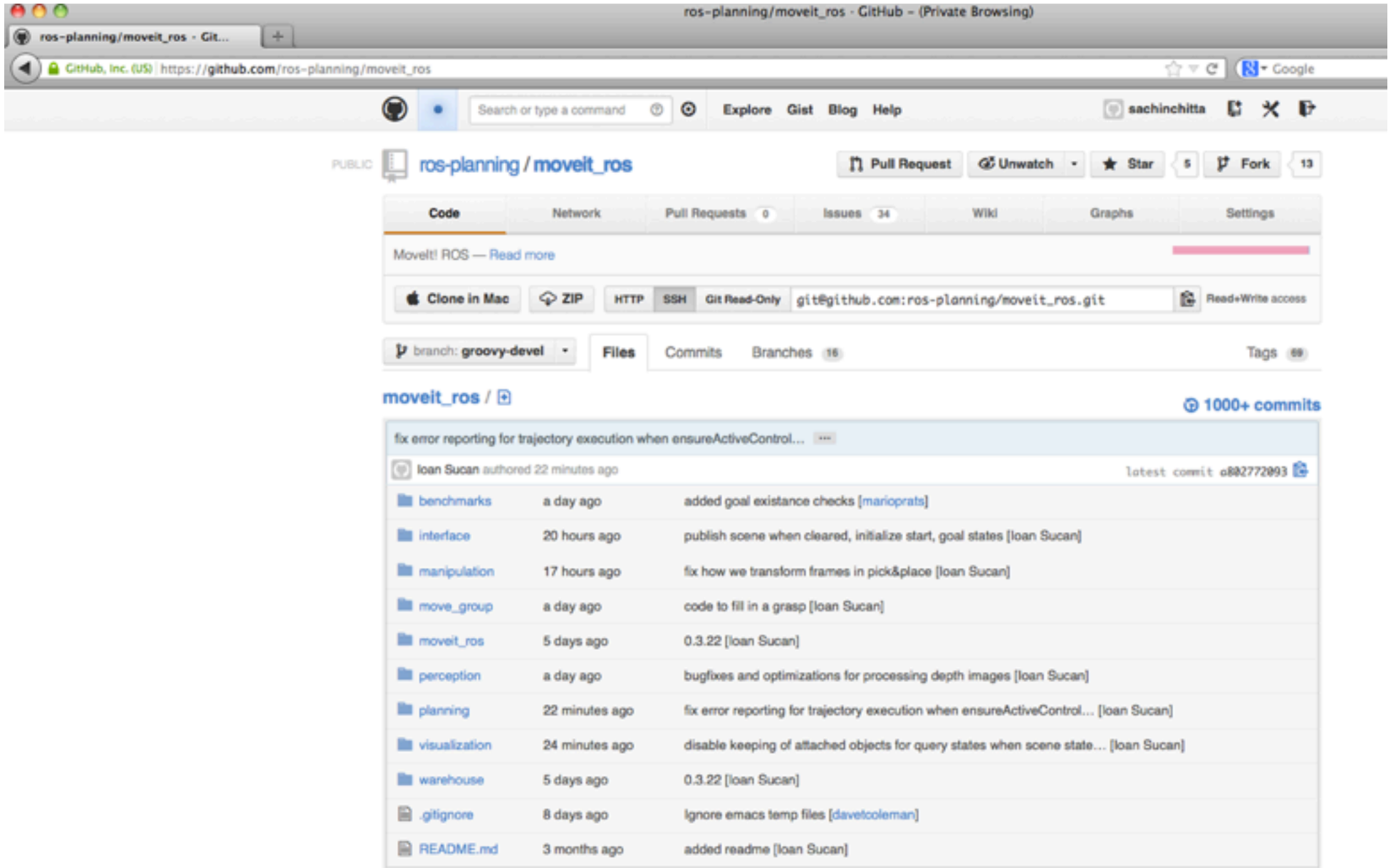
# Highlights

- Integrated Applications
  - Collision-free Motion Planning and Execution
  - Kinematic Analysis/ Reachability Analysis
  - Benchmarking
- More applications in development …
  - Pick and Place - more about this in afternoon session

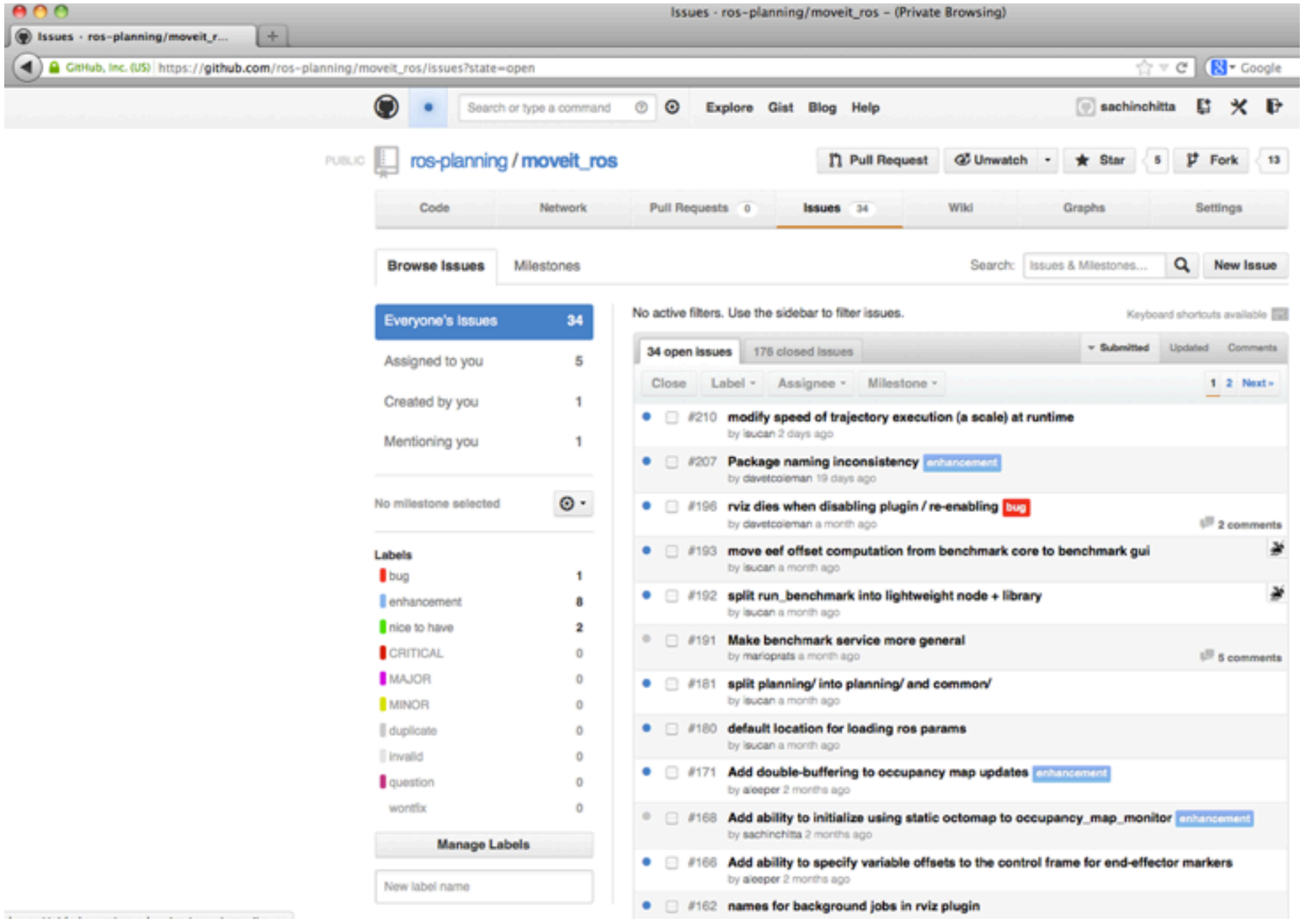
# Documentation - Wiki



# Github Repository



# Issue Tracking



# Community

- moveit-users@googlegroups.com - questions related to how you can use MoveIt!

# Where are we going?

- MoveIt!
  - ✓ what does it take to use MoveIt! in products
  - ✓ interest in enterprise level, supported versions of MoveIt! and associated capabilities in ROS?

# More information


Email: moveit@willowgarage.com