

# Motion Planning for Industrial Robots using MoveIt!

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- Manager and Research Scientist, Willow Garage, (2007-2013)
  - MoveIt!, Arm Navigation, ROS Control, 3D Navigation, FCL, SBPL, OMPL, ROS, PR2
- Founding Team, Redwood Robotics, (2010-2013)
  - ❖ acquired by Google last year
- Post-doc, University of Pennsylvania (2005-2007)
- PhD, GRASP Lab, University of Pennsylvania, 2005

# Robots In Industry



Need safety cages

Hard to program

*Robots in automation are currently inflexible - hard to setup and hard to program.*

# Expensive

- Typical cost of deploying/programming a robot is 70-80% of the cost of a robotics application

# 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

# MoveIt!

- A user-friendly platform for building **FLEXIBLE** industrial, research and commercial applications
  - ❖ Easy Configuration, Easy Programming, Quick switch-over
  - ❖ High Performance
  - ❖ Cross Platform

# Evolution - Arm Navigation

<http://youtu.be/tzUrdvhWgx8>

Arm Navigation - Chitta, Jones, Ciocarlie, Hsiao, Sucan, 2011

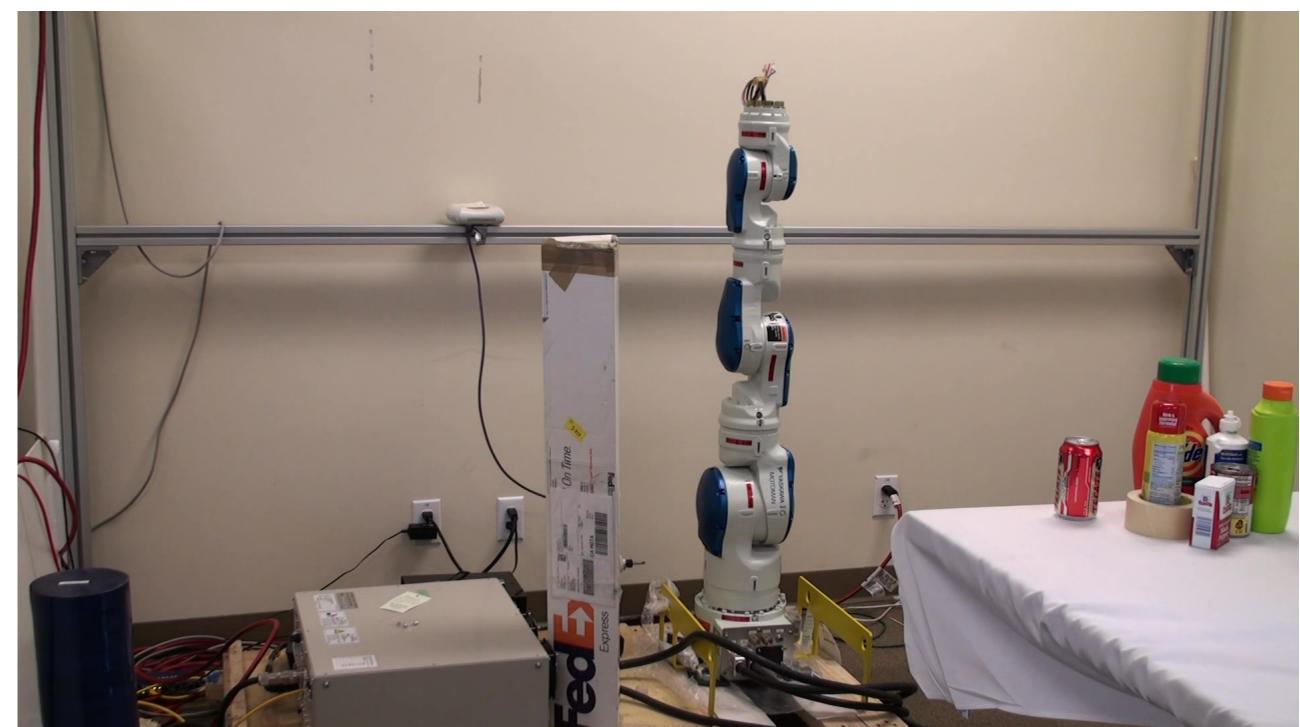
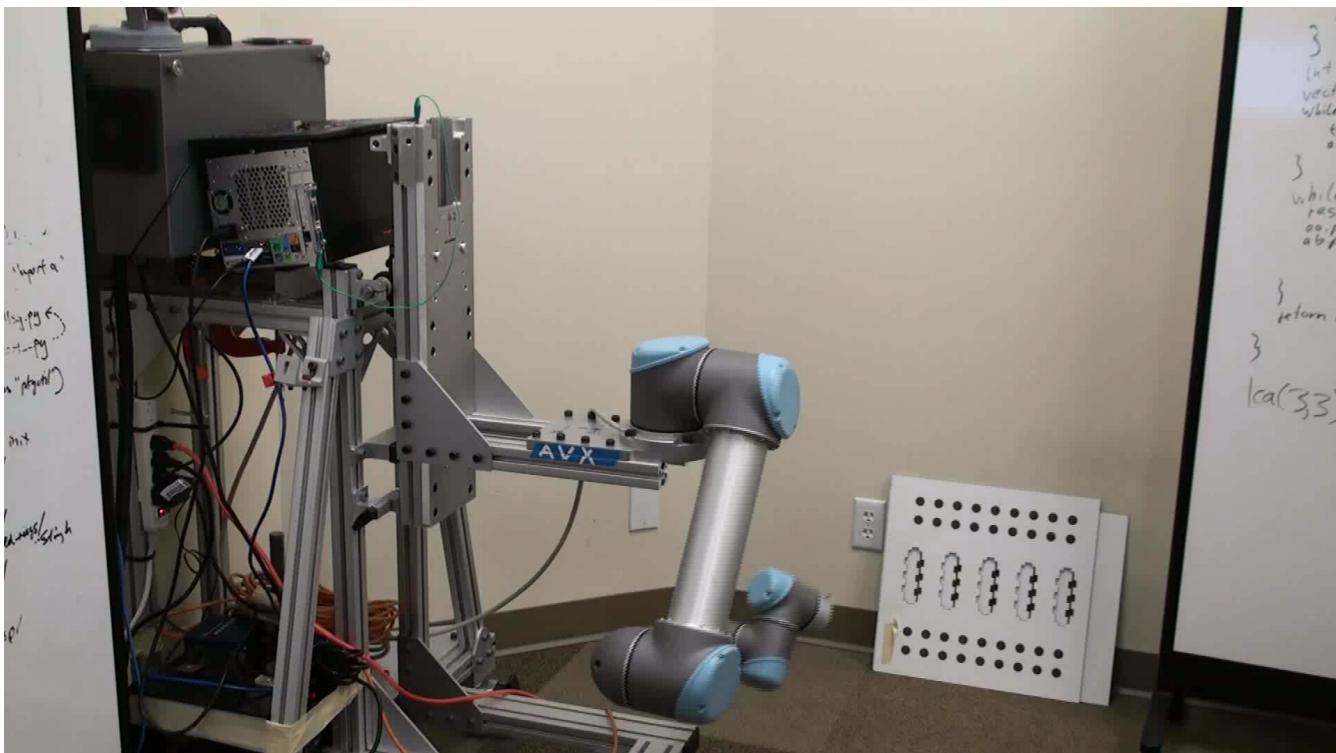
# Initial Industrial Application

<http://youtu.be/WG-45cZSUQ>

# MoveIt!

- Thread-based architecture
  - Parallelize motion planners and collision checking
- GPU acceleration for 3D perception
- Script based user interface
  - designing complex programs/tasks
- GUI based interface
  - make things easier for users
- Setup Tools
  - easy to import new robots

# MoveIt! - Initial Robots



# ROS-Industrial

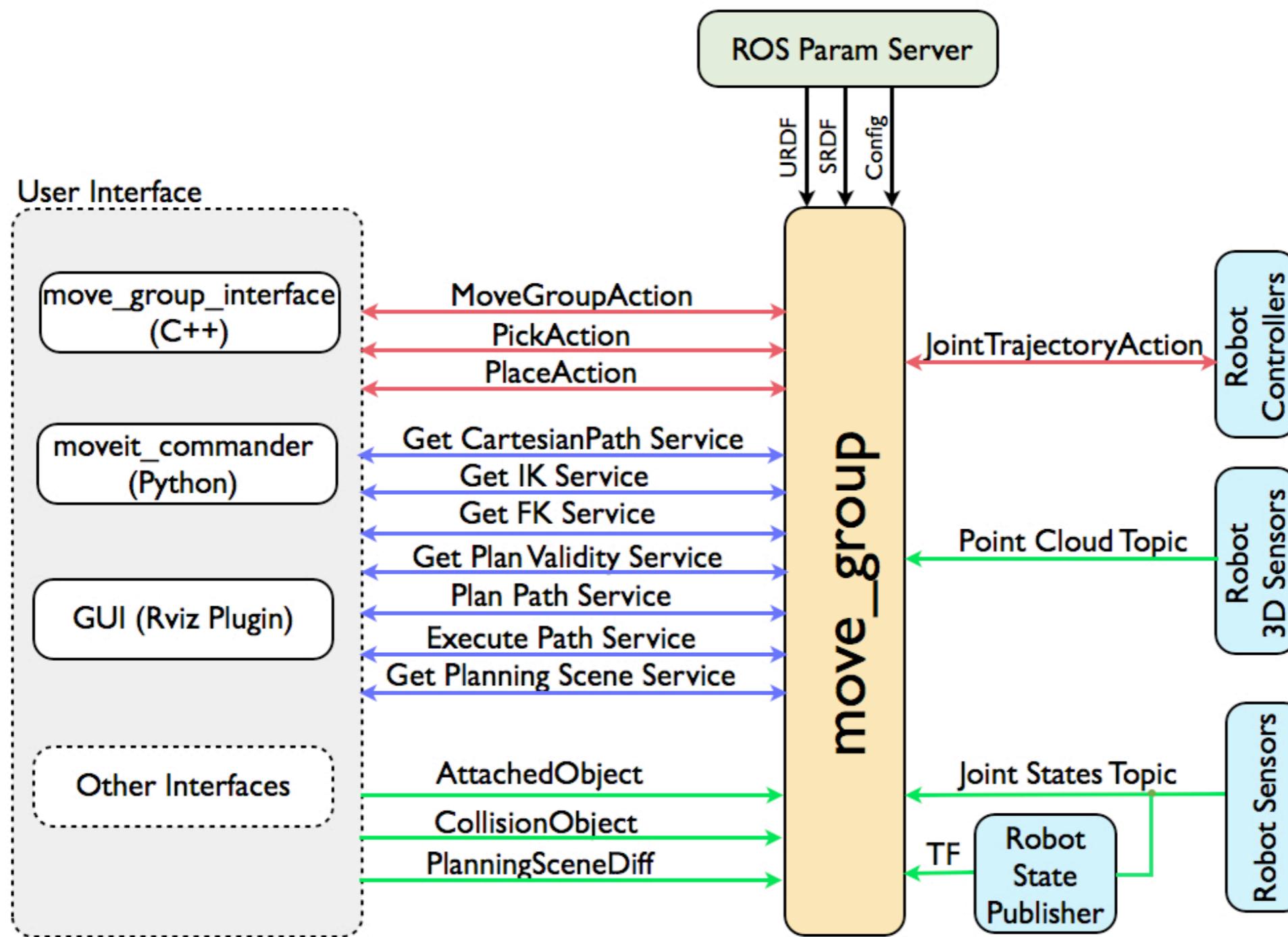


# What does MoveIt! offer?

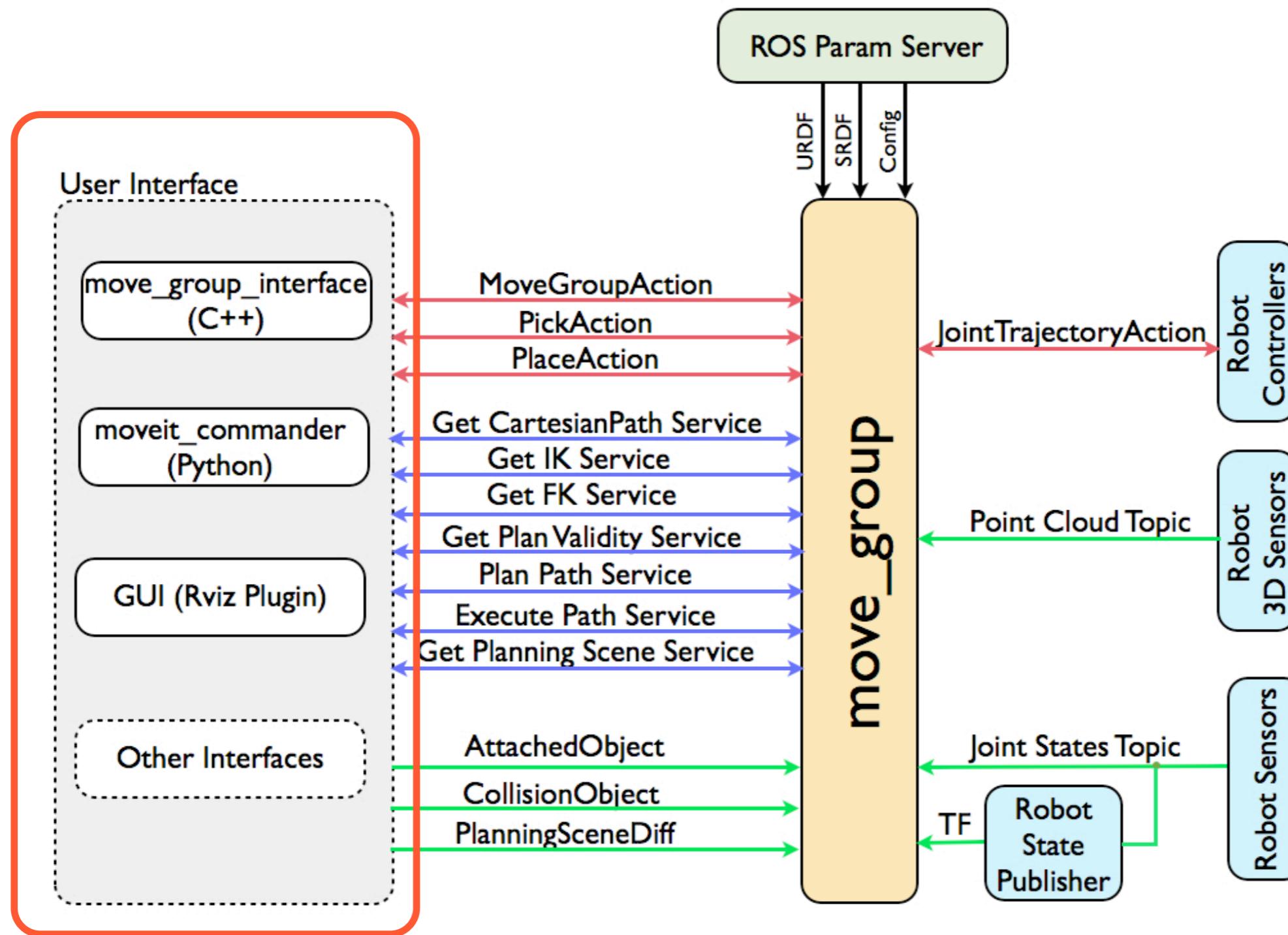
- Technical Capabilities

- ❖ 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

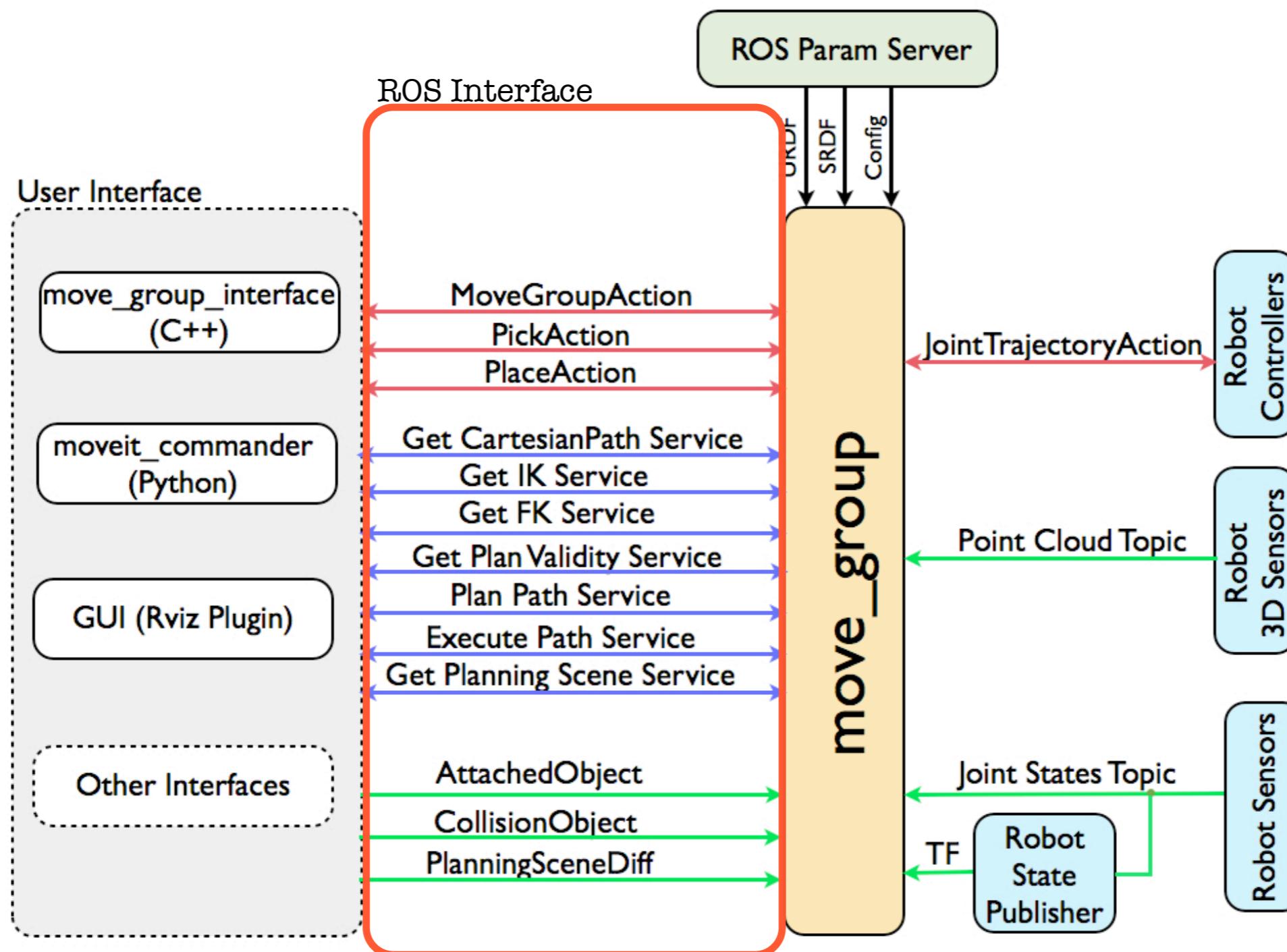
# System Architecture



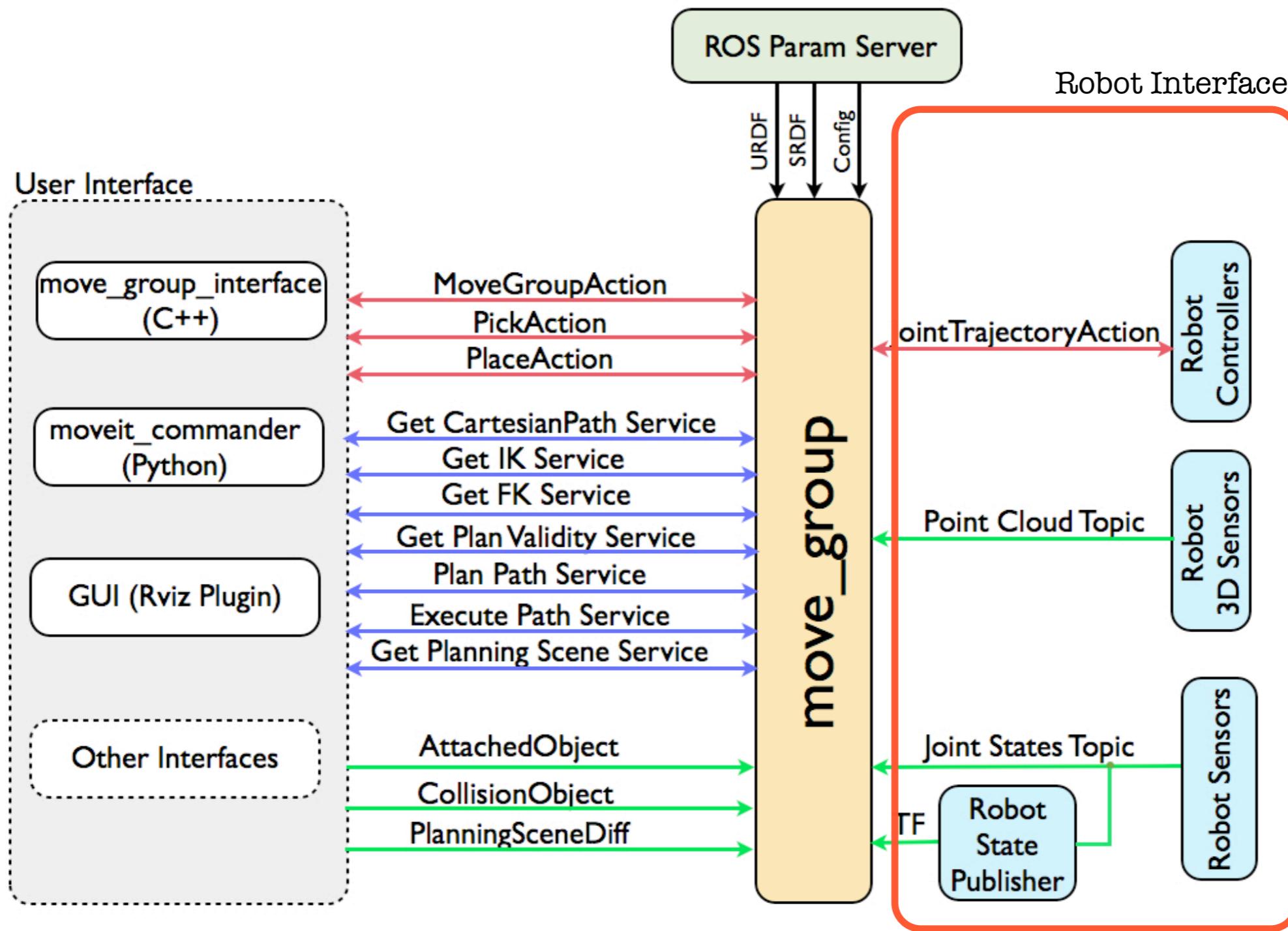
# System Architecture



# System Architecture



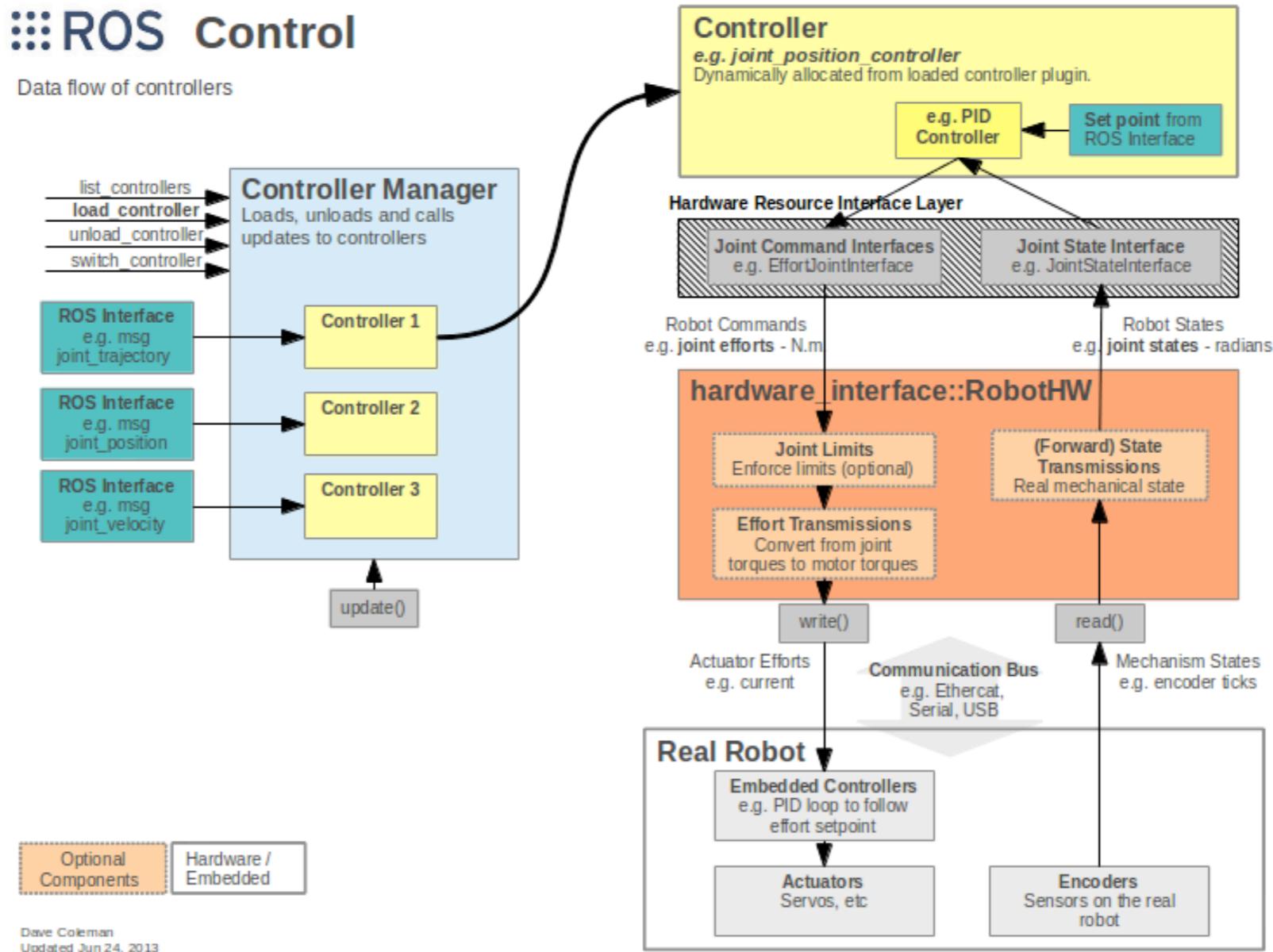
# System Architecture



# ROS Control

## ROS Control

Data flow of controllers

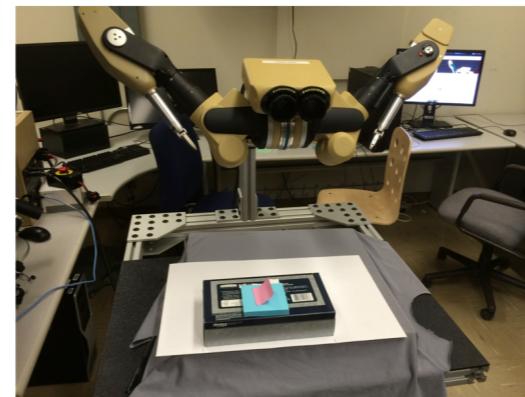


ROS-Control is based on the set of controllers originally developed for the PR2 robot

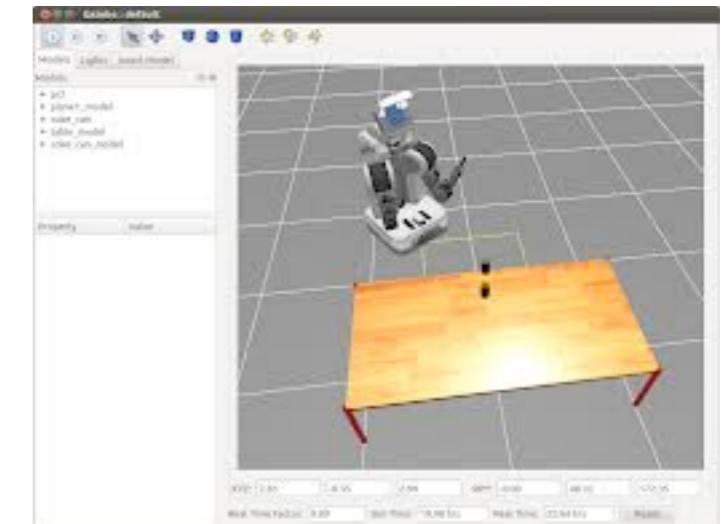
# ROS Control



REEM-C (PAL  
Robotics)



Taurus (SRI)



Gazebo



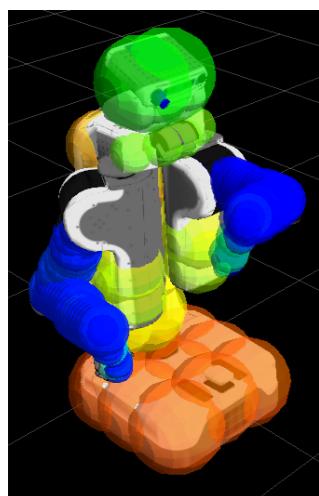
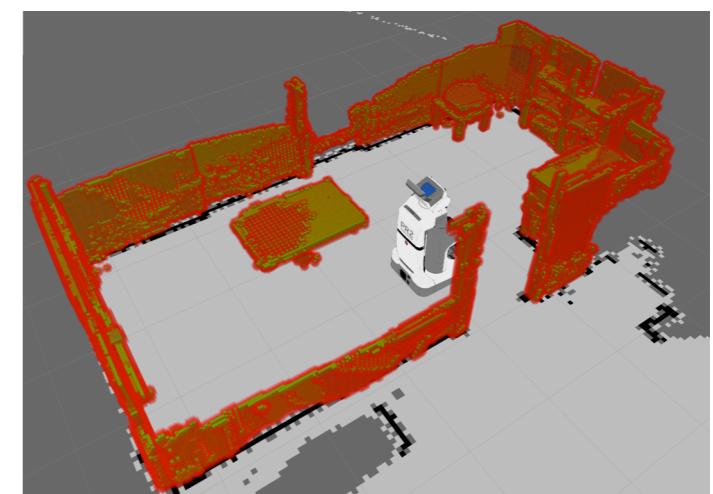
The Redwood Arm

# MoveIt!

- MoveIt! works online
  - ❖ directly deals with perception data
  - ❖ directly talks to controllers
- MoveIt! also works offline
  - ❖ import CAD model data
  - ❖ offline programming and planning of complex multi-step paths
- MoveIt! enables full applications

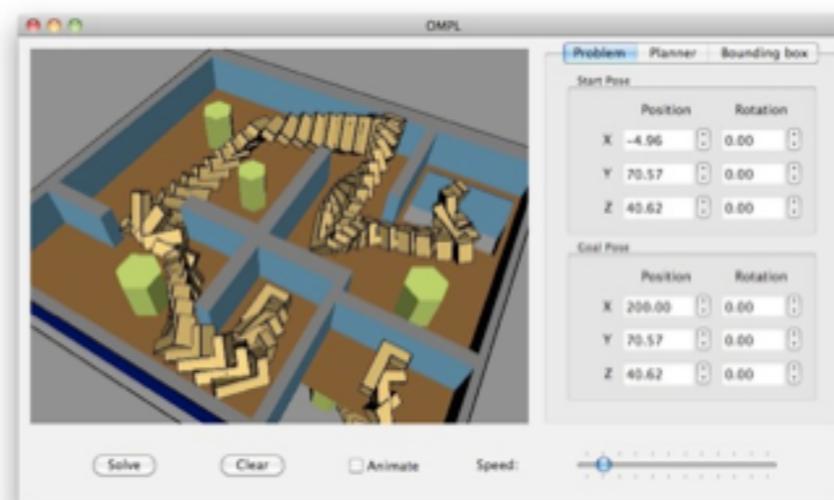
# Collision Checking

- 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

# Motion Planning

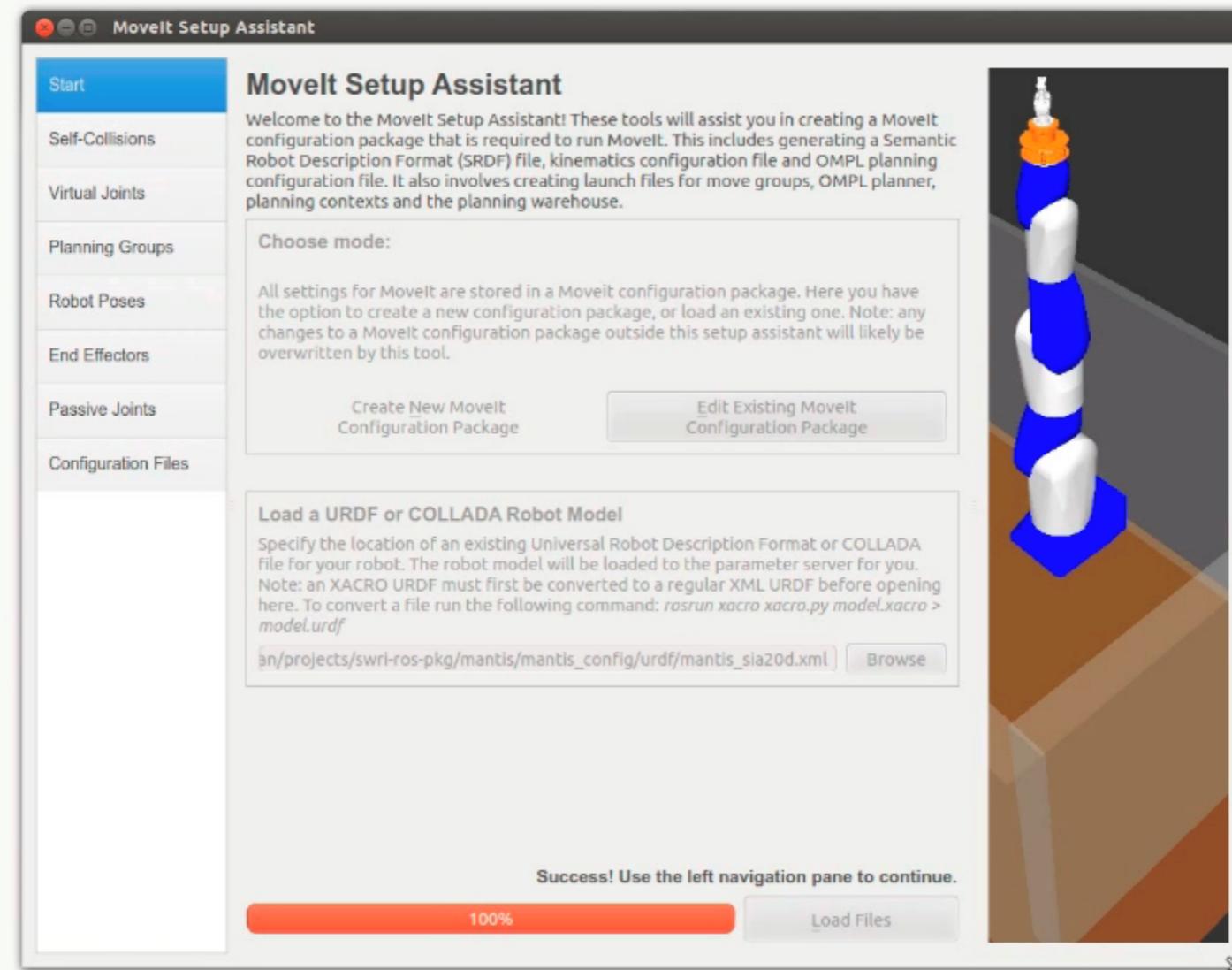


- Plugin interface for planners
- Integration with robots through MoveIt!
- Automatically configured using the MoveIt! Setup Assistant
  - ❖ Sampling based planners (OMPL)\*
  - ❖ Search Based Planning Library (SBPL)<sup>^</sup>

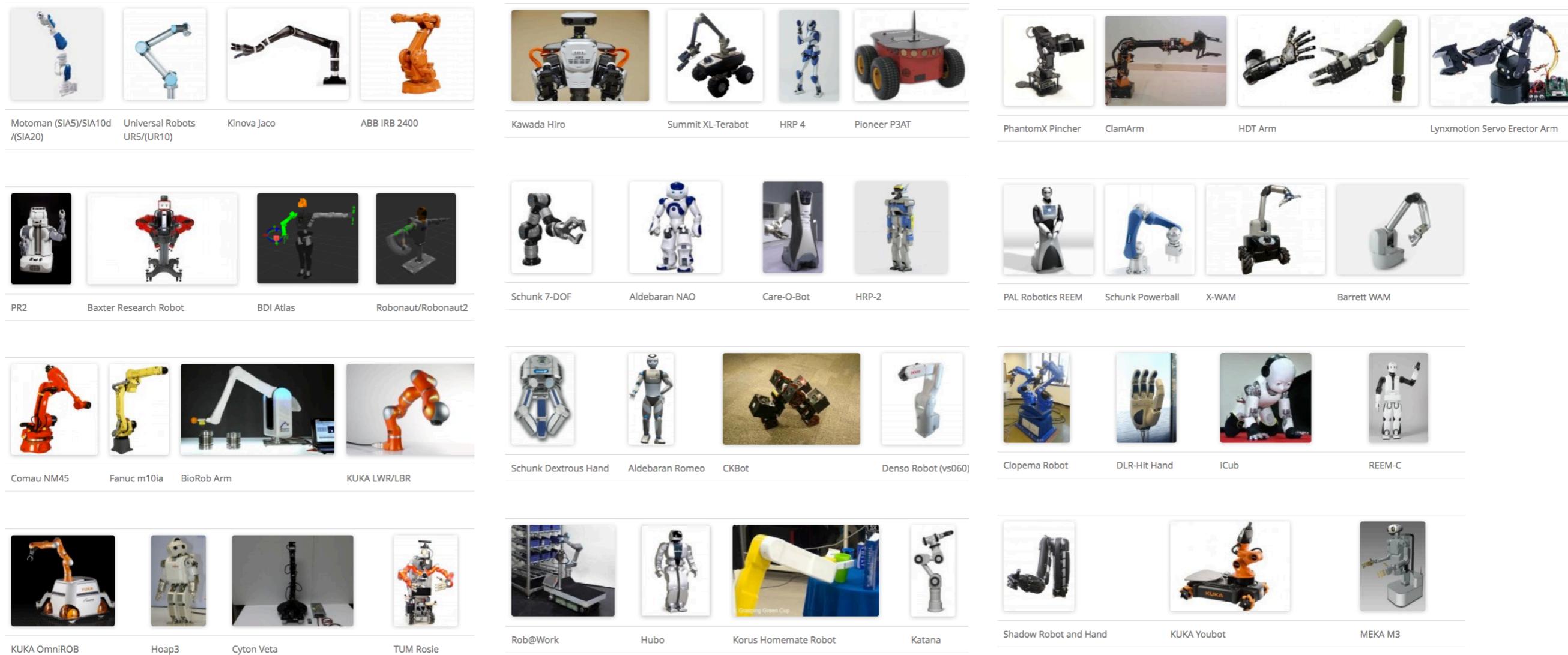
\* Lydia Kavraki, Ioan Sucan, Mark Moll, Ryan Luna, Sachin Chitta

<sup>^</sup>Maxim Likhachev, Mike Phillips, Ben Cohen, Andrew Dornbush, Sachin Chitta

# Easy Setup and Configuration

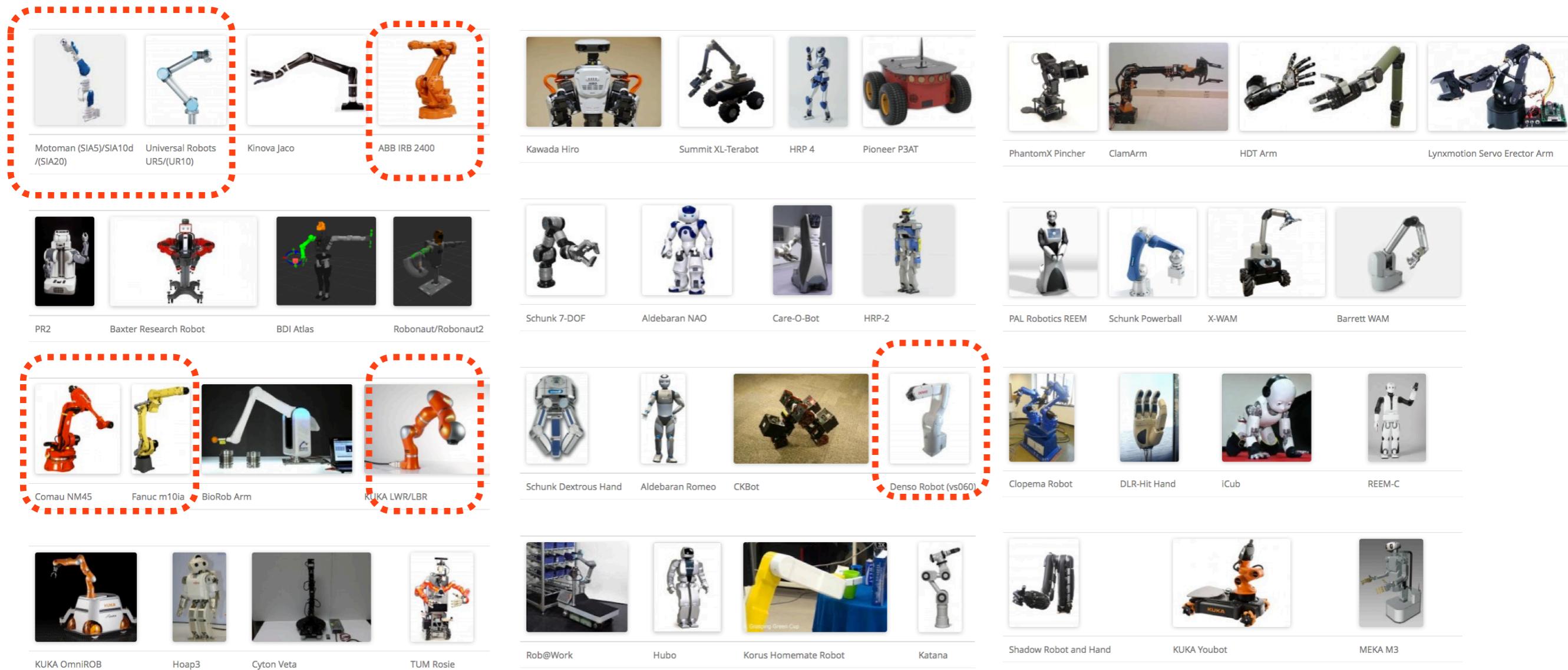


# Robots Using MoveIt!



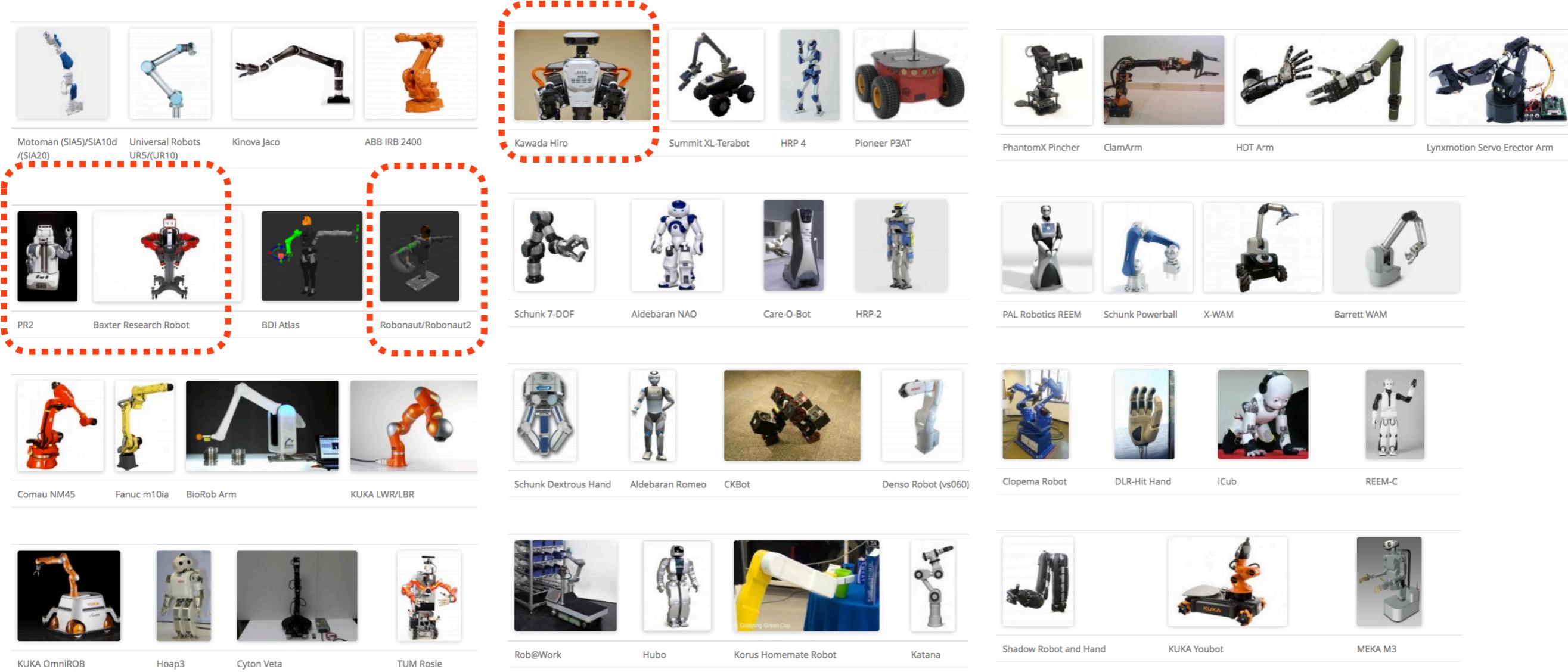
● <http://moveit.ros.org>

# Industrial



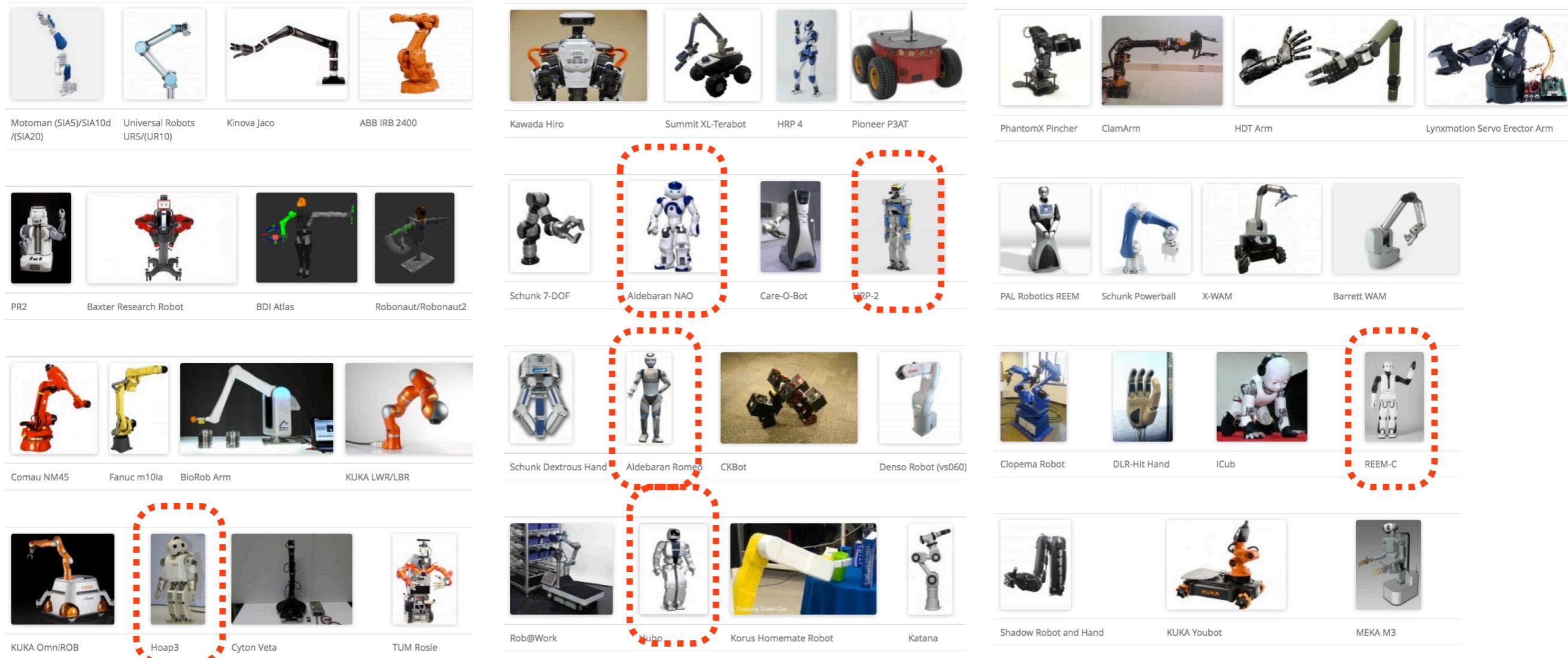
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# New Generation of Robots



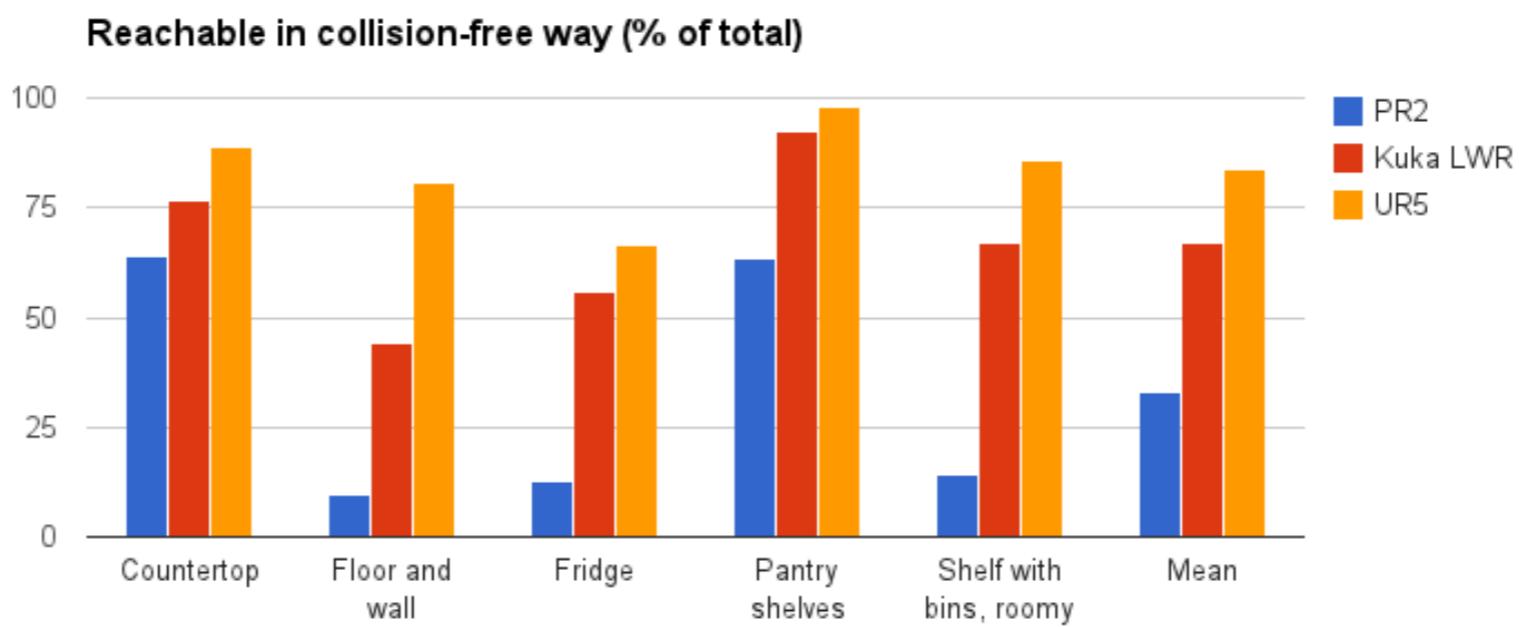
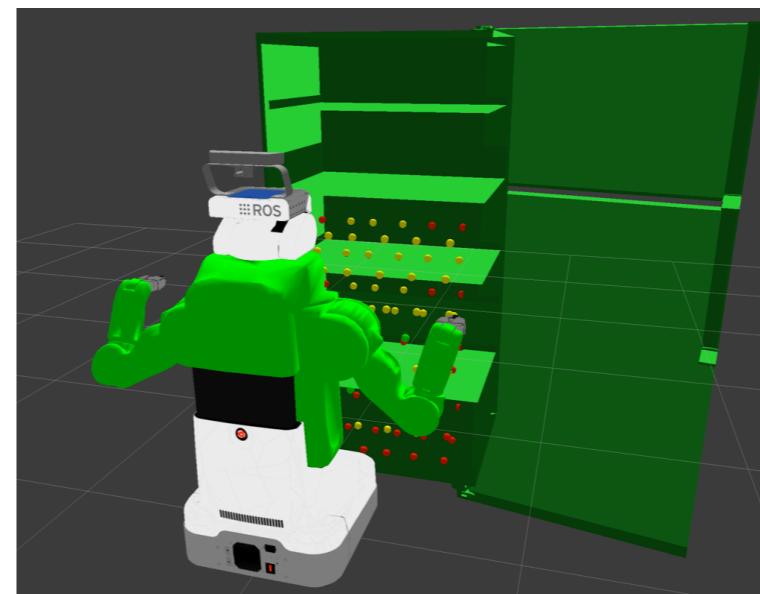
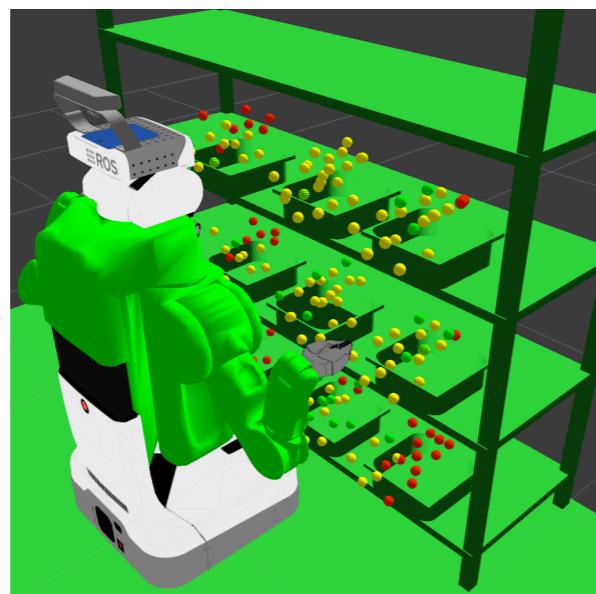
- <http://moveit.ros.org>

# Humanoid



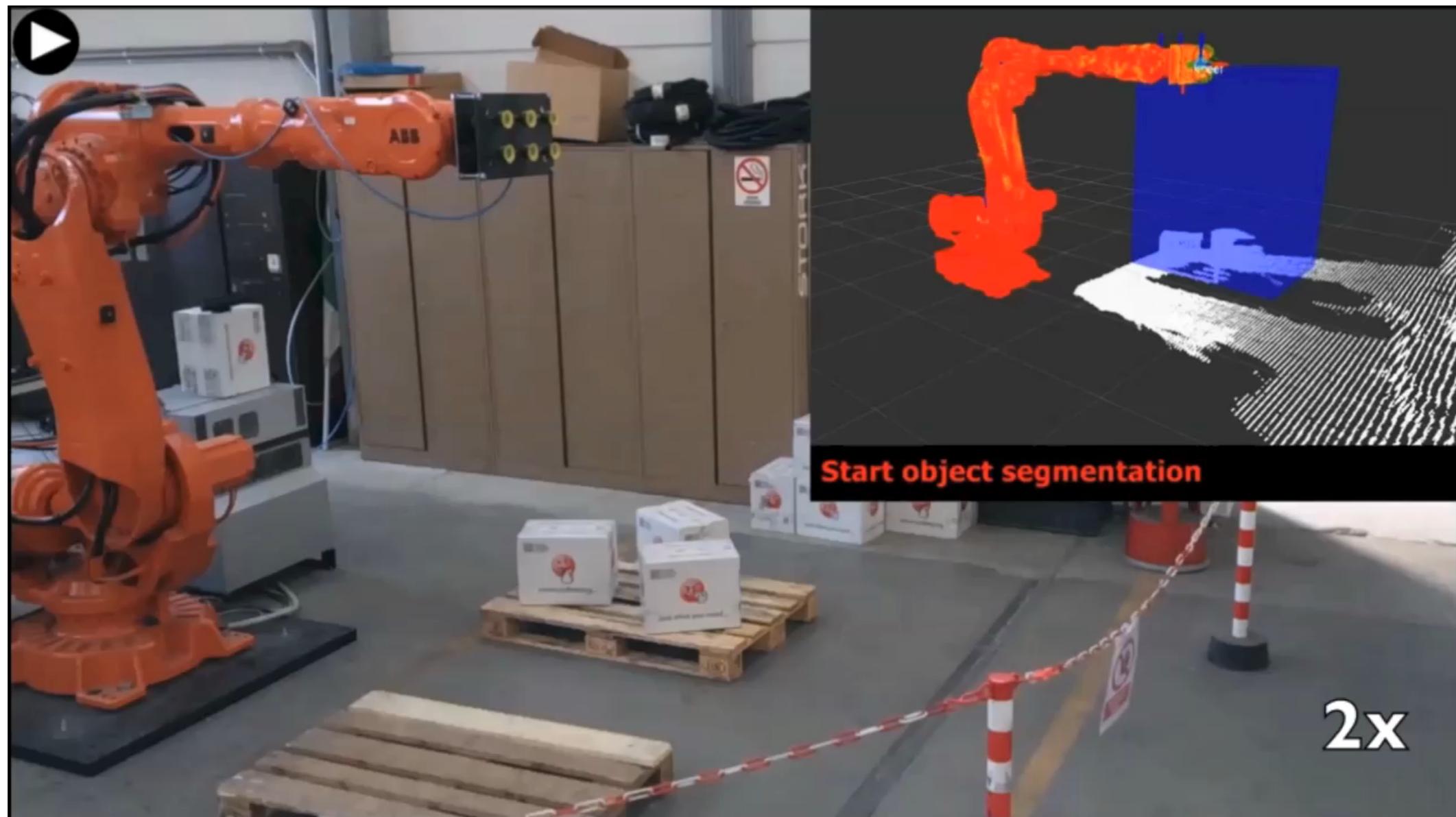
● <http://moveit.ros.org>

# Kinematic Workspace Analysis



# MoveIt! in Industry

## Unstructured Pick and Place



# MoveIt! in Industry

## Workcell Programming



# A Montage of Applications



MONTAGE 2013

## More Info ...

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- <http://moveit.ros.org>