Motion Planning for Industrial Robots using MoveIt!

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Robotics Systems and Software

SRI International
• 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 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

Fraunhofer, Willow Garage
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

User Interface
- move_group_interface (C++)
- moveit_commander (Python)
- GUI (Rviz Plugin)
- Other Interfaces

Robot Controllers

Robot 3D Sensors

Robot Sensors

ROS Param Server
- URDF
- SRDF
- Config

move_group
- MoveGroupAction
- PickAction
- PlaceAction
- Get CartesianPath Service
- Get IK Service
- Get FK Service
- Get Plan Validity Service
- Plan Path Service
- Execute Path Service
- Get Planning Scene Service
- AttachedObject
- CollisionObject
- PlanningSceneDiff

Point Cloud Topic

Joint States Topic

Robot State Publisher

TF
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**ROS Param Server**
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- `SRDF`
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**Robot Controllers**

**Robot 3D Sensors**

**Robot Sensors**

**Robot State Publisher**

**Point Cloud Topic**

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**TF**
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Robot Interface

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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

*Jia Pan, Ioan Sucan, Sachin Chitta, Dinesh Manocha*
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)^

* Lydia Kavraki, IoanSucan, Mark Moll, Ryan Luna, Sachin Chitta
^ Maxim Likhachev, Mike Phillips, Ben Cohen, Andrew Dornbush, Sachin Chitta
Easy Setup and Configuration
Robots Using MoveIt!

- NISTman (SA1/SA11b/SA12b)
- Universal Robots (UR5/UR10)
- Kinova Jaco
- ABB IRB 2400
- Kawasaki
- Kawada Hiro
- Summit XL Torobot
- HRP 4
- Pioneer P3AT
- PhantomX Pincher
- ClamArm
- HDT Arm
- Lynnmotion Servo Erector Arm
- PR2
- Baxter Research Robot
- BDI Atlas
- Rebonau/Rebonau2
- Schunk 7-DOF
- Aldebaran NAO
- Care-O-Rot
- HRP-2
- INL Robotics REEM
- Schunk Powerball
- X-WAR
- Barrett WAM
- Comau NIMIS
- Fanuc m10ia
- BioRob Arm
- KUKA LWR/LBR
- Schunk Destroid Hand
- Aldebaran Romeo
- CXBot
- Denso Robot (rs001)
- Coplema Robot
- DLR-Hit Hand
- iCub
- REEM-C
- KUKA OmniRDB
- Haasp3
- Cyton Yeta
- TUM-Resi
- Robo@Work
- Hubo
- Koro3 Homemate Robot
- Katana
- Shadow Robot and Hand
- KUKA Youbot
- MEKA M3

- 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

Reachable in collision-free way (% of total)

- PR2
- Kuka LWR
- UR5
MoveIt! in Industry

Unstructured Pick and Place
MoveIt! in Industry

Workcell Programming
A Montage of Applications

MONTAGE 2013
More Info ...

• [http://moveit.ros.org](http://moveit.ros.org)