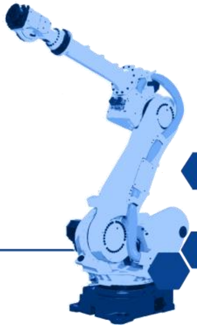
ROS-Industrial Basic Developer's Training Class

Southwest Research Institute



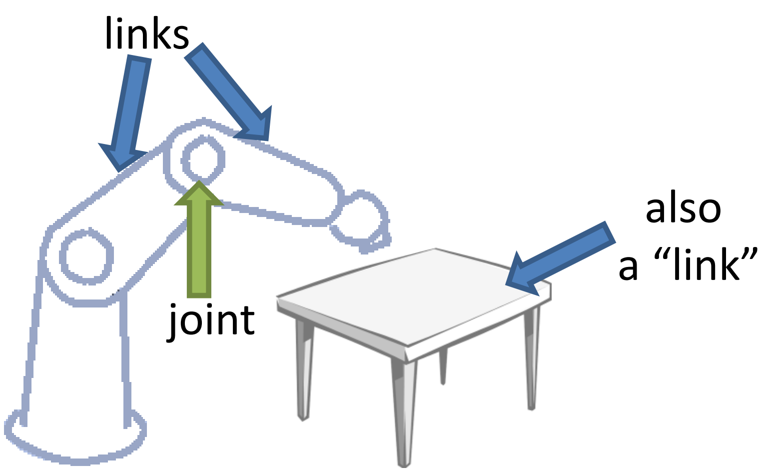
Session 3:
Motion Control of Manipulators

Southwest Research Institute

URDF:
Unified Robot Description Format

URDF: Overview

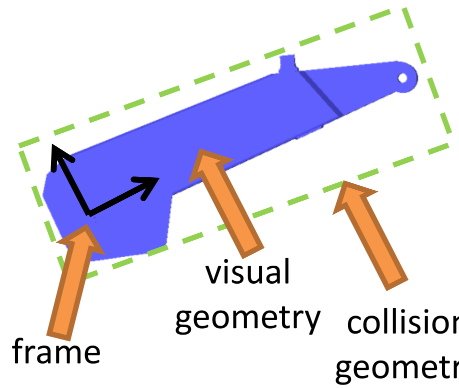
- URDF is an **XML**-formatted file containing:
  - **Links** : coordinate frames and associated geometry
  - **Joints** : connections between links
- Similar to DH-parameters (but way less painful)
- Can describe entire workspace, not just robots



URDF: Link

- A **Link** describes a physical or virtual object
  - Physical : robot link, workpiece, end-effector, ...
  - Virtual : TCP, robot base frame, ...
- Each link becomes a TF frame
- Can contain visual/collision geometry [optional]

```
<link name="link_4">
   <visual>
       <geometry>
           <mesh filename="link_4.stl"/>
       </geometry>
       <origin xyz="0 0 0" rpy="0 0 0" />
   </visual>
   <collision>
       <geometry>
           <cylinder length="0.5" radius="0.1"/>
       </geometry>
       <origin xyz="0 0 -0.05" rpy="0 0 0" />
   </collision>
</link>
```



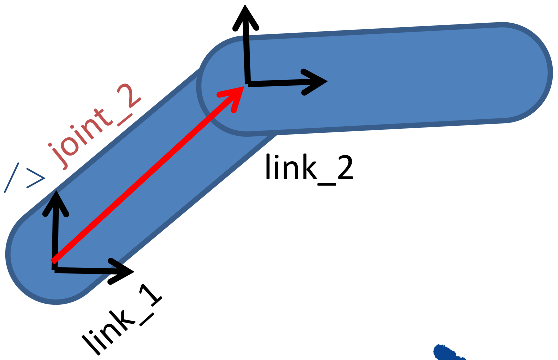
URDF Transforms

X/Y/Z	Roll/Pitch/Yaw
Meters	Radians

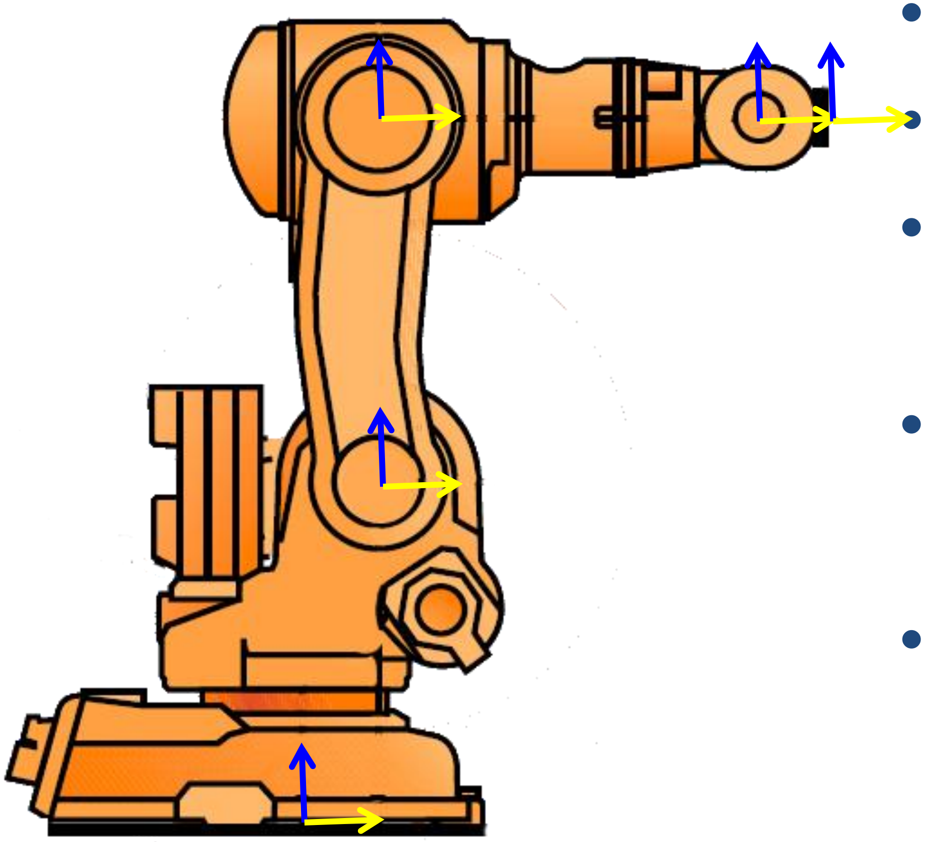
URDF: Joint

- A **Joint** connects two **Links**
  - Defines a **transform** between **parent** and **child** frames
    - Types: *fixed, free, linear, rotary*
  - Denotes axis of movement *(for linear / rotary)*
  - Contains joint limits on position and velocity

```
<joint name="joint_2" type="revolute">
   <parent link="link_1"/>
   <child link="link_2"/>
   <origin xyz="0.2 0.2 0" rpy="0 0 0"/>
   <axis xyz="0 0 1"/>
   <limit lower="-3.14" upper="3.14" velocity="1.0"/>
</joint>
```



ROS-I Conventions

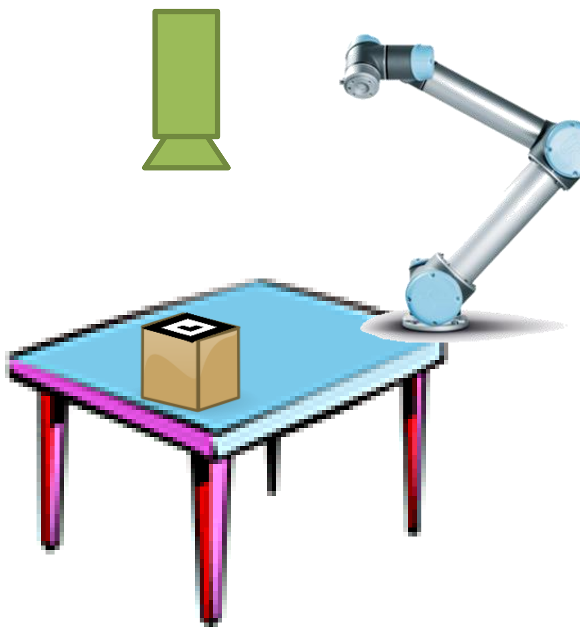


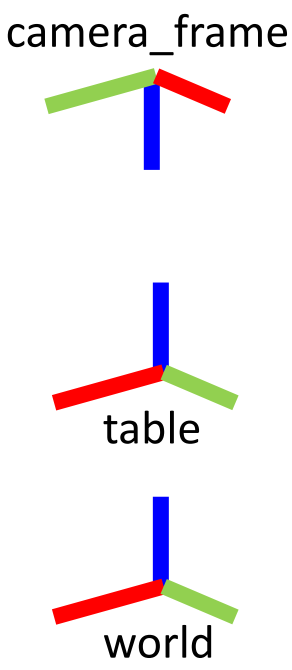
- Robot in Zero Position
- Place joints on axes
- Keep all frames same orientation
- X-Axis Front, Z-Axis Up

- *Unlike DH-Parameters, URDF allows free choice of frame orientation*

Exercise 3.0

Create a simple urdf





URDF: XACRO

- **XACRO** is an XML-based "macro language" for building URDFs
  - <Include> other XACROs, with parameters
  - Simple expressions: math, substitution
- Used to build complex URDFs
  - multi-robot workcells
  - reuse standard URDFs (e.g. robots, tooling)

```
<xacro:include filename="myRobot.xacro"/>

<xacro:myRobot prefix="left_"/>
<xacro:myRobot prefix="right_"/>

<property name="offset" value="1.3"/>

<joint name="world_to_left" type="fixed">
    <parent link="world"/>
    <child link="left_base_link"/>
    <origin xyz="${offset/2} 0 0" rpy="0 0 0"/>
</joint>
```

XACRO -> URDF

- Most ROS tools expect URDFs, not XACRO
- Run the “xacro” command to convert XACRO files to URDF:

```
rosrun xacro xacro robot.xacro > robot.urdf
```

- Typically, xacro conversion is triggered by launch files, not executed manually.

```
<param name="robot_description“
       command="$(find xacro)/xacro workcell.xacro" />
```

XACRO: Macros

Define XACRO Macro

robot.xacro

```
<xacro:macro name=“robot” params=“id”>
  <joint name=“${id}_joint1”>
    ...
</xacro>
```

Include and Call Macro

workcell.xacro

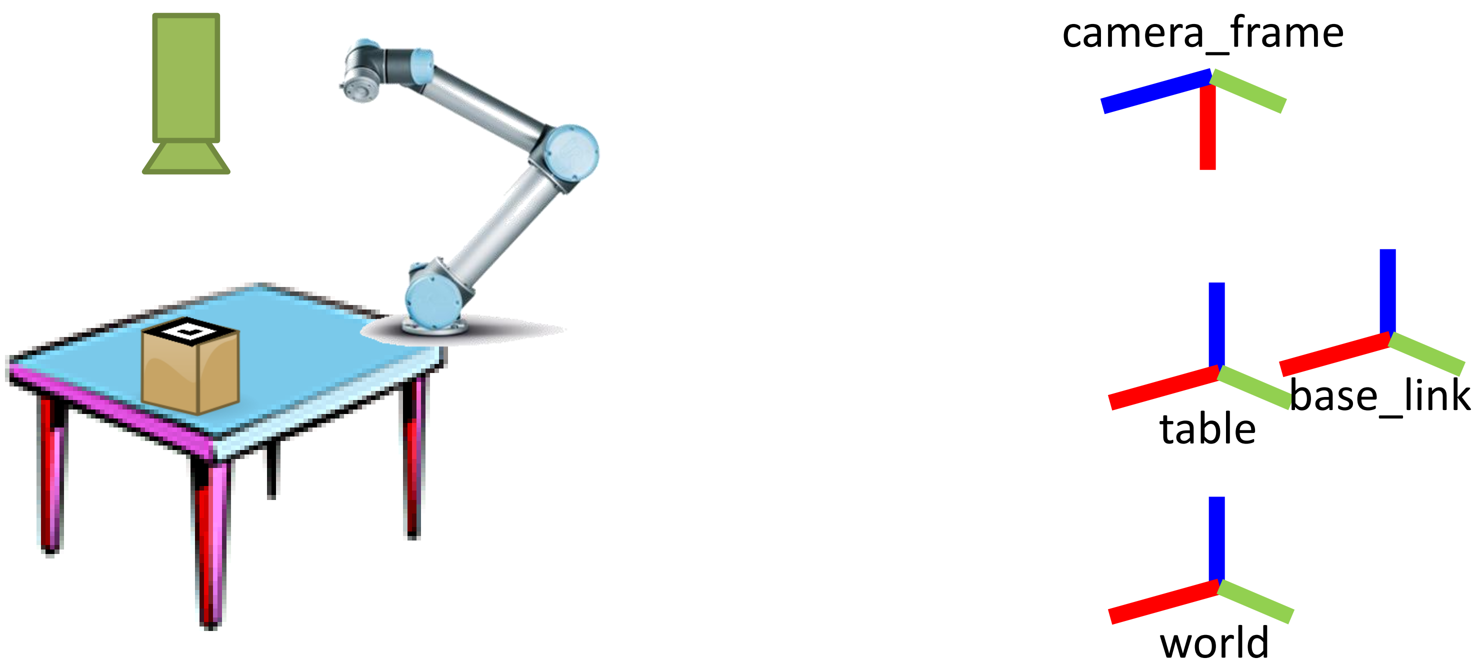
```
<xacro:include filename=“robot.xacro”/>

<xacro:robot id:=“left />
<xacro:robot id:=“right” />
```

URDF Practical Examples

- Let's take a quick look at the UR5's URDF:
  - *In* ***ur_description/urdf/ur5.urdf.xacro***

Exercise 3.1

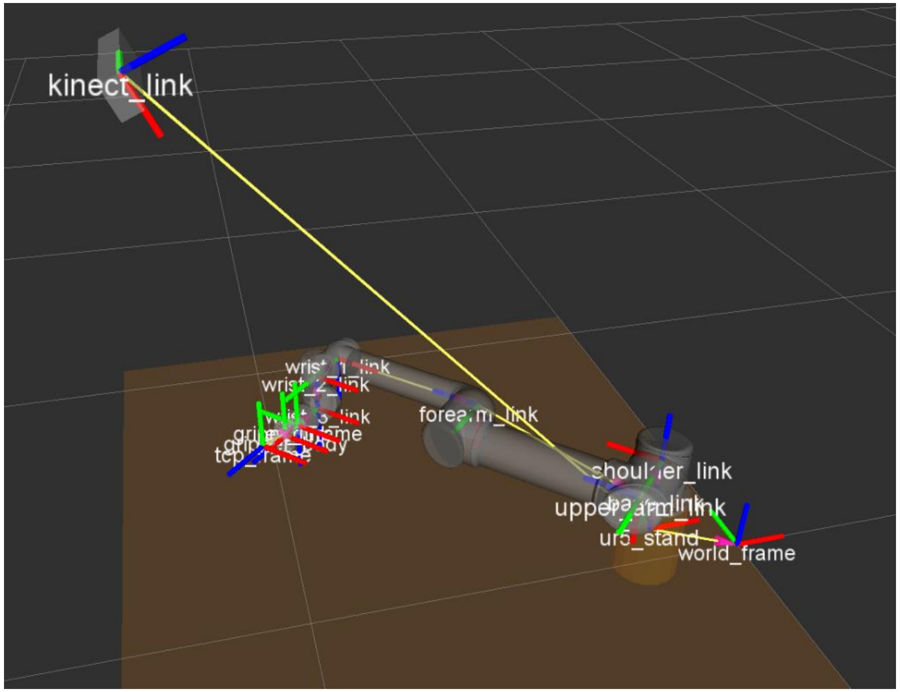
Combine simple urdf with ur5 xacro



TF – Transforms in ROS

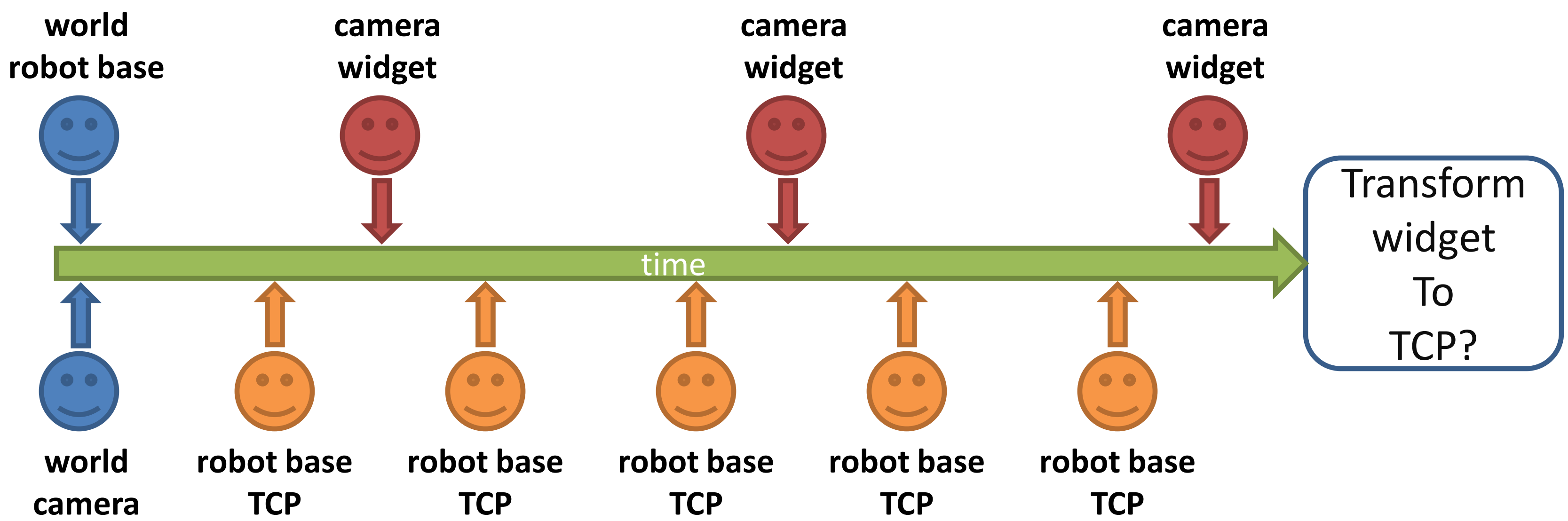
TF: Overview

- TF is a **distributed framework** to track **coordinate frames**
- Each frame is related to at least one other frame



TF: Time Sync

- TF tracks frame history
  - can be used to find transforms in the past!
  - essential for asynchronous / distributed system



TF: c++

- Each **node** has its own **`transformListener`**
  - listens to all tf messages, calculates relative transforms
  - Can try to transform in the past
  - ➢ Can only look as far back as it has been running

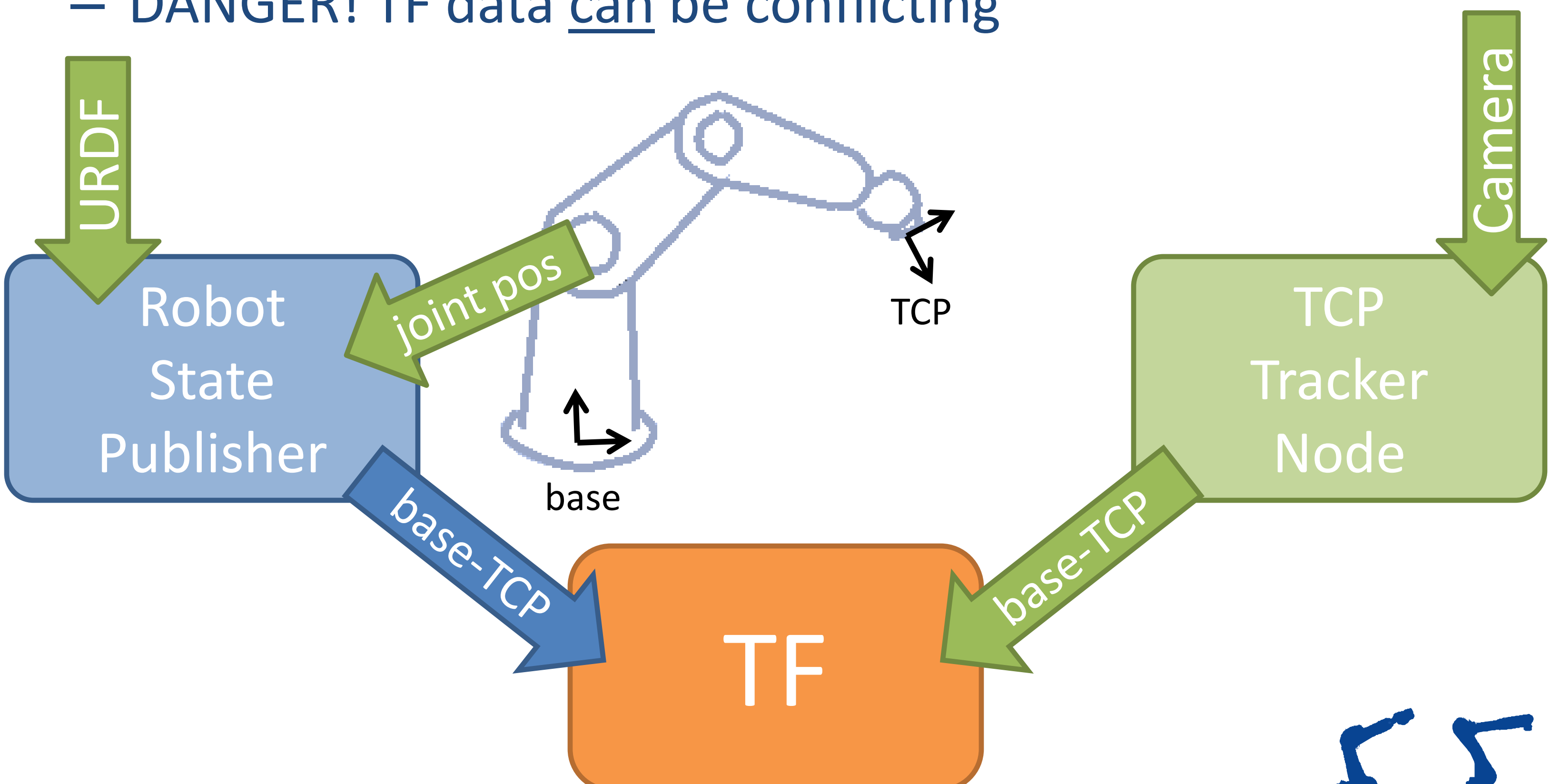
```
tf::TransformListener listener;
tf::StampedTransform transform;

listener.lookupTransform(“target”, “source”, ros::Time(), transform);
```

Parent Frame (“reference”) | Child Frame (“object”) | Time | Result

- Note confusing “target/source” naming convention
- ros::Time() or ros::Time(0) give **latest** available transform
- ros::Time::now() usually fails

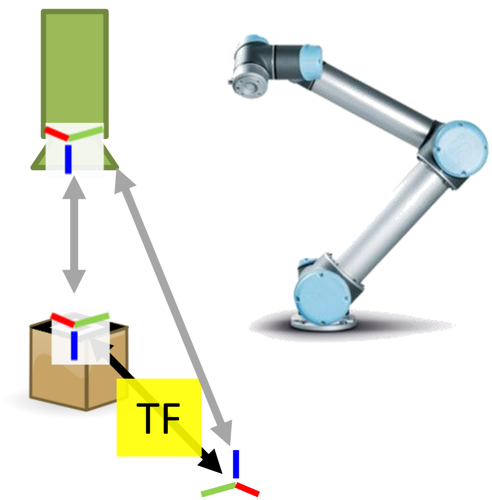
TF: Sources

- A `robot_state_publisher` provides TF data from a **URDF**
- Nodes can also publish TF data
  - DANGER! TF data <u>can</u> be conflicting

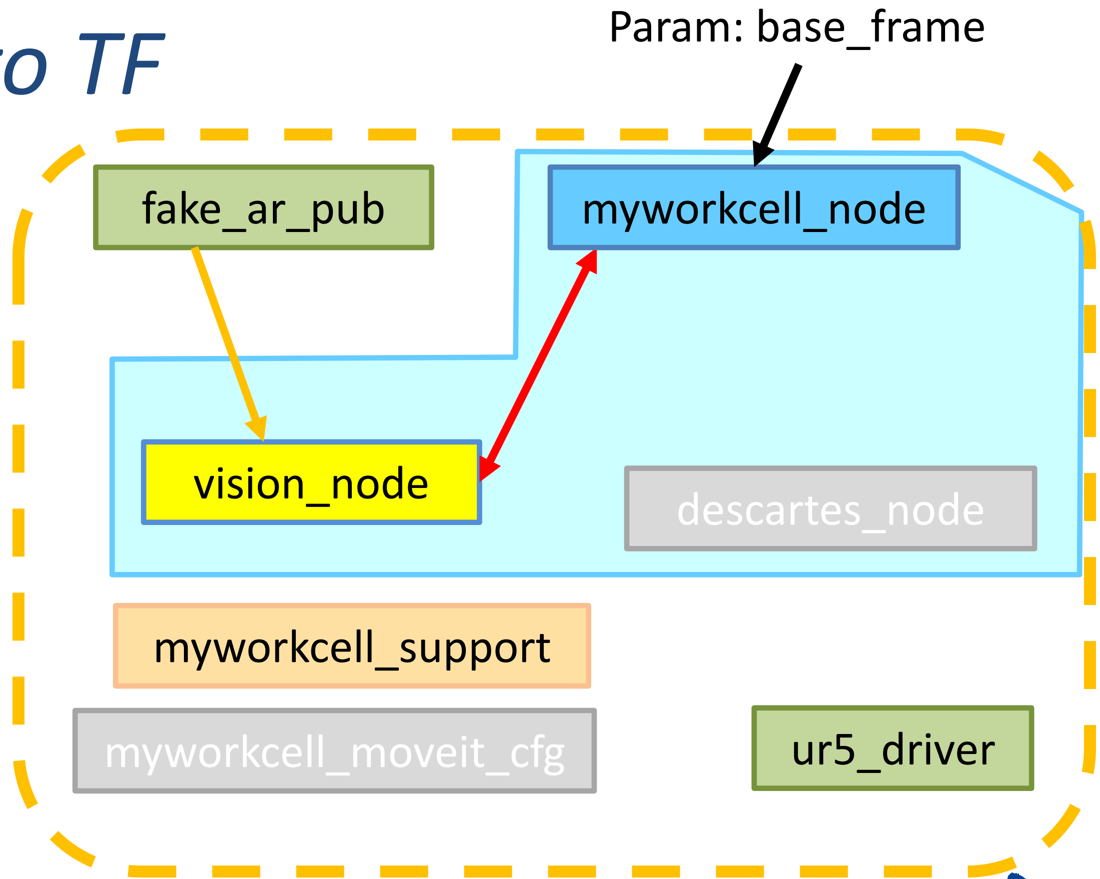


Exercise 3.2

Introduction to TF

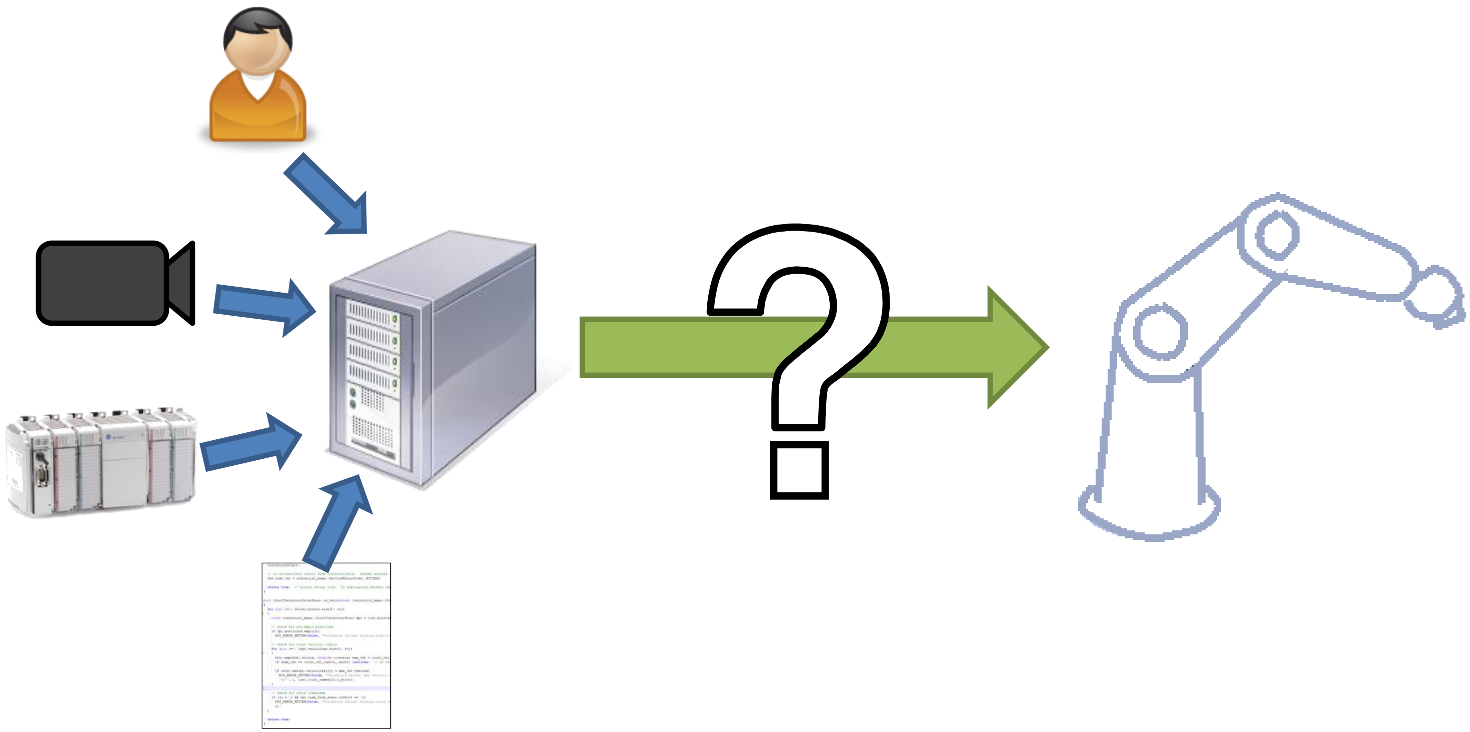


world->target = world->camera
* camera->target

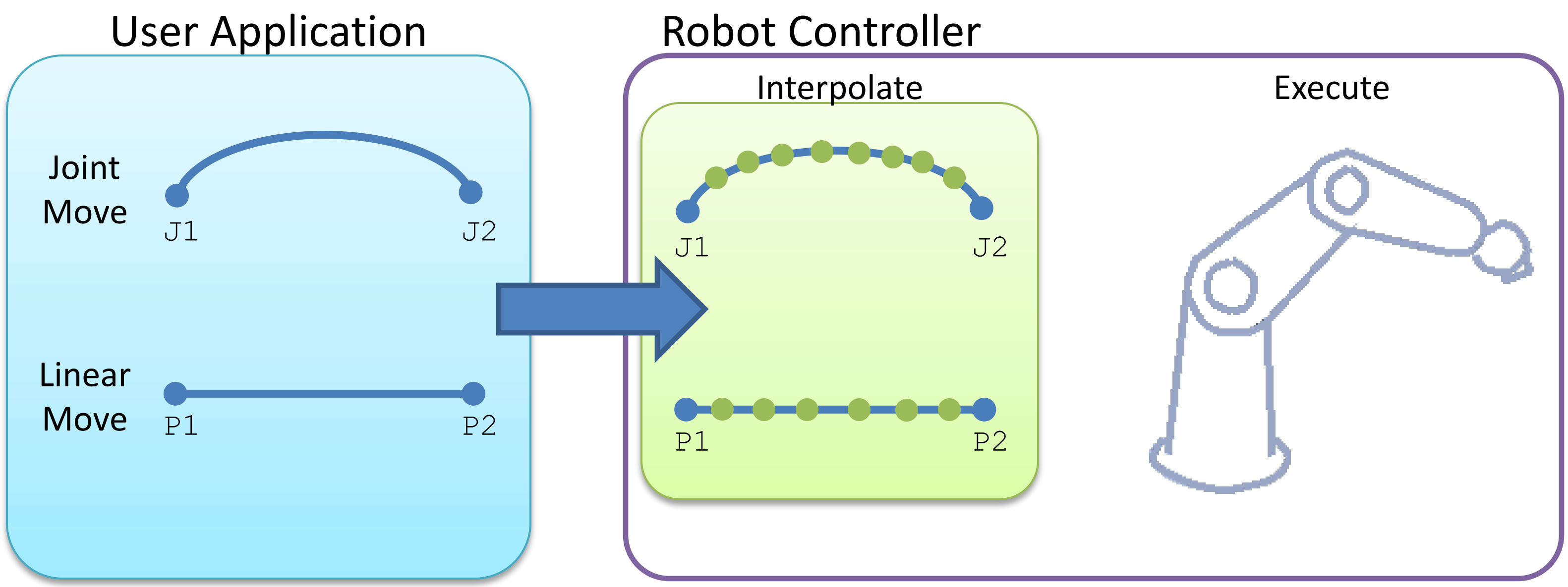


Motion Planning in ROS

Motion Planning in ROS

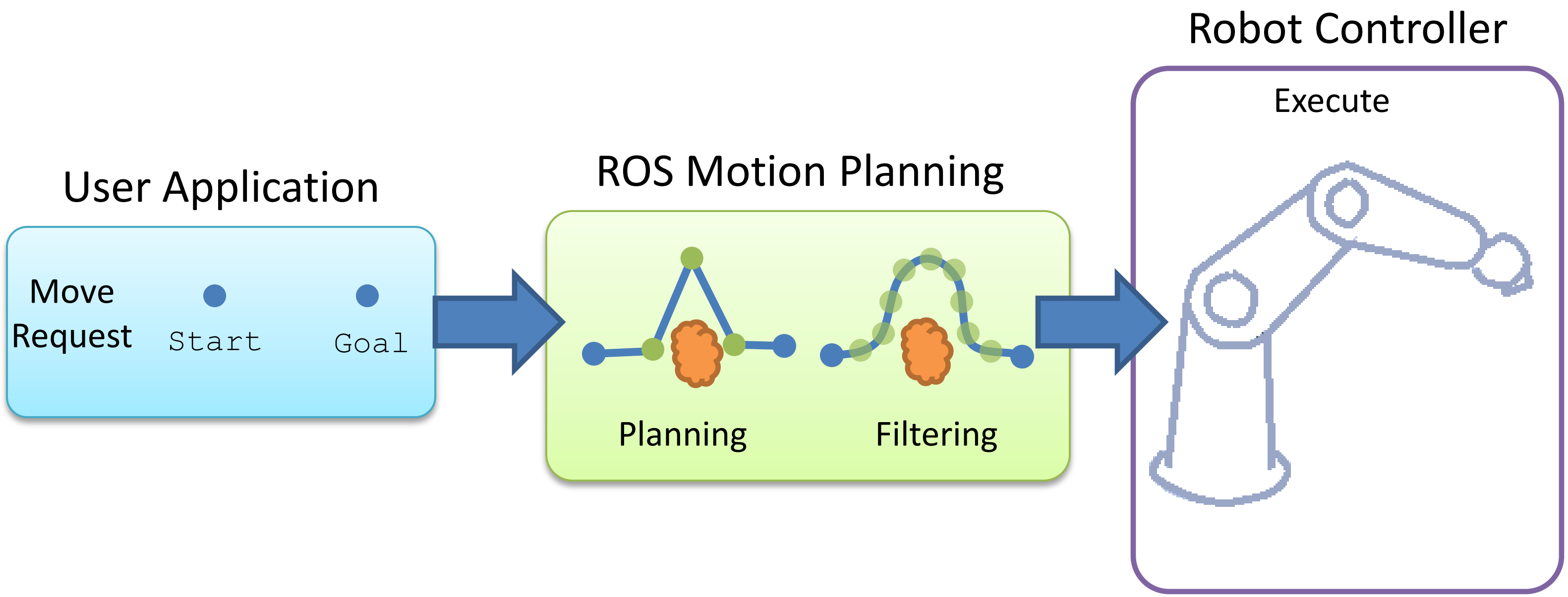


Traditional Robot Programming



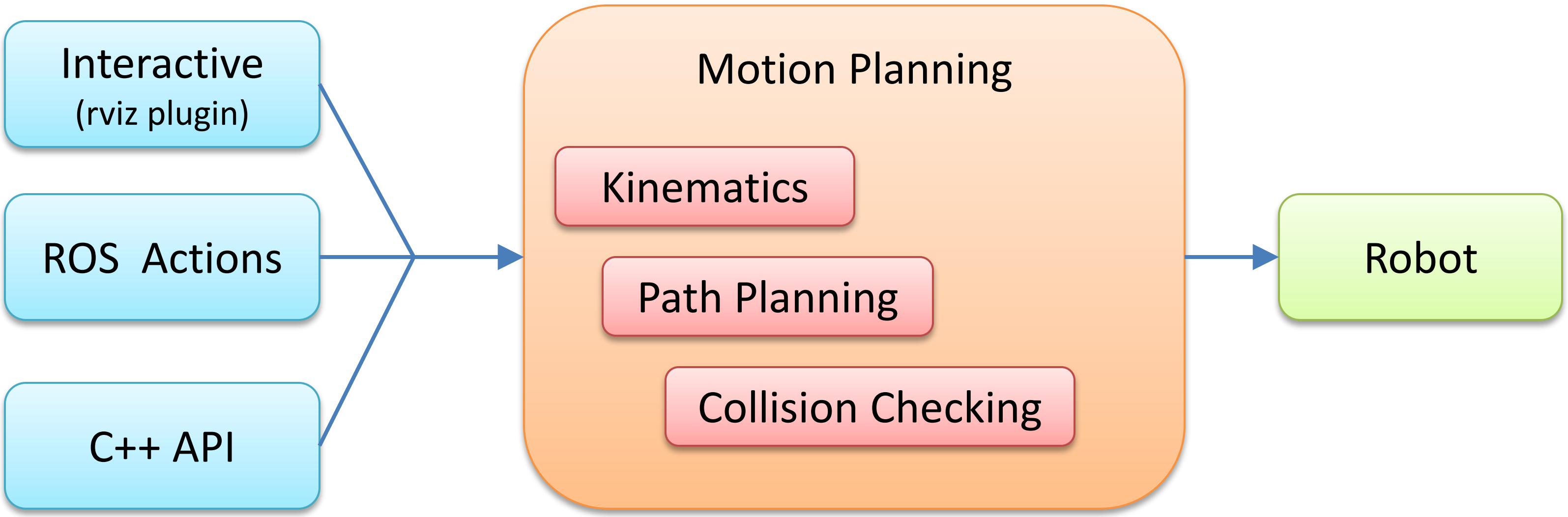
- Motion Types: *limited, but well-defined. One motion task.*
- Environment Model: *none*
- Execution Monitor: *application-specific*

MoveIt Motion Planning

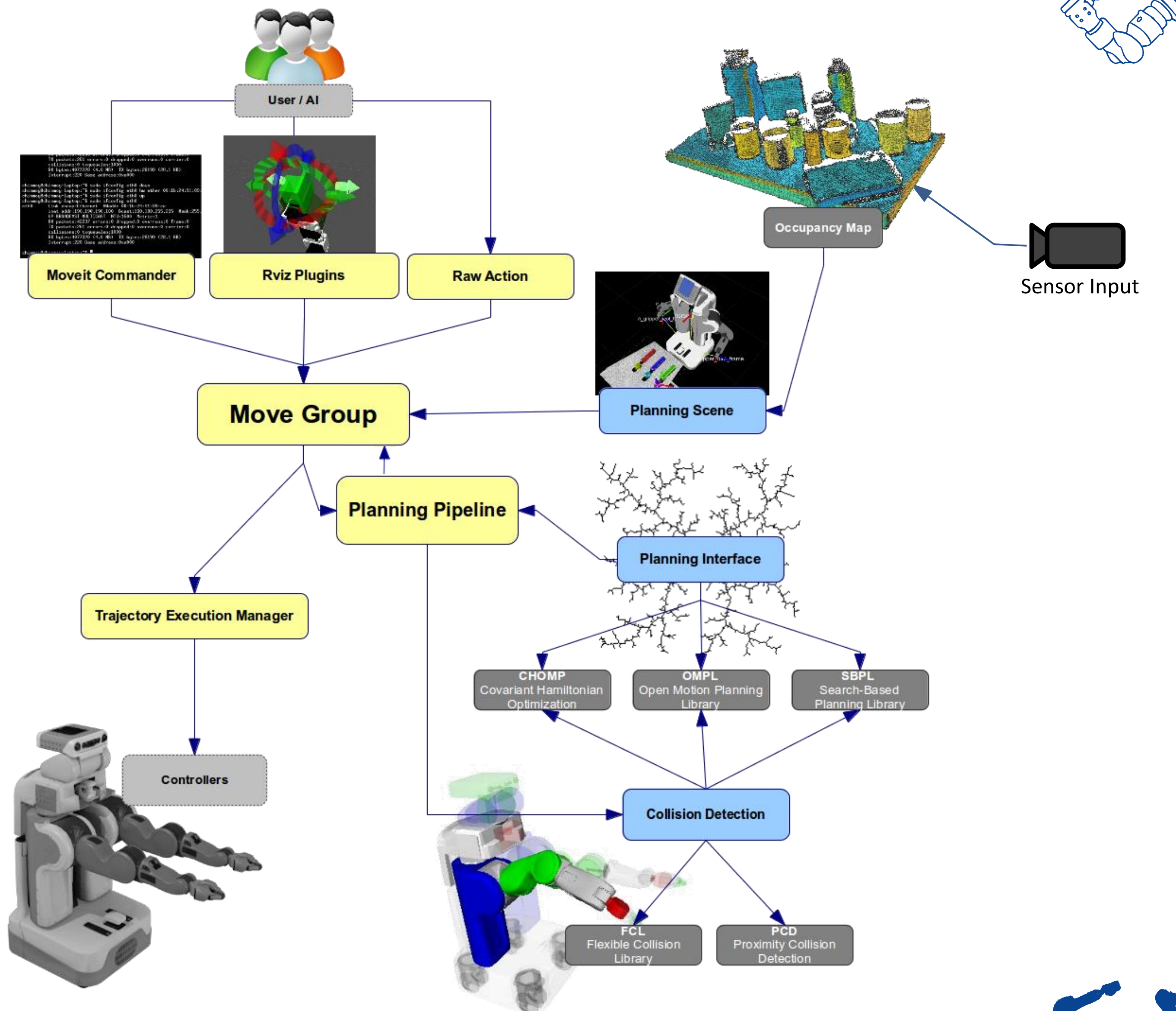


- Motion Types: *flexible, goal-driven, with constraints*
  but minimal control over actual path
- Environment Model: *automatic, based on live sensor feedback*
- Execution Monitor: *detects changes during motion*

Motion Planning Components

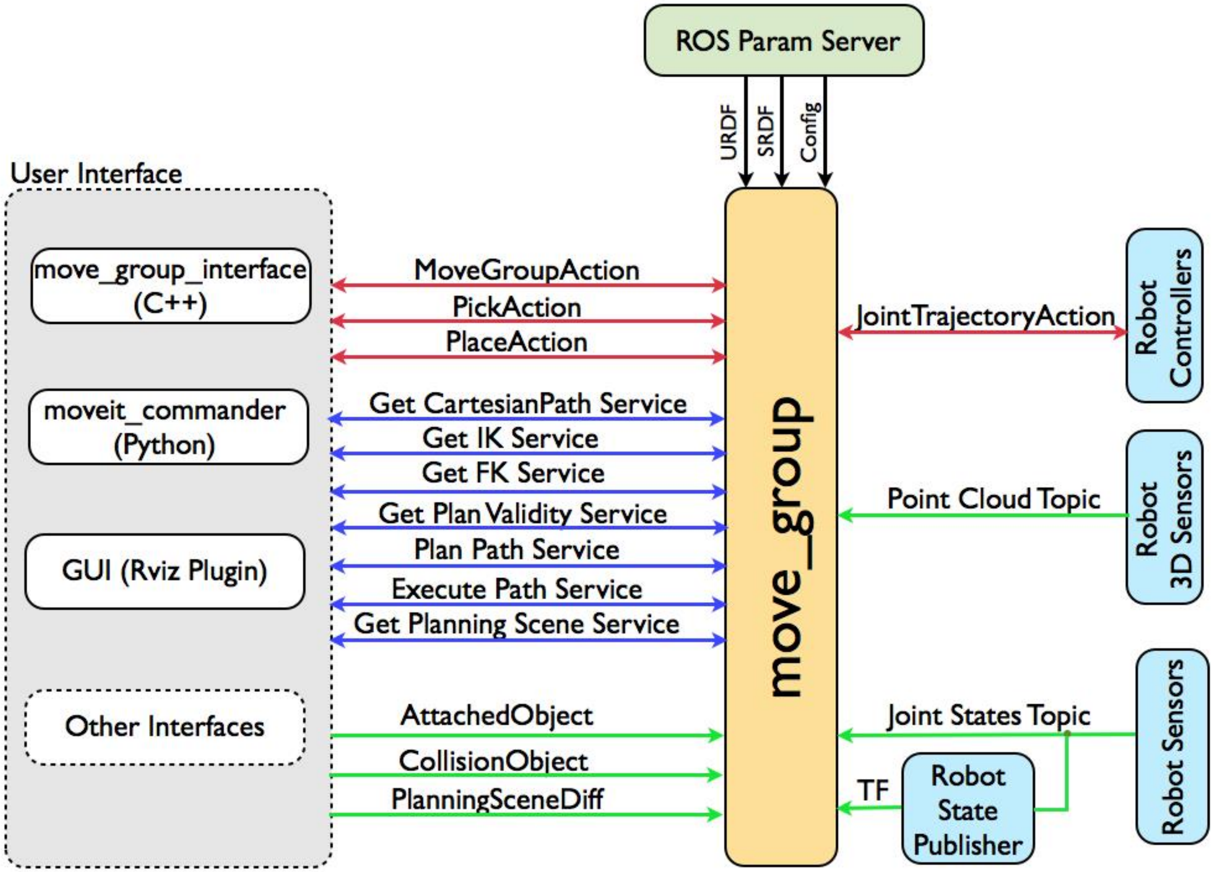


MoveIt Components



http://moveit.ros.org/wiki/High-level_Overview_Diagram
http://moveit.ros.org/wiki/Pipeline_Overview_Diagram

MoveIt Nodes



http://moveit.ros.org/documentation/concepts/

MoveIt! / Robot Integration

- A MoveIt! Package…
  - includes all required nodes, config, launch files
    - motion planning, filtering, collision detection, etc.
  - is unique to each individual robot model
    - includes references to URDF robot data
  - uses a standard interface to robots
    - publish trajectory, listen to joint angles
  - can (optionally) include workcell geometry
    - e.g. for collision checking

HowTo:

Set Up a New Robot

(or workcell)

Motivation

For each new robot model…

create a new MoveIt! package

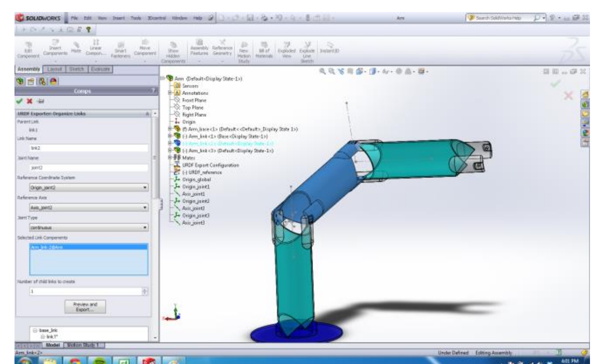
- Kinematics
  - physical configuration, lengths, etc.
- MoveIt! configuration
  - plugins, default parameter values
  - self-collision testing
  - pre-defined poses
- Robot connection
  - FollowJointTrajectory Action name

HowTo:
Set Up a New Robot

1. Create a URDF
2. Create a MoveIt! Package
3. Update MoveIt! Package for ROS-I
4. Test on ROS-I Simulator
5. Test on “Real” Robot

Create a URDF

- Previously covered URDF basics.
- Here are some tips:
  - create from datasheet or use [Solidworks Add-In]
  - double-check joint-offsets for accuracy
  - round near-zero offsets (if appropriate)
  - use "`base_link`" and "`tool0`"
  - use simplified collision models
    - convex-hull or primitives



Verify the URDF

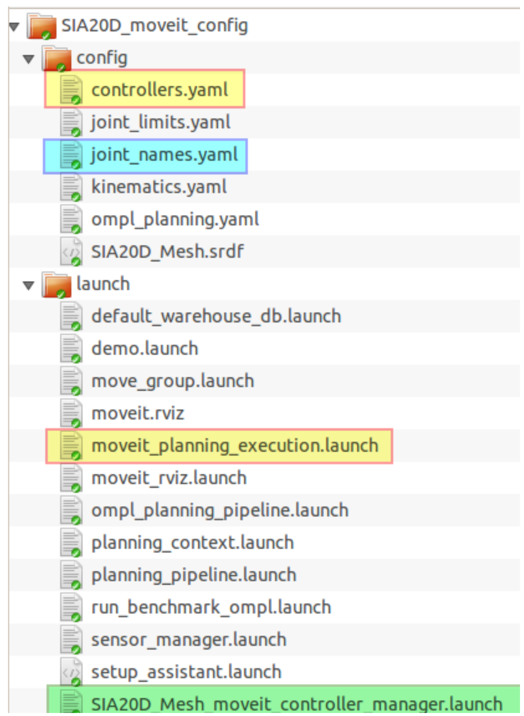
- It is **critical** to verify that your URDF matches the physical robot:
  - each joint moves as expected
  - joint-coupling issues are identified
  - min/max joint limits
  - joint directions (pos/neg)
  - correct zero-position, etc.
  - check forward kinematics

Create a MoveIt! Package

- Use the MoveIt! Setup Assistant
  - can create a new package or edit an existing one

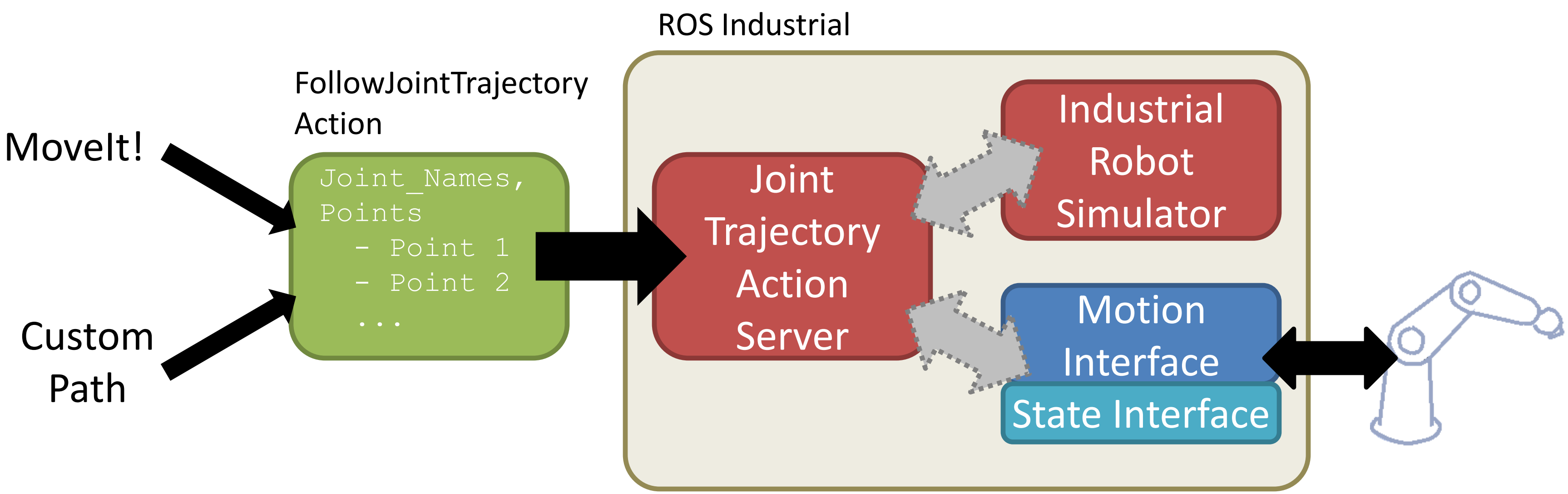
Update MoveIt! Package

- Setup Assistant generates a *generic* package
  - missing config. data to connect to a specific robot
  - ROS-I robots use a *standard* interface



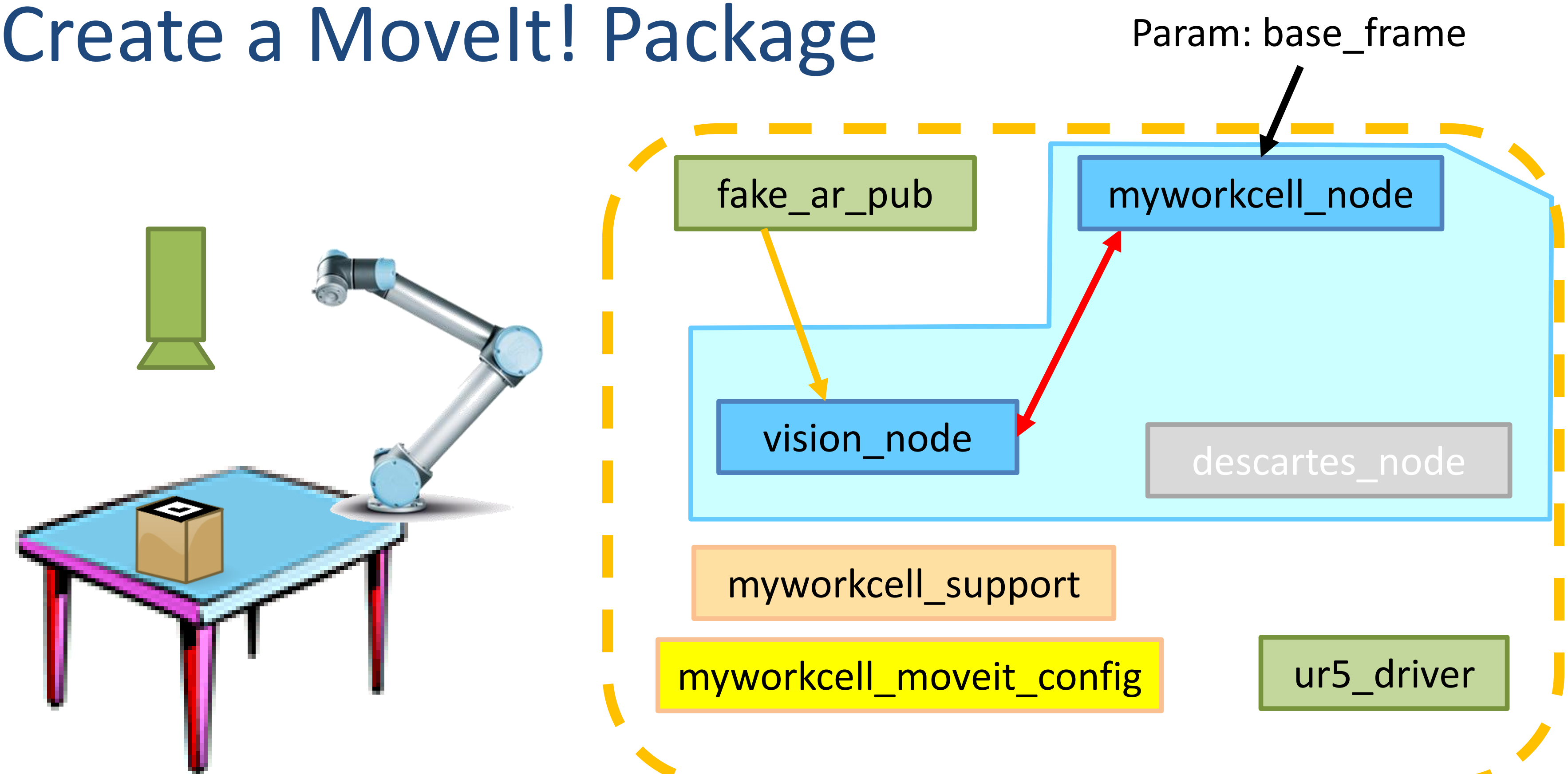
Update MoveIt! Package

- We'll generate launch files to run both:
  - **simulated** ROS-I robot
  - **real** robot-controller interface



Exercise 3.3:

Create a MoveIt! Package

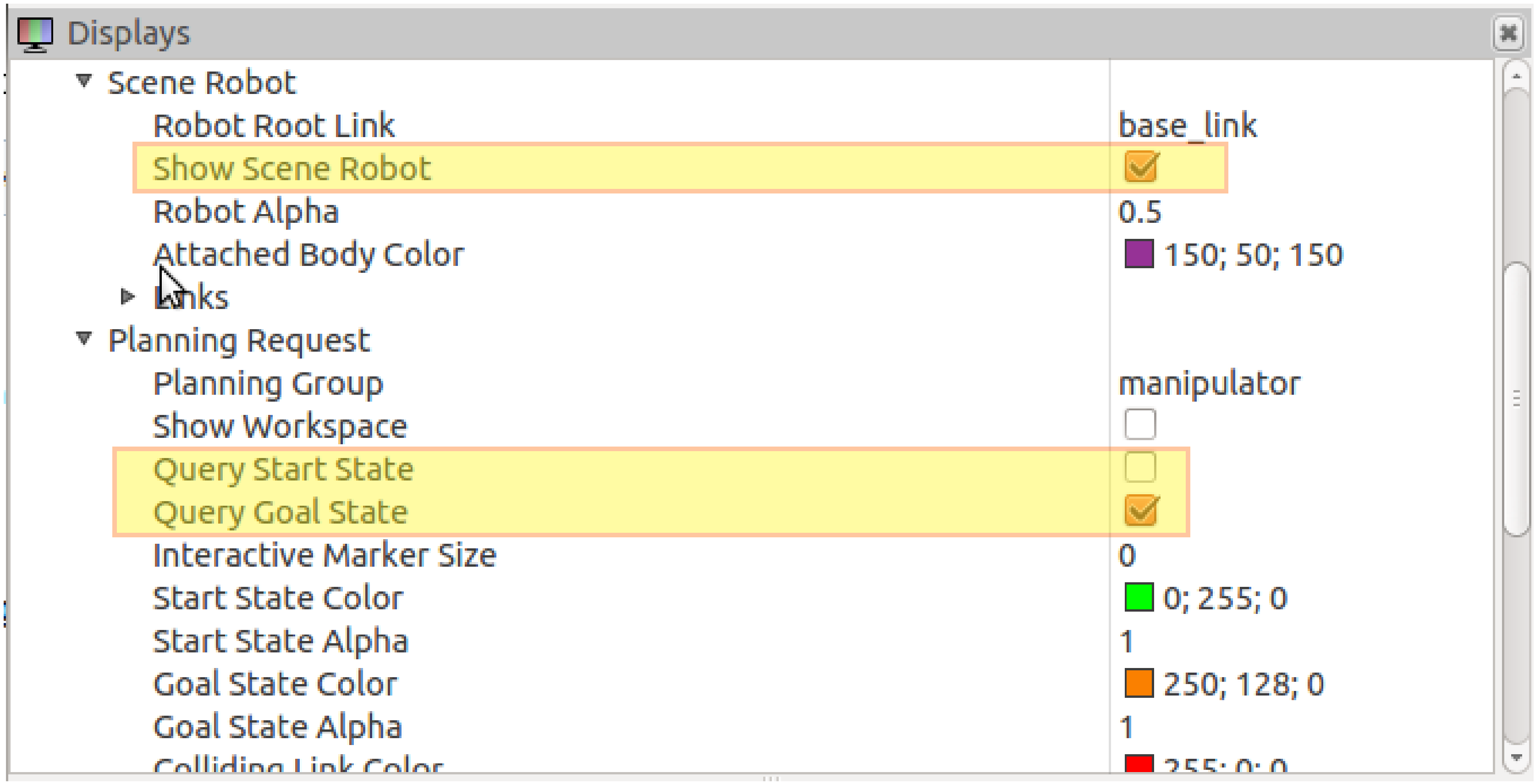


HowTo:
Motion Planning using MoveIt!

1. Motion Planning using RViz
2. Motion Planning using C++

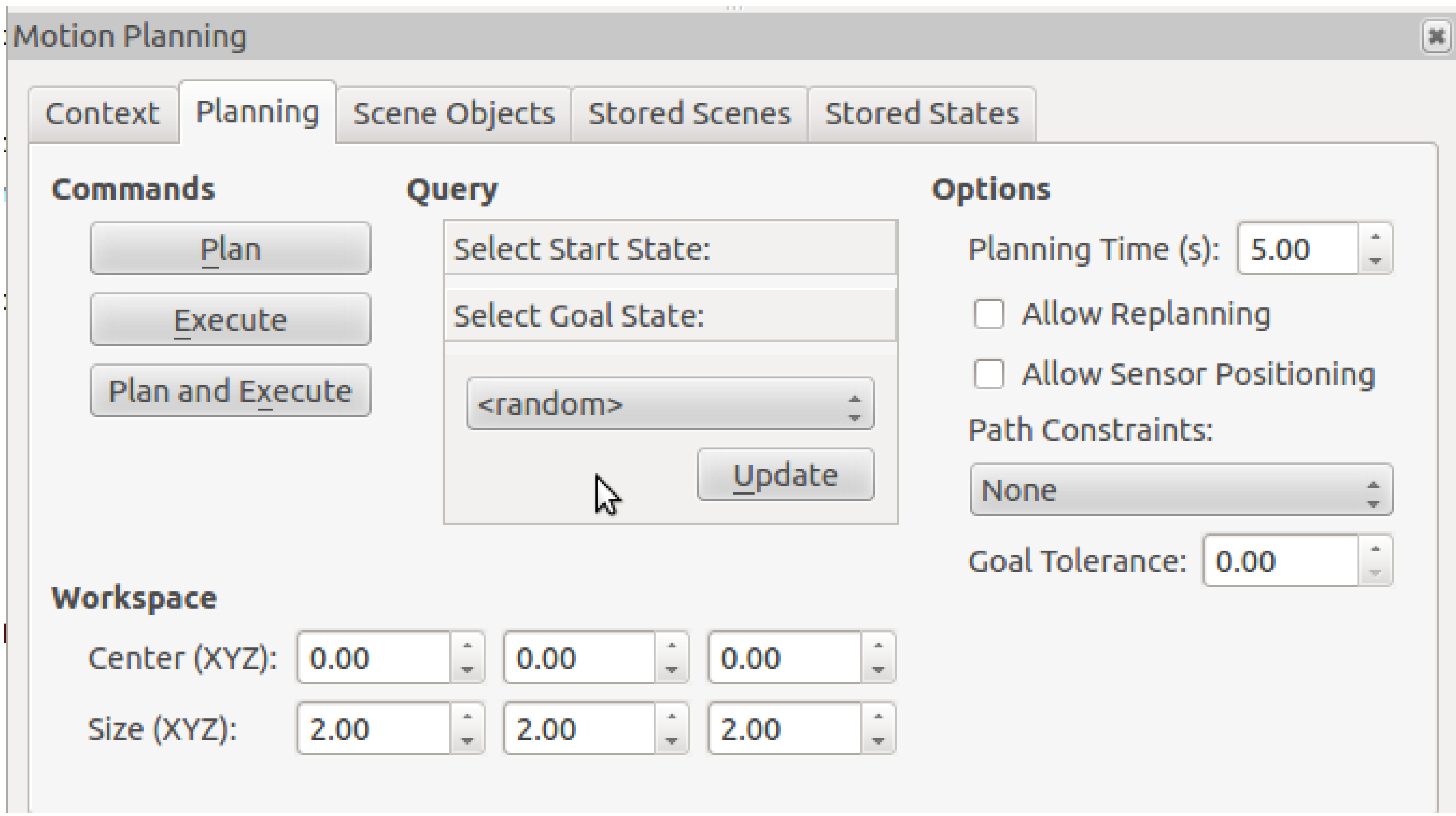
Motion Planning in RViz

Display Options



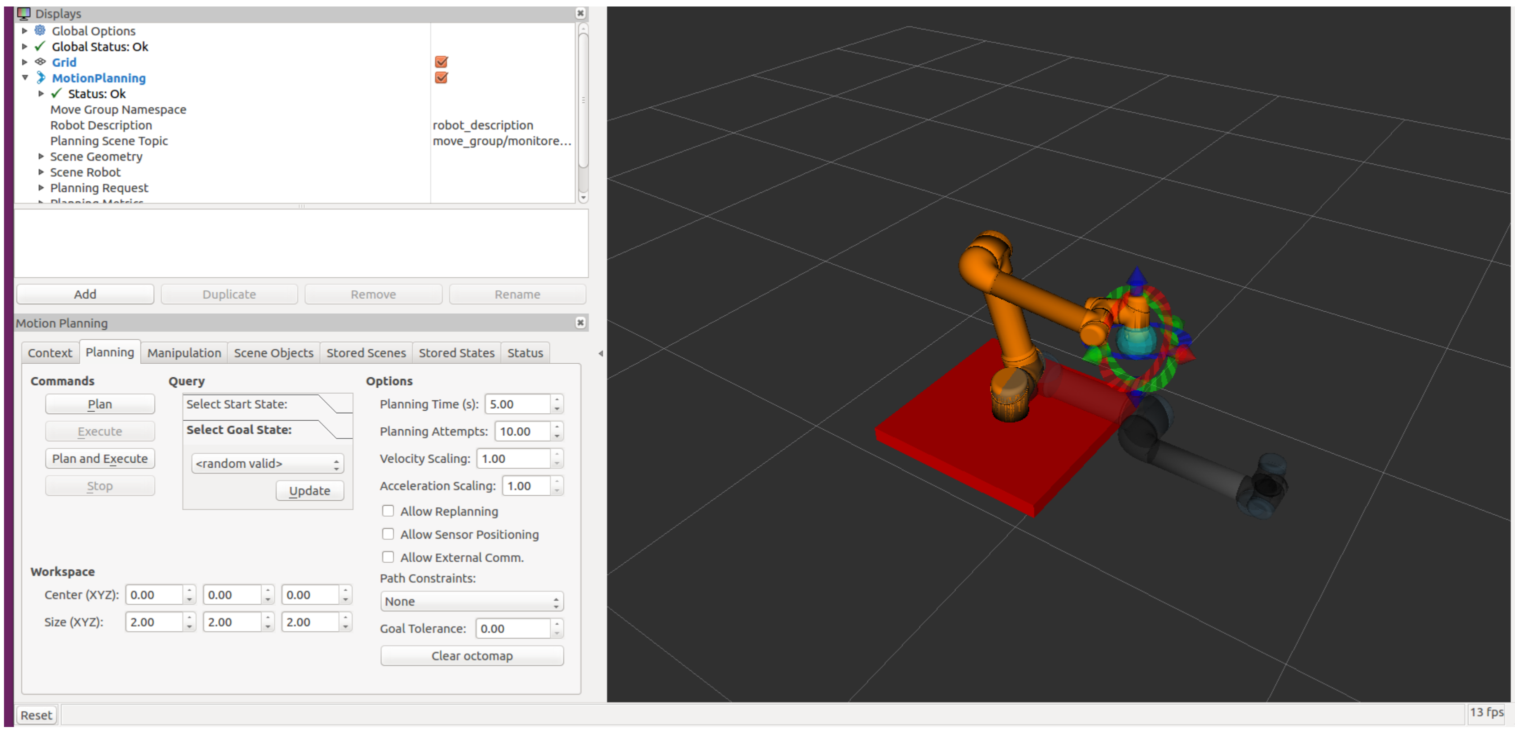
Motion Planning in RViz

Planning Options



Exercise 3.4:

Motion Planning using RVIZ



Review

ROS

- URDF
- MoveIt
- Path Planners
- RViz Planning

ROS-Industrial

- Robot Drivers
- Path Planners

Questions?

- ROS-I Architecture
- Setup Assistant
- Robot Launch Files
- RViz Planning