



Programming for Robotics

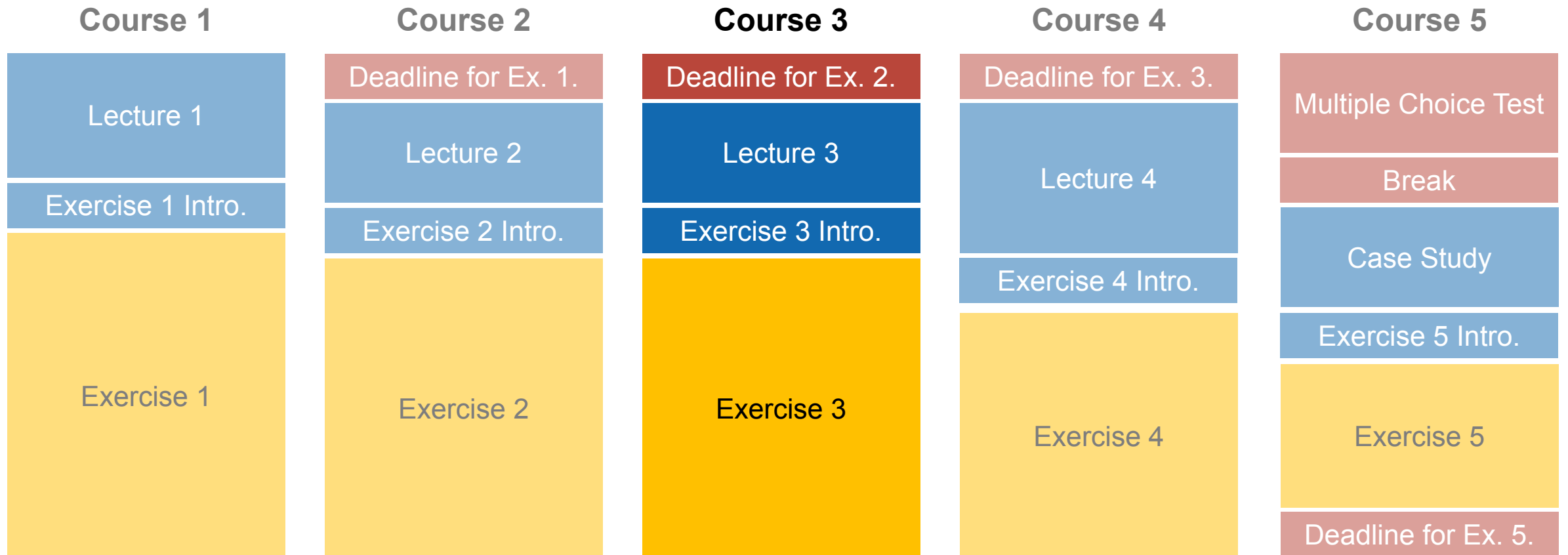
Introduction to ROS

Course 3

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 ROS

Course Structure



Evaluation – Multiple Choice Test

- Please be there 10 min before
- If you don't want to take the test please deregister by Monday (01.03.2021)
 - such that we can assign the seating schedule
- The multiple choice test takes place at the last course day:

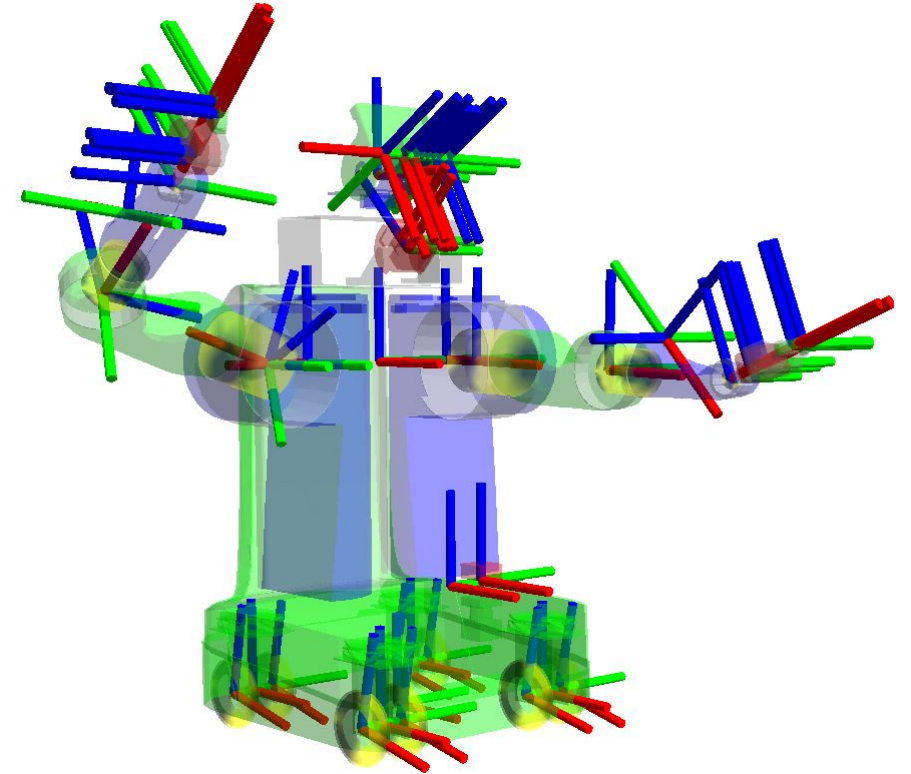
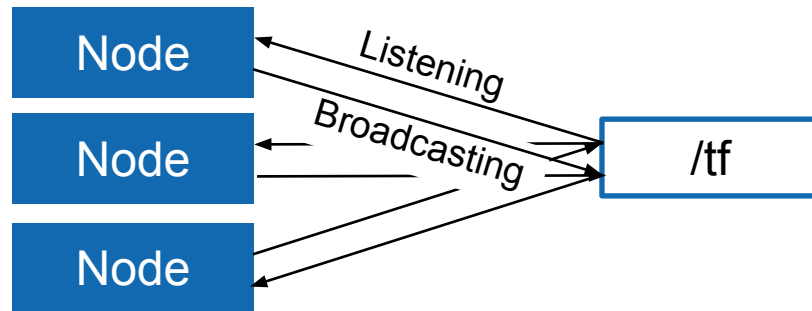
05.03.2021 at 08:00 (not 8:15)

Overview Course 3

- TF Transformation System
- rqt User Interface
- Robot models (URDF)
- Simulation descriptions (SDF)

TF Transformation System

- Tool for keeping track of coordinate frames over time
- Maintains relationship between coordinate frames in a tree structure buffered in time
- Lets the user transform points, vectors, etc. between coordinate frames at desired time
- Implemented as publisher/subscriber model on the topics `/tf` and `/tf_static`



More info
<http://wiki.ros.org/tf2>

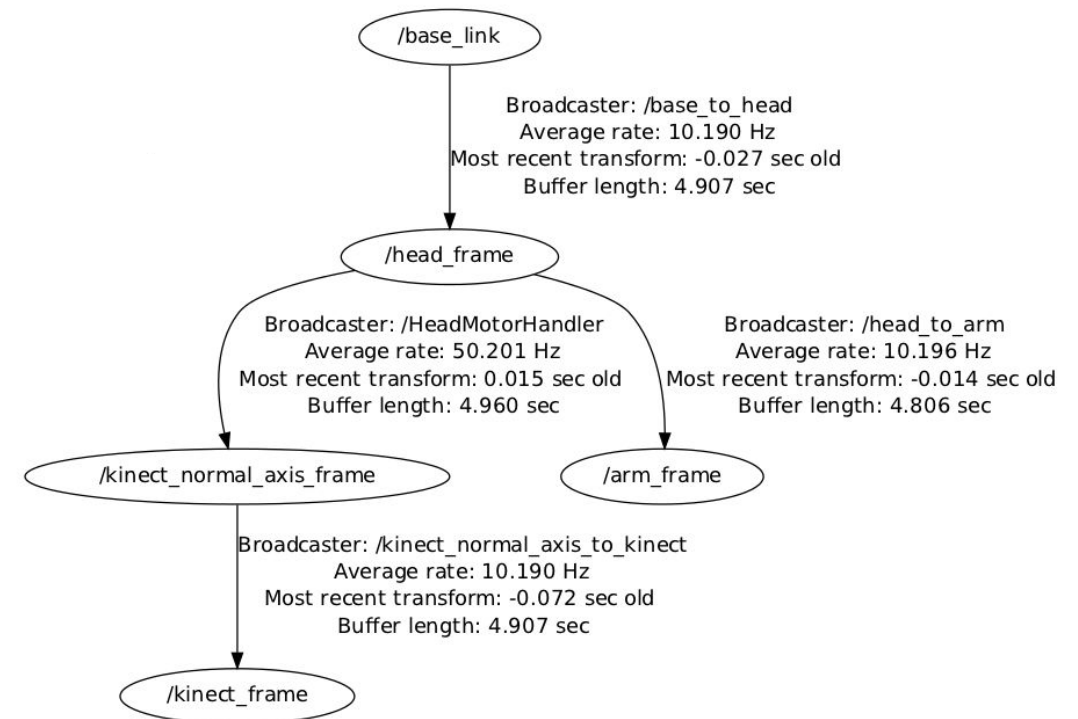
TF Transformation System

Transform Tree

- TF listeners use a buffer to listen to all broadcasted transforms
- Query for specific transforms from the transform tree

tf2_msgs/TFMessage.msg

```
geometry_msgs/TransformStamped[] transforms
std_msgs/Header header
uint32 seqtime stamp
string frame_id
string child_frame_id
geometry_msgs/Transform transform
geometry_msgs/Vector3 translation
geometry_msgs/Quaternion rotation
```



TF Transformation System Tools

Command line

Print information about the current transform tree

```
> rosrun tf tf_monitor
```

Print information about the transform between two frames

```
> rosrun tf tf_echo  
source_frame target_frame
```

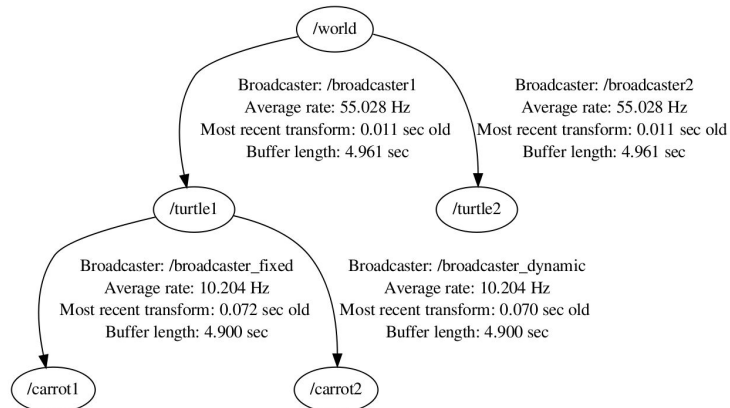
View Frames

Creates a visual graph (PDF) of the transform tree. Broken at the moment!!!!

<https://github.com/ros/geometry/pull/222>

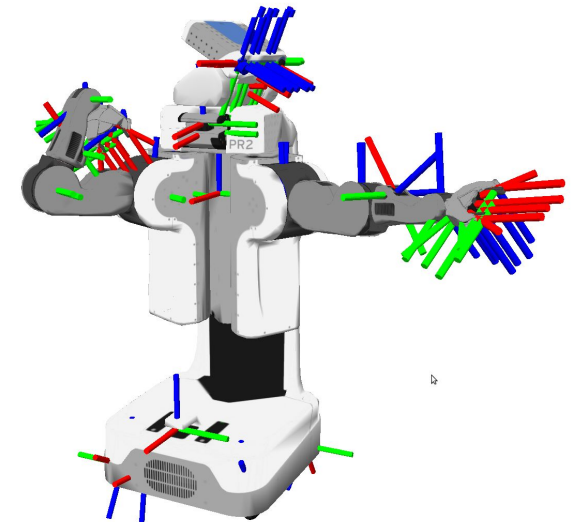
```
roslaunch tf view_frames
```

```
roslaunch tf2_tools view_frames.py
```

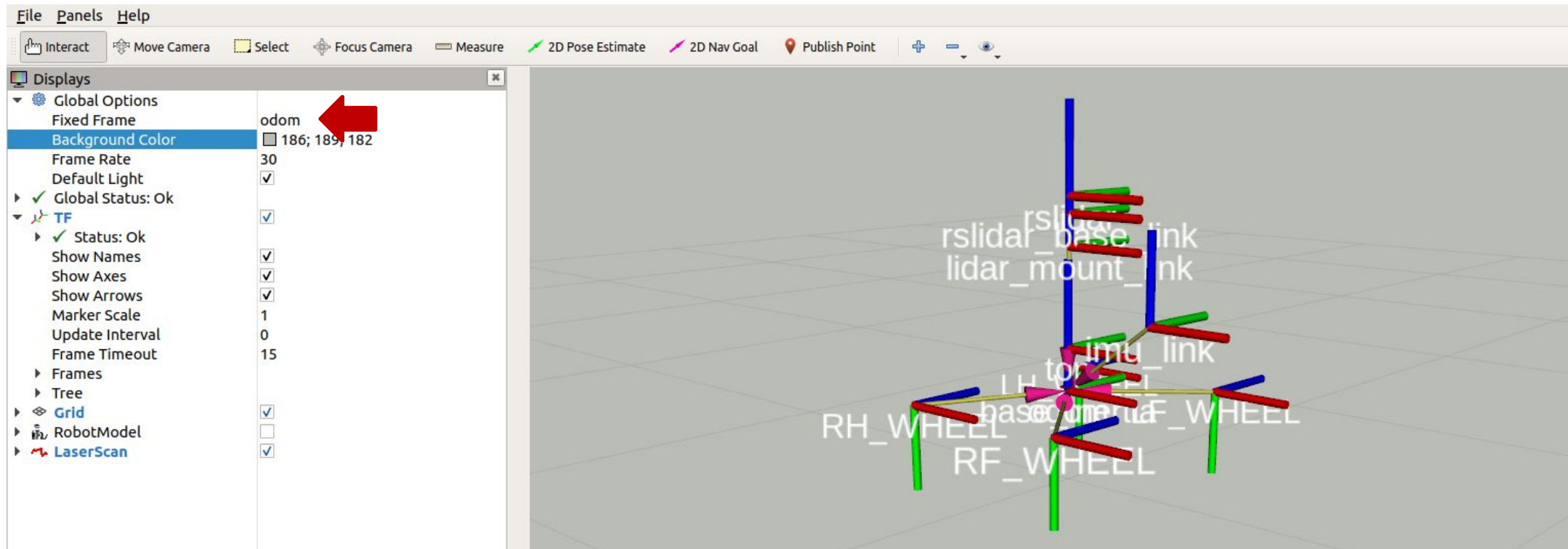


RViz

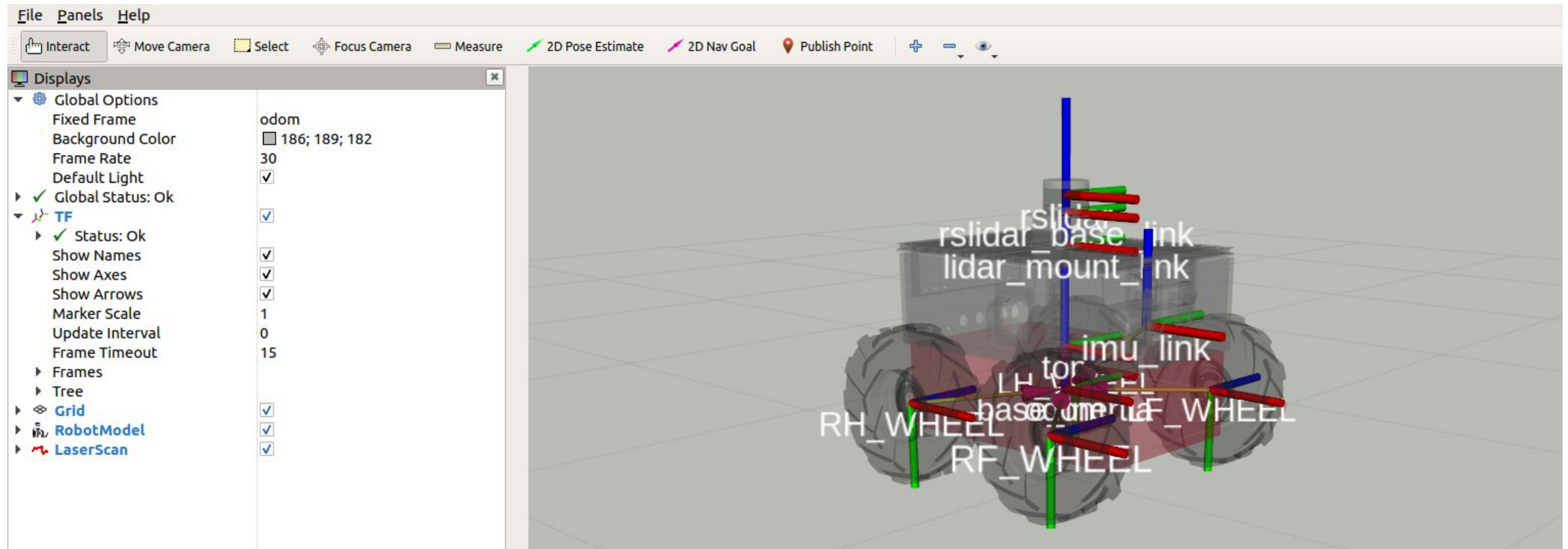
3D visualization of the transforms



TF Transformation System RViz Plugin



TF Transformation System RViz Plugin



TF Transformation System

Transform Listener C++ API

- Create a TF listener to fill up a buffer

```
tf2_ros::Buffer tfBuffer;
tf2_ros::TransformListener tfListener(tfBuffer);
```

- Make sure, that the listener does not run out of scope!
- To lookup transformations, use

```
geometry_msgs::TransformStamped transformStamped =
    tfBuffer.lookupTransform(target_frame_id,
                           source_frame_id, time);
```

- For time, use `ros::Time(0)` to get the latest available transform

```
#include <ros/ros.h>
#include <tf2_ros/transform_listener.h>
#include <geometry_msgs/TransformStamped.h>

int main(int argc, char** argv) {
    ros::init(argc, argv, "tf2_listener");
    ros::NodeHandle nodeHandle;
    tf2_ros::Buffer tfBuffer;
    tf2_ros::TransformListener tfListener(tfBuffer);

    ros::Rate rate(10.0);
    while (nodeHandle.ok()) {
        geometry_msgs::TransformStamped transformStamped;
        try {
            transformStamped = tfBuffer.lookupTransform("base",
                                                       "odom", ros::Time(0));
        } catch (tf2::TransformException &exception) {
            ROS_WARN("%s", exception.what());
            ros::Duration(1.0).sleep();
            continue;
        }
        rate.sleep();
    }
    return 0;
};
```

More info

<http://wiki.ros.org/tf2/Tutorials/Writing%20a%20tf2%20listener%20%28C%2B%2B%29>

rqt User Interface

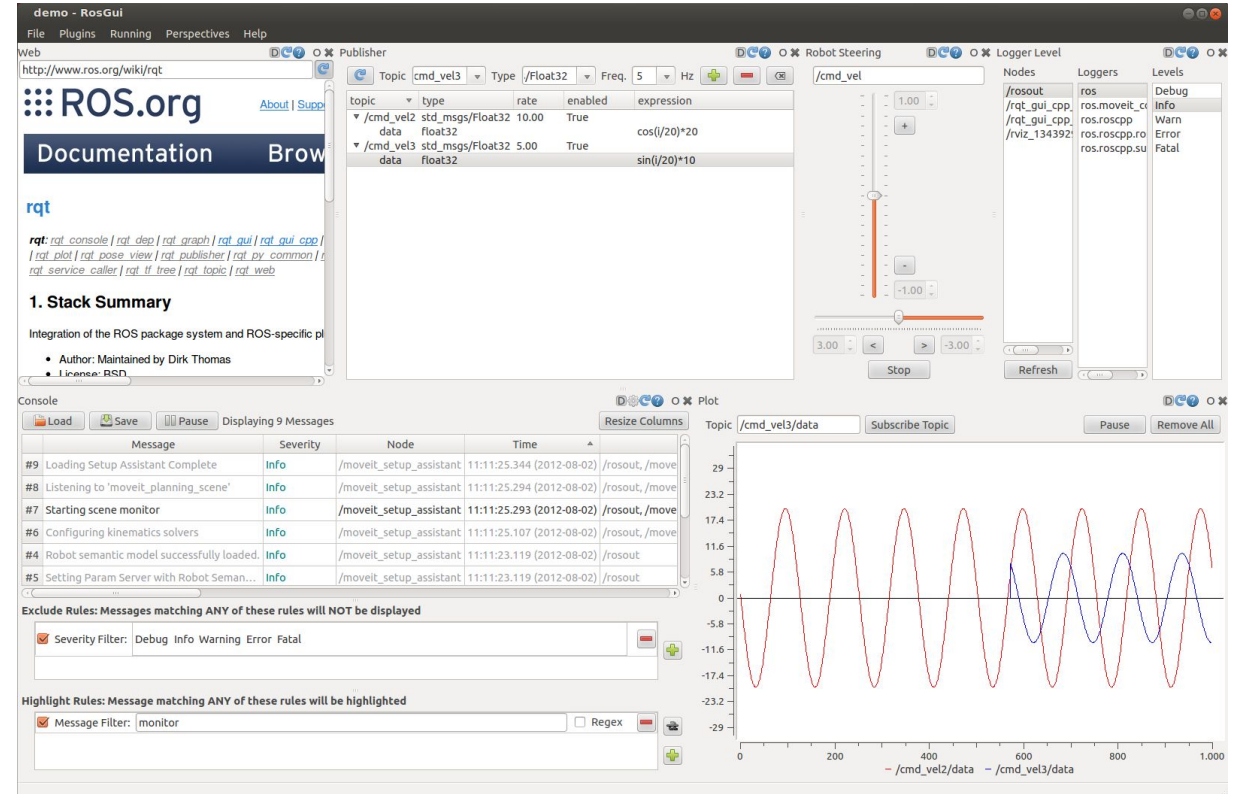
- User interface based on Qt
- Custom interfaces can be setup
- Lots of plugins exist
- Simple to write own plugins

Run RQT with

```
> rosrun rqt_gui rqt_gui
```

or

```
> rqt
```



More info

<http://wiki.ros.org/rqt/Plugins>

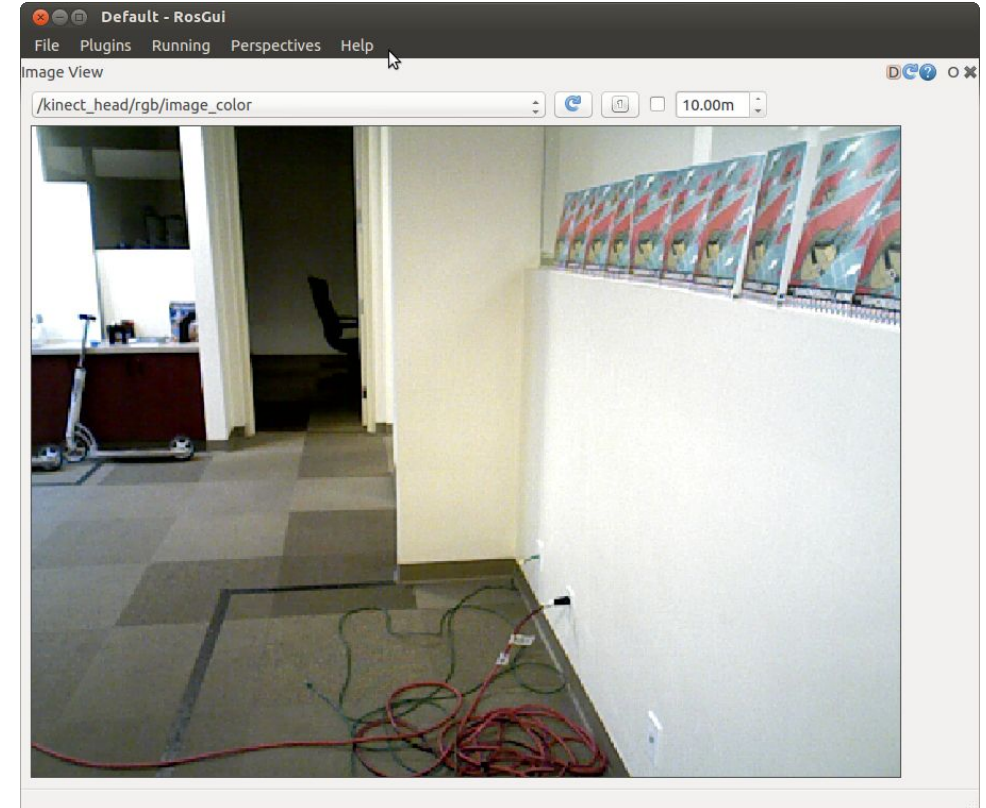
rqt User Interface

rqt_image_view

- Visualizing images

Run *rqt_image_view* with

```
> rosrun rqt_image_view rqt_image_view
```



More info

http://wiki.ros.org/rqt_image_view

rqt User Interface

rqt_multiplot

- Visualizing numeric values in 2D plots

Run *rqt_multiplot* with

```
> rosrun rqt_multiplot rqt_multiplot
```



More info

http://wiki.ros.org/rqt_multiplot

rqt User Interface

rqt_graph

- Visualizing the ROS computation graph

Run *rqt_graph* with

```
> rosrun rqt_graph rqt_graph
```



More info

http://wiki.ros.org/rqt_graph

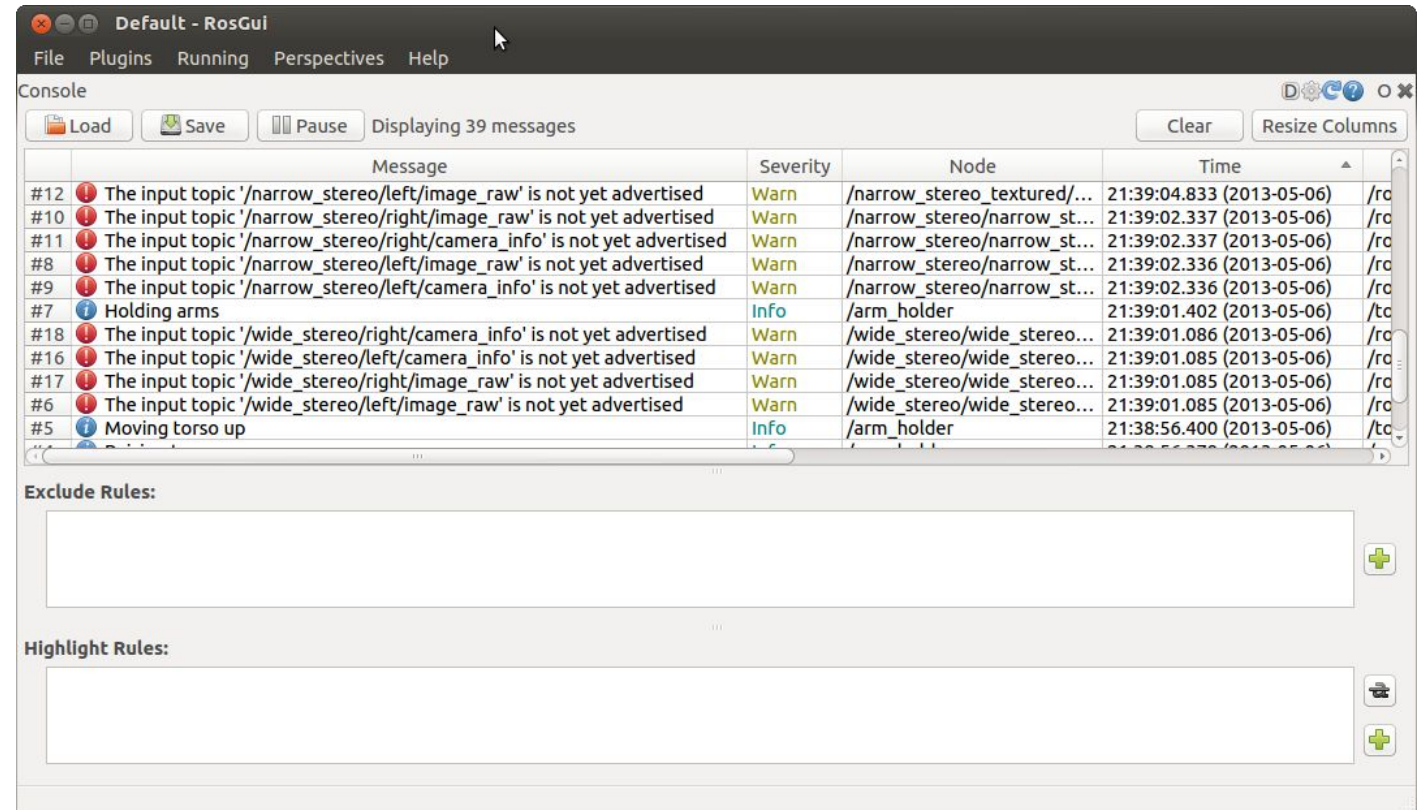
rqt User Interface

rqt_console

- Displaying and filtering ROS messages

Run *rqt_console* with

```
> rosrun rqt_console rqt_console
```



More info

http://wiki.ros.org/rqt_console

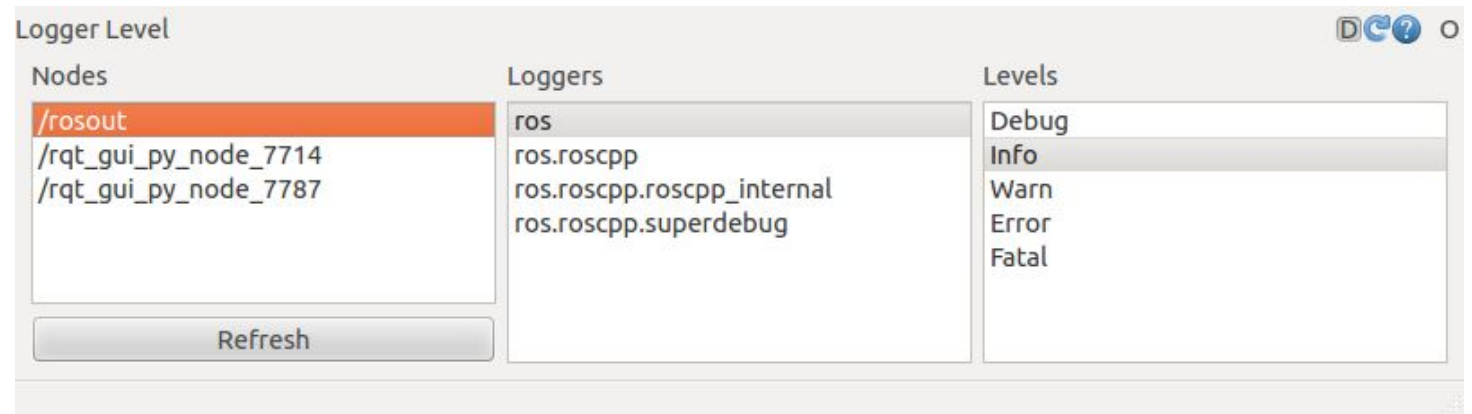
rqt User Interface

rqt_logger_level

- Configuring the logger level of ROS nodes

Run *rqt_logger_level* with

```
> rosrun rqt_logger_level  
rqt_logger_level
```



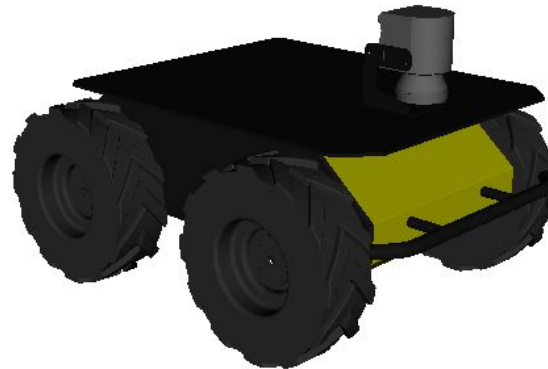
More info

http://wiki.ros.org/rqt_logger_level

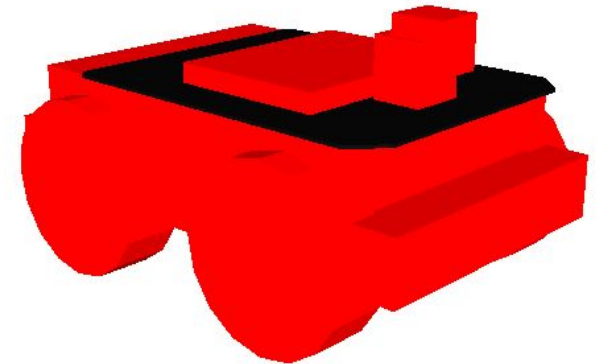
Robot Models

Unified Robot Description Format (URDF)

- Defines an XML format for representing a robot model
 - Kinematic and dynamic description
 - Visual representation
 - Collision model
- URDF generation can be scripted with *XACRO*



Mesh for visuals



Primitives for collision

More info

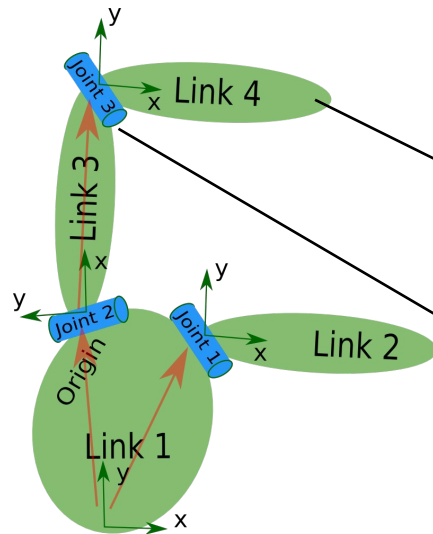
<http://wiki.ros.org/urdf>

<http://wiki.ros.org/xacro>

Robot Models

Unified Robot Description Format (URDF)

- Description consists of a set of *link* elements and a set of *joint* elements
- Joints connect the links together



robot.urdf

```
<robot name="robot">
  <link> ... </link>
  <link> ... </link>
  <link> ... </link>

  <joint> .... </joint>
  <joint> .... </joint>
  <joint> .... </joint>
</robot>
```

```
<link name="Link_name">
  <visual>
    <geometry>
      <mesh filename="mesh.dae"/>
    </geometry>
  </visual>
  <collision>
    <geometry>
      <cylinder length="0.6" radius="0.2"/>
    </geometry>
  </collision>
  <inertial>
    <mass value="10"/>
    <inertia ixx="0.4" ixy="0.0" .../>
  </inertial>
</link>
```


```
<joint name="joint_name" type="revolute">
  <axis xyz="0 0 1"/>
  <limit effort="1000.0" upper="0.548" ... />
  <origin rpy="0 0 0" xyz="0.2 0.01 0"/>
  <parent link="parent_link_name"/>
  <child link="child_link_name"/>
</joint>
```

More info

<http://wiki.ros.org/urdf/XML/model>

Robot Models

Usage in ROS

- The robot description (URDF) is stored on the parameter server (typically) under `/robot_description`
- You can visualize the robot model in Rviz with the  *RobotModel* plugin

control.launch

```
...  
<include file="$(find smb_description)/launch/load.launch">  
  <arg name="simulation"      value="$(arg simulation)"/>  
  <arg name="description_name" value="$(arg robot_description)"/>  
  <arg name="description_file" value="$(arg description_file)"/>  
  <arg name="wheel_joint_type" value="continuous"/>  
  <arg name="robot_namespace" value="$(arg robot_namespace)"/>  
</include>  
...
```

load.launch

```
...  
<param name="$(arg description_name)" command="$(find xacro)/xacro  
  $(arg description_file)  
  wheel_joint_type:=$(arg wheel_joint_type)  
  simulation:=$(arg simulation)  
  robot_namespace:=$(arg robot_namespace)  
  lidar:=$(arg lidar)  
  description_name_xacro:=$(arg description_name)  
  publish_tf:=$(arg publish_tf)"/>  
</launch>  
...
```

Simulation Descriptions

Simulation Description Format (SDF)

- Defines an XML format to describe
 - Environments (lighting, gravity etc.)
 - Objects (static and dynamic)
 - Sensors
 - Robots
- SDF is the standard format for Gazebo
- Gazebo converts a URDF to SDF automatically



More info

<http://sdformat.org>

Further References

- **ROS Wiki**
 - <http://wiki.ros.org/>
- **Installation**
 - <http://wiki.ros.org/ROS/Installation>
- **Tutorials**
 - <http://wiki.ros.org/ROS/Tutorials>
- **Available packages**
 - <http://www.ros.org/browse/>
- **ROS Cheat Sheet**
 - <https://www.clearpathrobotics.com/ros-robot-operating-system-cheat-sheet/>
 - https://kapeli.com/cheat_sheets/ROS.docset/Contents/Resources/Documents/index
- **ROS Best Practices**
 - https://github.com/leggedrobotics/ros_best_practices/wiki
- **ROS Package Template**
 - https://github.com/leggedrobotics/ros_best_practices/tree/master/ros_package_template

Contact Information

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Course website:

<http://www.rsl.ethz.ch/education-students/lectures/ros.html>