# [Lab] Kinematics

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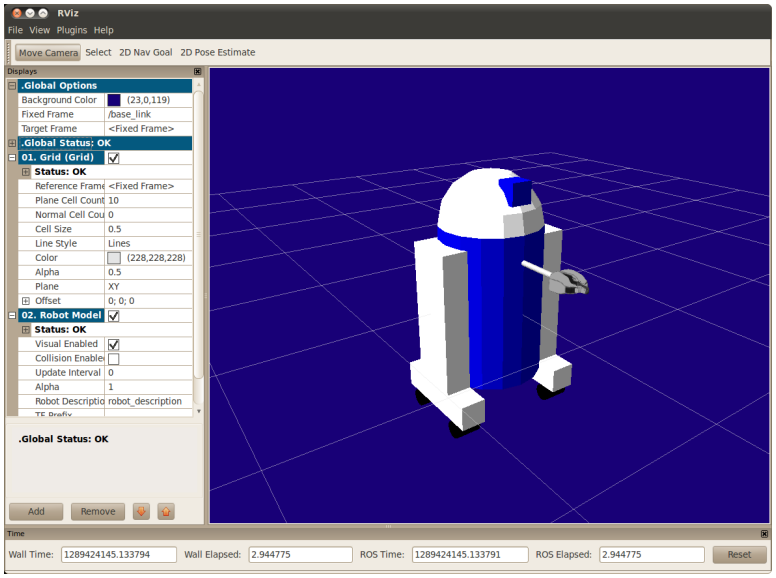
**<u>Evaluation</u>: Upload your exercise codes and snapshots of the demanded manipulator configurations (in group) on the course website (campus.ece.fr site).**

**<u>Due</u>: Before the next lab session**
**<u>Remark</u>: No late homework will be accepted.**

In this tutorial, we are going to build visual models of two different robots: R2D2 (for tutorial) and a robot arm (for homework). Before continuing, make sure you have the joint_state_publisher package installed.

## I. Building the geometric description of a mobile robot

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## 1) Creating `urdf_model` package

Create a ROS package called `urdf_model` with the following `CMakeLists.txt` and `package.xml` files.

`CMakeLists.txt`:

```
cmake_minimum_required(VERSION 2.8.3)
project(urdf_model)

find_package(catkin REQUIRED roslaunch)
catkin_package()

roslaunch_add_file_check(launch)

install(DIRECTORY config images launch rviz urdf
  DESTINATION ${CATKIN_PACKAGE_SHARE_DESTINATION})
```

`package.xml`:

```
<package>
  <name>urdf_model</name>
  <version>0.0.1</version>

  <description>This package contains a number of URDF models.</description>
  <author></author>

  <maintainer email="someone@gmail.com">Someone</maintainer>

  <license>BSD</license>
  <url>http://ros.org/wiki/urdf_tutorial</url>

  <buildtool_depend>catkin</buildtool_depend>
  <build_depend>roslaunch</build_depend>
  <run_depend>controller_manager</run_depend>
  <run_depend>diff_drive_controller</run_depend>
  <run_depend>gazebo_ros</run_depend>
  <run_depend>gazebo_ros_control</run_depend>
  <run_depend>joint_state_controller</run_depend>
  <run_depend>joint_state_publisher</run_depend>
  <run_depend>position_controllers</run_depend>
  <run_depend>pr2_description</run_depend>
  <run_depend>robot_state_publisher</run_depend>
  <run_depend>rqt_robot_steering</run_depend>
  <run_depend>rviz</run_depend>
  <run_depend>urdf</run_depend>
  <run_depend>xacro</run_depend>
</package>
```

## 2) Creating the `launch` directory

Create a directory called `launch` under the package directory. Then, create the `display.launch` file with the following content:
`display.launch`:

```
<launch>

  <arg name="model" default="$(find urdf_tutorial)/urdf/r2d2.xacro"/>
  <arg name="gui" default="true" />
  <arg name="rvizconfig" default="$(find urdf_model)/rviz/urdf.rviz" />

  <param name="robot_description"
   command="$(find xacro)/xacro.py $(arg model)" />
  <param name="use_gui" value="$(arg gui)"/>

  <node name="joint_state_publisher" pkg="joint_state_publisher"
   type="joint_state_publisher" />
  <node name="robot_state_publisher" pkg="robot_state_publisher"
   type="state_publisher" />
  <node name="rviz" pkg="rviz" type="rviz" args="-d $(arg rvizconfig)"
   required="true" />

</launch>
```

### 3) Creating the `mesh` directory

Create a directory called `mesh` under the package directory and save there the four .dae/.tif files available on the course site in campus.ece.fr. These are: l_finger.dae, l_finger_color.tif, l_finger_tip.dae, and l_finger_tip_color.tif

### 4) Creating the `urdf` robot models

Create a directory called `urdf` under the package directory and create `robot_fixed.urdf` file with the following content.
`robot_fixed.urdf`:

```
<?xml version="1.0"?>
<robot name="visual">

  <material name="blue">
    <color rgba="0 0 .8 1"/>
  </material>
  <material name="black">
    <color rgba="0 0 0 1"/>
  </material>
  <material name="white">
    <color rgba="1 1 1 1"/>
  </material>

  <link name="base_link">
    <visual>
```

```
    <geometry>
      <cylinder length="0.6" radius="0.2"/>
    </geometry>
    <material name="blue"/>
  </visual>
</link>

<link name="right_leg">
  <visual>
    <geometry>
      <box size="0.6 .1 .2"/>
    </geometry>
    <origin rpy="0 1.57075 0" xyz="0 0 -0.3"/>
    <material name="white"/>
  </visual>
</link>

<joint name="base_to_right_leg" type="fixed">
  <parent link="base_link"/>
  <child link="right_leg"/>
  <origin xyz="0 -0.22 .25"/>
</joint>

<link name="right_base">
  <visual>
    <geometry>
      <box size="0.4 .1 .1"/>
    </geometry>
    <material name="white"/>
  </visual>
</link>

<joint name="right_base_joint" type="fixed">
  <parent link="right_leg"/>
  <child link="right_base"/>
  <origin xyz="0 0 -0.6"/>
</joint>

<link name="right_front_wheel">
  <visual>
    <origin rpy="1.57075 0 0" xyz="0 0 0"/>
    <geometry>
      <cylinder length="0.1" radius="0.035"/>
    </geometry>
    <material name="black"/>
    <origin rpy="0 0 0" xyz="0 0 0"/>
  </visual>
</link>
```

```
<joint name="right_front_wheel_joint" type="fixed">
  <axis rpy="0 0 0" xyz="0 1 0"/>
  <parent link="right_base"/>
  <child link="right_front_wheel"/>
  <origin rpy="0 0 0" xyz="0.133333333333 0 -0.085"/>
</joint>

<link name="right_back_wheel">
  <visual>
    <origin rpy="1.57075 0 0" xyz="0 0 0"/>
    <geometry>
      <cylinder length="0.1" radius="0.035"/>
    </geometry>
    <material name="black"/>
  </visual>
</link>
<joint name="right_back_wheel_joint" type="fixed">
  <axis rpy="0 0 0" xyz="0 1 0"/>
  <parent link="right_base"/>
  <child link="right_back_wheel"/>
  <origin rpy="0 0 0" xyz="-0.133333333333 0 -0.085"/>
</joint>

<link name="left_leg">
  <visual>
    <geometry>
      <box size="0.6 .1 .2"/>
    </geometry>
    <origin rpy="0 1.57075 0" xyz="0 0 -0.3"/>
    <material name="white"/>
  </visual>
</link>

<joint name="base_to_left_leg" type="fixed">
  <parent link="base_link"/>
  <child link="left_leg"/>
  <origin xyz="0 0.22 .25"/>
</joint>

<link name="left_base">
  <visual>
    <geometry>
      <box size="0.4 .1 .1"/>
    </geometry>
    <material name="white"/>
  </visual>
</link>
```

```
<joint name="left_base_joint" type="fixed">
  <parent link="left_leg"/>
  <child link="left_base"/>
  <origin xyz="0 0 -0.6"/>
</joint>

<link name="left_front_wheel">
  <visual>
    <origin rpy="1.57075 0 0" xyz="0 0 0"/>
    <geometry>
      <cylinder length="0.1" radius="0.035"/>
    </geometry>
    <material name="black"/>
  </visual>
</link>
<joint name="left_front_wheel_joint" type="fixed">
  <parent link="left_base"/>
  <child link="left_front_wheel"/>
  <origin rpy="0 0 0" xyz="0.133333333333 0 -0.085"/>
</joint>

<link name="left_back_wheel">
  <visual>
    <origin rpy="1.57075 0 0" xyz="0 0 0"/>
    <geometry>
      <cylinder length="0.1" radius="0.035"/>
    </geometry>
    <material name="black"/>
  </visual>
</link>
<joint name="left_back_wheel_joint" type="fixed">
  <axis rpy="0 0 0" xyz="0 1 0"/>
  <parent link="left_base"/>
  <child link="left_back_wheel"/>
  <origin rpy="0 0 0" xyz="-0.133333333333 0 -0.085"/>
</joint>

<joint name="gripper_extension" type="prismatic">
  <parent link="base_link"/>
  <child link="gripper_pole"/>
  <limit effort="1000.0" lower="-0.38" upper="0" velocity="0.5"/>
  <origin rpy="0 0 0" xyz="0.19 0 .2"/>
</joint>

<link name="gripper_pole">
  <visual>
    <geometry>
      <cylinder length="0.2" radius=".01"/>
```

```
    </geometry>
    <origin rpy="0 1.57075 0 " xyz="0.1 0 0"/>
  </visual>
</link>

<joint name="left_gripper_joint" type="fixed">
  <origin rpy="0 0 0" xyz="0.2 0.01 0"/>
  <parent link="gripper_pole"/>
  <child link="left_gripper"/>
</joint>

<link name="left_gripper">
  <visual>
    <origin rpy="0.0 0 0" xyz="0 0 0"/>
    <geometry>
      <mesh filename="package://urdf_model/mesh/l_finger.dae"/>
    </geometry>
  </visual>
</link>

<joint name="left_tip_joint" type="fixed">
  <parent link="left_gripper"/>
  <child link="left_tip"/>
</joint>

<link name="left_tip">
  <visual>
    <origin rpy="0.0 0 0" xyz="0.09137 0.00495 0"/>
    <geometry>
      <mesh filename="package://urdf_model/mesh/l_finger_tip.dae"/>
    </geometry>
  </visual>
</link>
<joint name="right_gripper_joint" type="fixed">
  <origin rpy="0 0 0" xyz="0.2 -0.01 0"/>
  <parent link="gripper_pole"/>
  <child link="right_gripper"/>
</joint>

<link name="right_gripper">
  <visual>
    <origin rpy="-3.1415 0 0" xyz="0 0 0"/>
    <geometry>
      <mesh filename="package://urdf_model/mesh/l_finger.dae"/>
    </geometry>
  </visual>
</link>
```

```
  <joint name="right_tip_joint" type="fixed">
    <parent link="right_gripper"/>
    <child link="right_tip"/>
  </joint>

  <link name="right_tip">
    <visual>
      <origin rpy="-3.1415 0 0" xyz="0.09137 0.00495 0"/>
      <geometry>
        <mesh filename="package://urdf_model/mesh/l_finger_tip.dae"/>
      </geometry>
    </visual>
  </link>

  <link name="head">
    <visual>
      <geometry>
        <sphere radius="0.2"/>
      </geometry>
      <material name="white"/>
    </visual>
  </link>
  <joint name="head_swivel" type="fixed">
    <parent link="base_link"/>
    <child link="head"/>
    <origin xyz="0 0 0.3"/>
  </joint>

  <link name="box">
    <visual>
      <geometry>
        <box size=".08 .08 .08"/>
      </geometry>
      <material name="blue"/>
    </visual>
  </link>

  <joint name="tobox" type="fixed">
    <parent link="head"/>
    <child link="box"/>
    <origin xyz="0.1814 0 0.1414"/>
  </joint>
</robot>
```

**5) Compiling the `urdf_model` package**

As you did during the last lab session, compile the `catkin_ws` and source the corresponding `setup.bash` file.

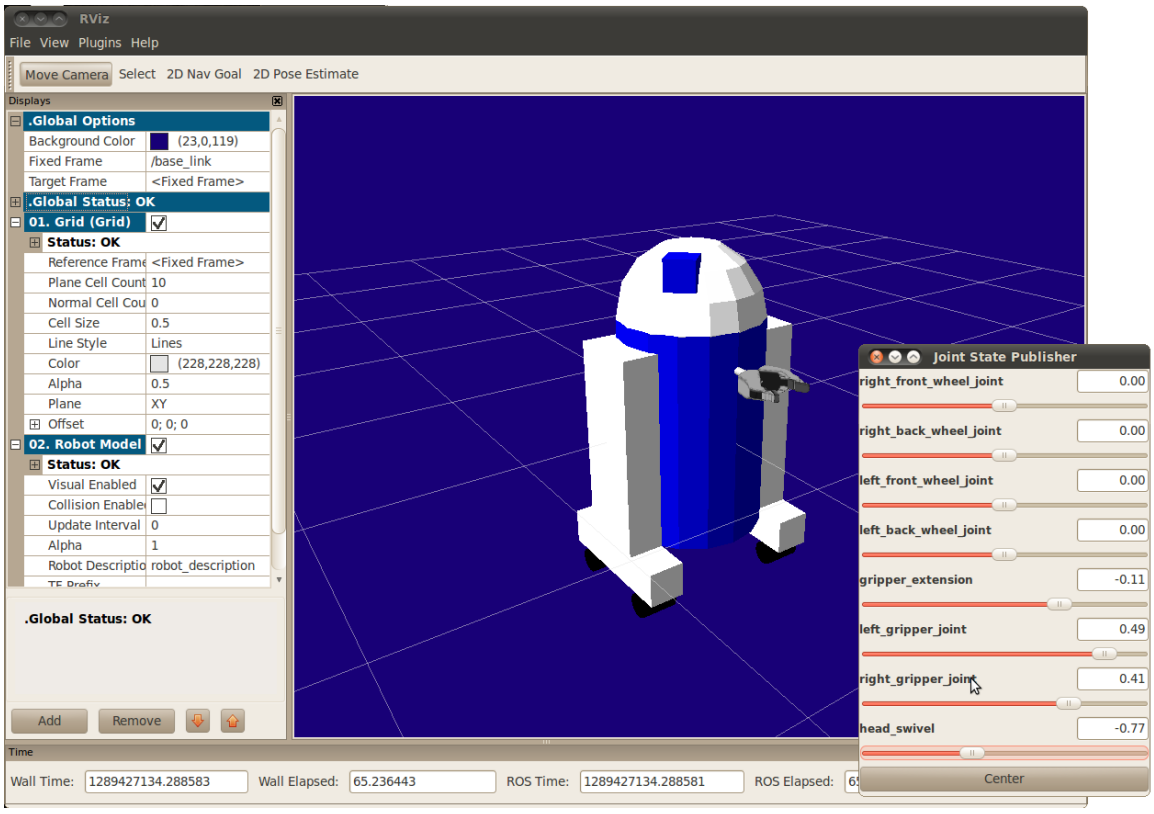
**6) Launching the `display.launch` file**

Launch `display.launch` file overriding the robot model name with the newly generated model called `robot_fixed.urdf` as follows:

```
roslaunch urdf_model display.launch \
  model:='$(find urdf_model)/urdf/robot_fixed.urdf'
```

In RVIZ, add the display options for the `RobotModel` and `TF`. In addition, make sure that the value for `Fixed Frame` is `base_link`.
Notice that when you launch a .launch file, during its execution time, the existence of ROS Master is verified. If this is not the case, then ROS Master is executed before the execution of the content of the .launch file.

# II. Building a movable robot




## 1) Creating the`urdf` model for a movable robot

In the `urdf` directory, create `robot_mobile.urdf` file with the following content.
`robot_mobile.urdf`:

```
<?xml version="1.0"?>
<robot name="visual">

<material name="blue">
    <color rgba="0 0 .8 1"/>
  </material>
  <material name="black">
    <color rgba="0 0 0 1"/>
```

```
</material>
<material name="white">
  <color rgba="1 1 1 1"/>
</material>

<link name="base_link">
  <visual>
    <geometry>
      <cylinder length="0.6" radius="0.2"/>
    </geometry>
    <material name="blue"/>
  </visual>
</link>

<link name="right_leg">
  <visual>
    <geometry>
      <box size="0.6 .1 .2"/>
    </geometry>
    <origin rpy="0 1.57075 0" xyz="0 0 -0.3"/>
    <material name="white"/>
  </visual>
</link>

<joint name="base_to_right_leg" type="fixed">
  <parent link="base_link"/>
  <child link="right_leg"/>
  <origin xyz="0 -0.22 .25"/>
</joint>

<link name="right_base">
  <visual>
    <geometry>
      <box size="0.4 .1 .1"/>
    </geometry>
    <material name="white"/>
  </visual>
</link>

<joint name="right_base_joint" type="fixed">
  <parent link="right_leg"/>
  <child link="right_base"/>
  <origin xyz="0 0 -0.6"/>
</joint>

<link name="right_front_wheel">
  <visual>
    <origin rpy="1.57075 0 0" xyz="0 0 0"/>
```

```
    <geometry>
      <cylinder length="0.1" radius="0.035"/>
    </geometry>
    <material name="black"/>
    <origin rpy="0 0 0" xyz="0 0 0"/>
  </visual>
</link>
<joint name="right_front_wheel_joint" type="continuous">
  <axis rpy="0 0 0" xyz="0 1 0"/>
  <parent link="right_base"/>
  <child link="right_front_wheel"/>
  <origin rpy="0 0 0" xyz="0.133333333333 0 -0.085"/>
</joint>

<link name="right_back_wheel">
  <visual>
    <origin rpy="1.57075 0 0" xyz="0 0 0"/>
    <geometry>
      <cylinder length="0.1" radius="0.035"/>
    </geometry>
    <material name="black"/>
  </visual>
</link>
<joint name="right_back_wheel_joint" type="continuous">
  <axis rpy="0 0 0" xyz="0 1 0"/>
  <parent link="right_base"/>
  <child link="right_back_wheel"/>
  <origin rpy="0 0 0" xyz="-0.133333333333 0 -0.085"/>
</joint>

<link name="left_leg">
  <visual>
    <geometry>
      <box size="0.6 .1 .2"/>
    </geometry>
    <origin rpy="0 1.57075 0" xyz="0 0 -0.3"/>
    <material name="white"/>
  </visual>
</link>

<joint name="base_to_left_leg" type="fixed">
  <parent link="base_link"/>
  <child link="left_leg"/>
  <origin xyz="0 0.22 .25"/>
</joint>

<link name="left_base">
  <visual>
```

```
    <geometry>
      <box size="0.4 .1 .1"/>
    </geometry>
    <material name="white"/>
  </visual>
</link>

<joint name="left_base_joint" type="fixed">
  <parent link="left_leg"/>
  <child link="left_base"/>
  <origin xyz="0 0 -0.6"/>
</joint>

<link name="left_front_wheel">
  <visual>
    <origin rpy="1.57075 0 0" xyz="0 0 0"/>
    <geometry>
      <cylinder length="0.1" radius="0.035"/>
    </geometry>
    <material name="black"/>
  </visual>
</link>
<joint name="left_front_wheel_joint" type="continuous">
  <axis rpy="0 0 0" xyz="0 1 0"/>
  <parent link="left_base"/>
  <child link="left_front_wheel"/>
  <origin rpy="0 0 0" xyz="0.133333333333 0 -0.085"/>
</joint>

<link name="left_back_wheel">
  <visual>
    <origin rpy="1.57075 0 0" xyz="0 0 0"/>
    <geometry>
      <cylinder length="0.1" radius="0.035"/>
    </geometry>
    <material name="black"/>
  </visual>
</link>
<joint name="left_back_wheel_joint" type="continuous">
  <axis rpy="0 0 0" xyz="0 1 0"/>
  <parent link="left_base"/>
  <child link="left_back_wheel"/>
  <origin rpy="0 0 0" xyz="-0.133333333333 0 -0.085"/>
</joint>

<joint name="gripper_extension" type="prismatic">
  <parent link="base_link"/>
  <child link="gripper_pole"/>
```

```
  <limit effort="1000.0" lower="-0.38" upper="0" velocity="0.5"/>
  <origin rpy="0 0 0" xyz="0.19 0 .2"/>
</joint>

<link name="gripper_pole">
  <visual>
    <geometry>
      <cylinder length="0.2" radius=".01"/>
    </geometry>
    <origin rpy="0 1.57075 0 " xyz="0.1 0 0"/>
  </visual>
</link>

<joint name="left_gripper_joint" type="revolute">
  <axis xyz="0 0 1"/>
  <limit effort="1000.0" lower="0.0" upper="0.548" velocity="0.5"/>
  <origin rpy="0 0 0" xyz="0.2 0.01 0"/>
  <parent link="gripper_pole"/>
  <child link="left_gripper"/>
</joint>

<link name="left_gripper">
  <visual>
    <origin rpy="0.0 0 0" xyz="0 0 0"/>
    <geometry>
      <mesh filename="package://urdf_model/mesh/l_finger.dae"/>
    </geometry>
  </visual>
</link>

<joint name="left_tip_joint" type="fixed">
  <parent link="left_gripper"/>
  <child link="left_tip"/>
</joint>

<link name="left_tip">
  <visual>
    <origin rpy="0.0 0 0" xyz="0.09137 0.00495 0"/>
    <geometry>
      <mesh filename="package://urdf_model/mesh/l_finger_tip.dae"/>
    </geometry>
  </visual>
</link>
<joint name="right_gripper_joint" type="revolute">
  <axis xyz="0 0 -1"/>
  <limit effort="1000.0" lower="0.0" upper="0.548" velocity="0.5"/>
  <origin rpy="0 0 0" xyz="0.2 -0.01 0"/>
  <parent link="gripper_pole"/>
```

```
  <child link="right_gripper"/>
</joint>

<link name="right_gripper">
  <visual>
    <origin rpy="-3.1415 0 0" xyz="0 0 0"/>
    <geometry>
      <mesh filename="package://urdf_model/mesh/l_finger.dae"/>
    </geometry>
  </visual>
</link>

<joint name="right_tip_joint" type="fixed">
  <parent link="right_gripper"/>
  <child link="right_tip"/>
</joint>

<link name="right_tip">
  <visual>
    <origin rpy="-3.1415 0 0" xyz="0.09137 0.00495 0"/>
    <geometry>
      <mesh filename="package://urdf_model/mesh/l_finger_tip.dae"/>
    </geometry>
  </visual>
</link>

<link name="head">
  <visual>
    <geometry>
      <sphere radius="0.2"/>
    </geometry>
    <material name="white"/>
  </visual>
</link>
<joint name="head_swivel" type="continuous">
  <parent link="base_link"/>
  <child link="head"/>
  <origin xyz="0 0 0.3"/>
</joint>

<link name="box">
  <visual>
    <geometry>
      <box size=".08 .08 .08"/>
    </geometry>
    <material name="blue"/>
  </visual>
</link>
```

```
  <joint name="tobox" type="fixed">
    <parent link="head"/>
    <child link="box"/>
    <origin xyz="0.1814 0 0.1414"/>
  </joint>
</robot>
```

Now, launch `display.launch` file overriding the robot model name with the newly generated model called `robot_mobile.urdf` with the option of GUI to control the robot joints:

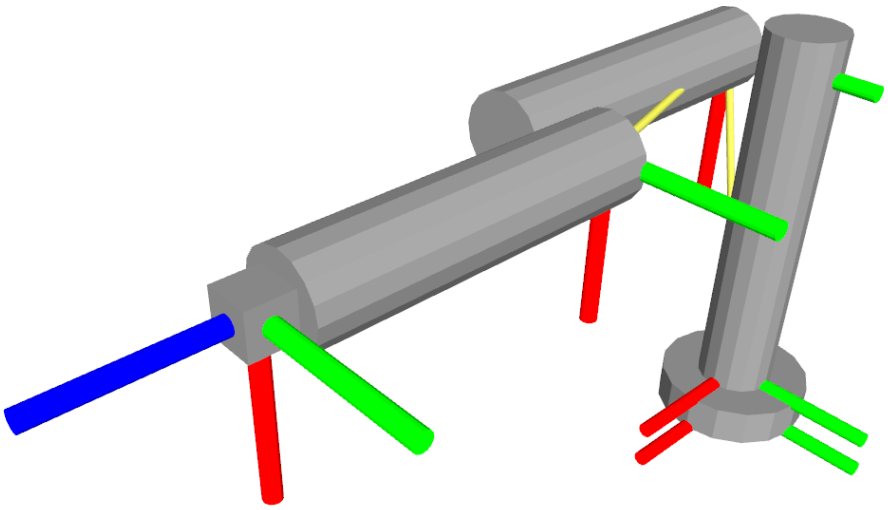
```
roslaunch urdf_model display.launch \
  model:='$(find urdf_model)/urdf/robot_mobile.urdf' gui:=True
```

In RVIZ, add the display options for the `RobotModel` and `TF`. In addition, make sure that the value for `Fixed Frame` is `base_link`.

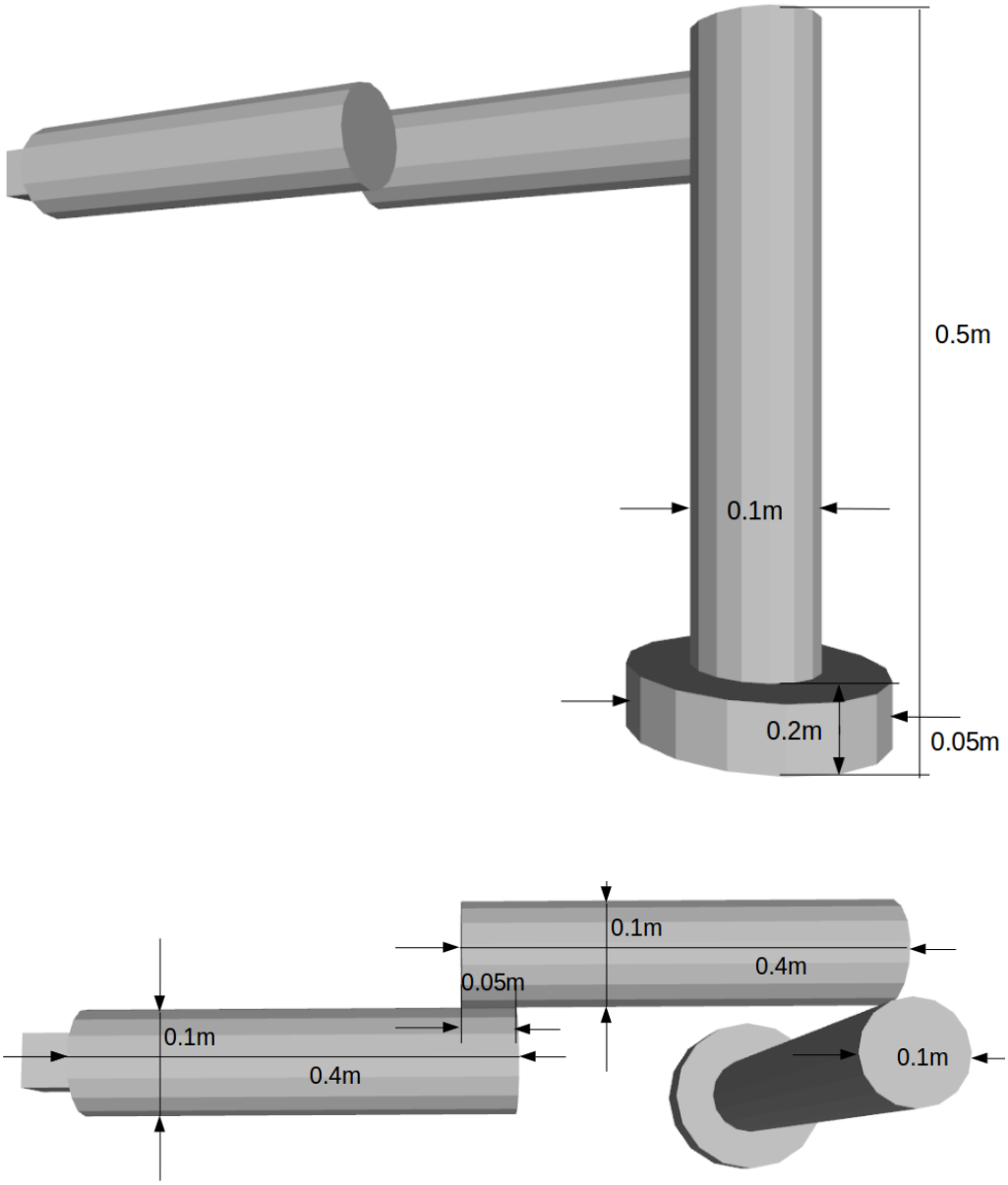
From the robot joint control panel, scroll up and down each of the controllers to see the corresponding effects by observing the changes made on the robot displayed in RVIZ.

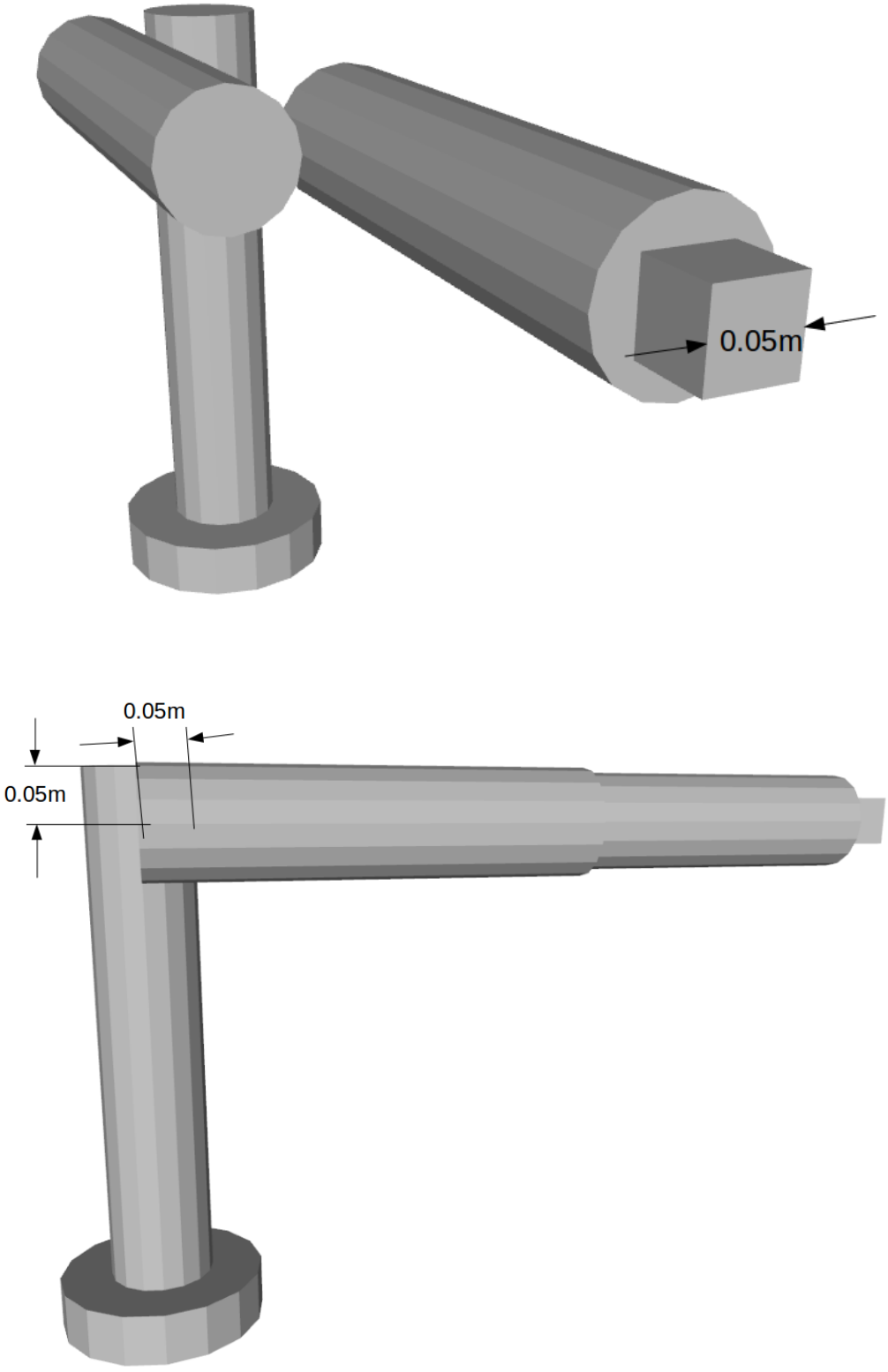
Notice that when you launch a .launch file, during its execution time, the existence of ROS Master is verified. If this is not the case, then ROS Master is executed before the execution of the content of the .launch file.

# III. [Exercise] Building a robot arm



In this exercise, you are asked to construct the robot arm shown above by writing the `robot_arm.urdf` file from scratch. For this purpose, you can use the urdf files that are provided in the previous sections. The dimensions of this arm are given in the following figures.


0.5m
0.1m
0.2m
0.05m
0.1m
0.4m
0.05m
0.1m
0.4m
0.1m




**1) Creating the `urdf` model for a robot arm**

In the `urdf` directory, create `robot_arm.urdf` file taking into account the information given in the above figure. Make sure that all the joints are of type "continuous".

**2) Place the robot arm at various configurations indicated as follows**

3.1) $(\theta_1, \theta_2, \theta_3, \theta_4)$=$(0, 0, 0, 0)$

3.2) $(\theta_1, \theta_2, \theta_3, \theta_4)$=$(\pi/2, 0, 0, 0)$

3.3) $(\theta_1, \theta_2, \theta_3, \theta_4)$=$(\pi/2, \pi/2, 0, 0)$

3.4) $(\theta_1, \theta_2, \theta_3, \theta_4)$=$(\pi/2, \pi/2, \pi/2, 0)$

3.5) $(\theta_1, \theta_2, \theta_3, \theta_4)$=$(\pi/2, \pi/2, \pi/2, \pi/2)$

**3) Controlling the robot arm**

As done in Section II, launch the `display.launch` with the right parameters and show that you can control the motion of all four joints.

# 1 References


- ROS URDF Tutorials, http://wiki.ros.org/urdf/Tutorials