Introduction to URDF: **MANIPULATOR DESIGN AND CONTROL**

**http://wiki.ros.org/urdf/Tutorials/Adding%20Physical%20and%20Collision%20Properties%20to%20a%20URDF%20Model**

**Execute in Terminal #1**

```
sudo apt-get install ros-foxy-teleop-twist-keyboard
sudo apt-get install ros-foxy-joint-state-publisher*
sudo apt-get install ros-foxy-joint-trajectory-controller
sudo apt-get install ros-foxy-controller-manager
```

```
cd ros2_ws/src/urdf_tutorial/urdf
touch manipulator.urdf
```

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

    <link name="world"/>
    <link name="base_link">
        <visual>
            <geometry>
                <cylinder length="0.05" radius="0.2"/>
            </geometry>
            <material name="Black">
                <color rgba="0 0 0 1"/>
            </material>
            <origin rpy="0 0 0" xyz="0 0 0.025"/>
        </visual>

        <collision>
            <geometry>
                <cylinder length="0.05" radius="0.2"/>
            </geometry>
            <origin rpy="0 0 0" xyz="0 0 0.025"/>
        </collision>

        <inertial>
            <origin rpy="0 0 0" xyz="0 0 0.025"/>
            <mass value="5.0"/>
            <inertia ixx="0.0135" ixy="0.0" ixz="0.0" iyy="0.0135" iyz="0.0" izz="0.05"/>
        </inertial>
    </link>

    <joint name="fixed" type="fixed">
        <parent link="world"/>
        <child link="base_link"/>
        <dynamics damping="10" friction="1.0"/>
```

```
</joint>

<link name="link_1">
    <visual>
        <geometry>
            <cylinder length="0.5" radius="0.08"/>
        </geometry>
        <material name="blue">
            <color rgba="0 0 0.8 1"/>
        </material>
        <origin rpy="0 0 0" xyz="0 0 0.25"/>
    </visual>

    <collision>
        <geometry>
            <cylinder length="0.5" radius="0.08"/>
        </geometry>
        <origin rpy="0 0 0" xyz="0 0 0.25"/>
    </collision>

    <inertial>
        <origin rpy="0 0 0" xyz="0 0 0.25"/>
        <mass value="5.0"/>
        <inertia ixx="0.107" ixy="0.0" ixz="0.0" iyy="0.107" iyz="0.0" izz="0.0125"/>
    </inertial>

</link>

<joint name="joint_1" type="continuous">
    <axis xyz="0 0 1"/>
    <parent link="base_link"/>
    <child link="link_1"/>
    <origin rpy="0 0 0" xyz="0.0 0.0 0.05"/>
    <dynamics damping="10" friction="1.0"/>
</joint>

<link name="link_2">
    <inertial>
        <origin rpy="0 0 0" xyz="0 0 0.2"/>
        <mass value="2.0"/>
        <inertia ixx="0.027" ixy="0.0" ixz="0.0" iyy="0.027" iyz="0.0" izz="0.0025"/>
    </inertial>

    <visual>
        <geometry>
        <cylinder length="0.1" radius="0.08"/>
        </geometry>
        <material name="Red">
            <color rgba="1 0 0 1"/>
        </material>
```

```
    </visual>

    <collision>
        <geometry>
            <cylinder length="0.1" radius="0.08"/>
        </geometry>
    </collision>
</link>

<joint name="joint_2" type="continuous">
    <axis xyz="0 0 1"/>
    <parent link="link_1"/>
    <child link="link_2"/>
    <origin rpy="0 1.5708 0" xyz="0.0 -0.005 0.58"/>
    <limit lower="-0.25" upper="3.34" effort="10" velocity="0.5"/>
    <dynamics damping="10" friction="1.0"/>
</joint>

<link name="link_3">
    <inertial>
        <origin rpy="0 0 0" xyz="0 0 0.2"/>
        <mass value="0.01"/>
        <inertia ixx="0.027" ixy="0.0" ixz="0.0" iyy="0.027" iyz="0.0" izz="0.0025"/>
    </inertial>

    <visual>
        <geometry>
        <cylinder length="0.4" radius="0.05"/>
        </geometry>
        <material name="blue">
            <color rgba="0.5 0.5 0.5 1"/>
        </material>
    </visual>

    <collision>
        <geometry>
            <cylinder length="0.4" radius="0.05"/>
        </geometry>
    </collision>
</link>

<joint name="joint_3" type="fixed">
    <parent link="link_2"/>
    <child link="link_3"/>
    <origin rpy="1.57 0 0" xyz="0.0 0.2 0 "/>
    <dynamics damping="10" friction="1.0"/>
</joint>

<link name="link_4">
    <inertial>
```

```
      <origin rpy="0 0 0" xyz="0 0 0.2"/>
      <mass value="0.01"/>
      <inertia ixx="0.027" ixy="0.0" ixz="0.0" iyy="0.027" iyz="0.0" izz="0.0025"/>
    </inertial>

    <visual>
      <geometry>
      <cylinder length="0.1" radius="0.06"/>
      </geometry>
      <material name="Red">
        <color rgba="1 0 0 1"/>
      </material>
    </visual>

    <collision>
      <geometry>
        <cylinder length="0.1" radius="0.06"/>
      </geometry>
    </collision>

</link>

<joint name="joint_4" type="continuous">
    <parent link="link_3"/>
    <child link="link_4"/>
    <origin rpy="1.57 0 0" xyz=" 0 0 -0.25"/>
    <axis xyz=" 0 0 1"/>
    <limit lower="-1.92" upper="1.92" effort="10" velocity="0.5"/>
    <dynamics damping="10" friction="1.0"/>
</joint>

<link name="link_5">
    <inertial>
      <origin rpy="0 0 0" xyz="0 0 0.2"/>
      <mass value="0.01"/>
      <inertia ixx="0.027" ixy="0.0" ixz="0.0" iyy="0.027" iyz="0.0" izz="0.0025"/>
    </inertial>

    <visual>
      <geometry>
      <cylinder length="0.3" radius="0.03"/>
      </geometry>
      <material name="yello">
        <color rgba="0 1 0.5 1"/>
      </material>
      </visual>

    <collision>
      <geometry>
        <cylinder length="0.3" radius="0.03"/>
```

```
      </geometry>
    <dynamics damping="0.0" friction="0.0"/>

    </collision>
</link>

<joint name="joint_5" type="fixed">
    <parent link="link_4"/>
    <child link="link_5"/>
    <origin rpy="1.57 0 0" xyz="0.0 -0.2 0 "/>
    <dynamics damping="10" friction="1.0"/>
</joint>

<gazebo reference="base_link">
    <material>Gazebo/Black</material>
</gazebo>

<gazebo reference="link_1">
    <material>Gazebo/White</material>
</gazebo>

<gazebo reference="link_3">
    <material>Gazebo/White</material>
</gazebo>

<gazebo reference="link_2">
    <material>Gazebo/Blue</material>
</gazebo>

<gazebo reference="link_4">
    <material>Gazebo/Blue</material>
</gazebo>

<gazebo reference="link_5">
    <material>Gazebo/White</material>
</gazebo>



<gazebo>
<plugin filename="libgazebo_ros2_control.so" name="gazebo_ros2_control">
    <robot_sim_type>gazebo_ros2_control/GazeboSystem</robot_sim_type>
    <parameters>/home/asha/ros2_ws/src/urdf_tutorial/config/control.yaml</parameters>
</plugin>
</gazebo>

<ros2_control name="GazeboSystem" type="system">
    <hardware>
    <plugin>gazebo_ros2_control/GazeboSystem</plugin>
</hardware>
```

```
    <joint name="joint_1">
        <command_interface name="position">
        <param name="min">-3.14</param>
        <param name="max">3.14</param>
        </command_interface>
        <state_interface name="position"/>
        <param name="initial_position">0.0</param>
    </joint>
    <joint name="joint_2">
        <command_interface name="position">
        <param name="min">-3.14</param>
        <param name="max">3.14</param>
        </command_interface>
        <state_interface name="position"/>
        <param name="initial_position">-1.57</param>
    </joint>
    <joint name="joint_4">
        <command_interface name="position">
        <param name="min">-3.14</param>
        <param name="max">3.14</param>
        </command_interface>
        <state_interface name="position"/>
        <param name="initial_position">0.0</param>
    </joint>

    </ros2_control>

</robot>
```

```
cd ..
cd launch
touch arm_rviz.launch.py
```

```
from launch import LaunchDescription
from launch_ros.actions import Node
import os


def generate_launch_description():

    urdf_file = urdf = '/home/asha/ros2_ws/src/urdf_tutorial/urdf/manipulator.urdf'



    joint_state_publisher_node = Node(
        package="joint_state_publisher_gui",
        executable="joint_state_publisher_gui",
```

```
    )
    robot_state_publisher_node = Node(
        package="robot_state_publisher",
        executable="robot_state_publisher",
        output="both",
        arguments=[urdf_file]
    )
    rviz_node = Node(
        package="rviz2",
        executable="rviz2",
        name="rviz2",
        output="log"
    )

    nodes_to_run = [
        joint_state_publisher_node,
        robot_state_publisher_node,
        rviz_node
    ]

    return LaunchDescription(nodes_to_run)
```

touch arm_gazebo.launch.py

```
import os
from launch import LaunchDescription
from launch.actions import ExecuteProcess
from launch_ros.actions import Node

def generate_launch_description():
    urdf_file = '/home/asha/ros2_ws/src/urdf_tutorial/urdf/manipulator.urdf'

    return LaunchDescription(
        [
            ExecuteProcess(
                cmd=["gazebo","-s","libgazebo_ros_factory.so",],
                output="screen",
            ),
            Node(
                package="gazebo_ros",
                executable="spawn_entity.py",
                arguments=["-entity","urdf_tutorial","-b","-file", urdf_file],
            ),
            Node(
                package="robot_state_publisher",
                executable="robot_state_publisher",
                output="screen",
                arguments=[urdf_file],
            ),
```

```
        ]
    )
```

```
cd ~/ros2_ws/src/urdf_tutorial
mkdir config
cd config
touch control.yaml
```

```
controller_manager:
  ros__parameters:
    update_rate: 100
    joint_state_broadcaster:
      type: joint_state_broadcaster/JointStateBroadcaster
    joint_trajectory_controller:
      type: joint_trajectory_controller/JointTrajectoryController

joint_trajectory_controller:
  ros__parameters:
    joints:
      - joint_1
      - joint_2
      - joint_4

    command_interfaces:
      - position

    state_interfaces:
      - position

    state_publish_rate: 50.0
    action_monitor_rate: 20.0

    allow_partial_joints_goal: false
    open_loop_control: true
    constraints:
      stopped_velocity_tolerance: 0.01
      goal_time: 0.0
      joint1:
        trajectory: 0.05
        goal: 0.03
```

```
touch arm_control.launch.py
Edit arm_control.launch.py
```

```
import os
from launch import LaunchDescription
```

```
from launch.actions import ExecuteProcess
from launch_ros.actions import Node
from scripts import GazeboRosPaths

def generate_launch_description():
    urdf_file = '/home/asha/ros2_ws/src/urdf_tutorial/urdf/manipulator.urdf'


    controller_file = '/home/asha/ros2_ws/src/urdf_tutorial/config/control.yaml'
    robot_description = {"robot_description": urdf_file}
    return LaunchDescription(
        [
            ExecuteProcess(
                cmd=["gazebo","-s","libgazebo_ros_factory.so",],
                output="screen",
            ),
            Node(
                package="gazebo_ros",
                node_executable="spawn_entity.py",
                arguments=["-entity","urdf_tutorial","-b","-file", urdf_file],
            ),
            Node(
                package="robot_state_publisher",
                executable="robot_state_publisher",
                output="screen",
                arguments=[urdf_file],
            ),

            Node(
                package="controller_manager",
                executable="ros2_control_node",
                parameters=[robot_description, controller_file],
                output={
                    "stdout": "screen",
                    "stderr": "screen",
                },
            ),
            Node(
            package="controller_manager",
            executable="spawner.py",
            arguments=["joint_state_broadcaster", "--controller-manager",
"/controller_manager"],
                ),

            Node(
                package="controller_manager",
                executable="spawner.py",
                arguments=["joint_trajectory_controller", "-c", "/controller_manager"],
            )
        ]
```

```
    )
```

Add extensions in Visual Studio

ros
ros snippet
xml
xml tools
urdf
xml complete
icons

**Execute in Terminal #1**
colcon build --packages-select urdf_tutorial
**Execute in Terminal #1**
ros2 launch urdf_tutorial arm_rviz.launch.py
**Execute in Terminal #2**
ros2 launch urdf_tutorial arm_gazebo.launch.py
**Execute in Terminal #3**
ros2 launch urdf_tutorial arm_control.launch.py

cd ros2_ws/src/urdf_tutorial/urdf_tutorial/
touch controller.py
**chmod +x controller.py**

```
#!/usr/bin/env python3

import rclpy
from rclpy.node import Node
from builtin_interfaces.msg import Duration
from trajectory_msgs.msg import JointTrajectory, JointTrajectoryPoint

class TrajectoryPublisher(Node):

    def __init__(self):
        super().__init__('trajectory_node')
        topic_ = "/joint_trajectory_controller/joint_trajectory"
        self.publisher_ = self.create_publisher(JointTrajectory, topic_, 10)
        self.timer_ = self.create_timer(1,self.timer_callback)
        self.joints = ['joint_1', 'joint_2', 'joint_4']
        self.goal_ =[1.5, 0.5, 1.2]


    def timer_callback(self):
        msg = JointTrajectory()
        msg.joint_names = self.joints
        point = JointTrajectoryPoint()
        point.positions = self.goal_
```

```
        point.time_from_start = Duration(sec=2)
        msg.points.append(point)
        self.publisher_.publish(msg)

def main(args=None):
    rclpy.init(args=args)
    node = TrajectoryPublisher()
    rclpy.spin(node)
    node.destroy_node()
    rclpy.shutdown()

if __name__ == '__main__':
    main()
```

Edit setup.py as

```
from setuptools import setup
import os
from glob import glob
package_name = 'urdf_tutorial'

setup(
    name=package_name,
    version='0.0.0',
    packages=[package_name],
    data_files=[
        ('share/ament_index/resource_index/packages',
            ['resource/' + package_name]),
        ('share/' + package_name, ['package.xml']),
          (os.path.join('share', package_name), glob('urdf/*')),
          (os.path.join('share', package_name), glob('launch/*')),
          (os.path.join('share', package_name), glob('config/*'))


    ],
    install_requires=['setuptools'],
    zip_safe=True,
    maintainer='asha',
    maintainer_email='asha@todo.todo',
    description='TODO: Package description',
    license='TODO: License declaration',
    tests_require=['pytest'],
    entry_points={
        'console_scripts': [
            'controller = urdf_tutorial.controller:main'
        ],
    },
)
```

**Execute in Terminal #1**

colcon build --packages-select urdf_tutorial

**Execute in Terminal #1**

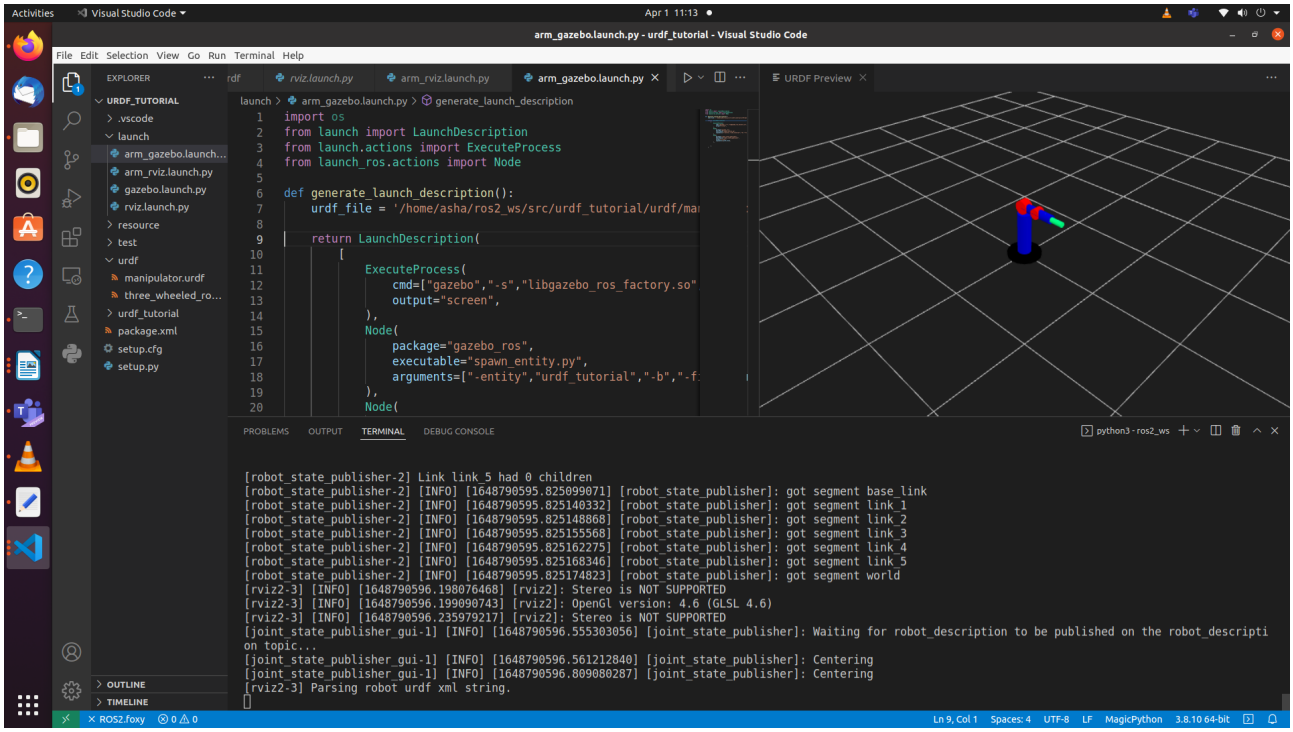
ros2 launch urdf_tutorial arm_rviz.launch.py

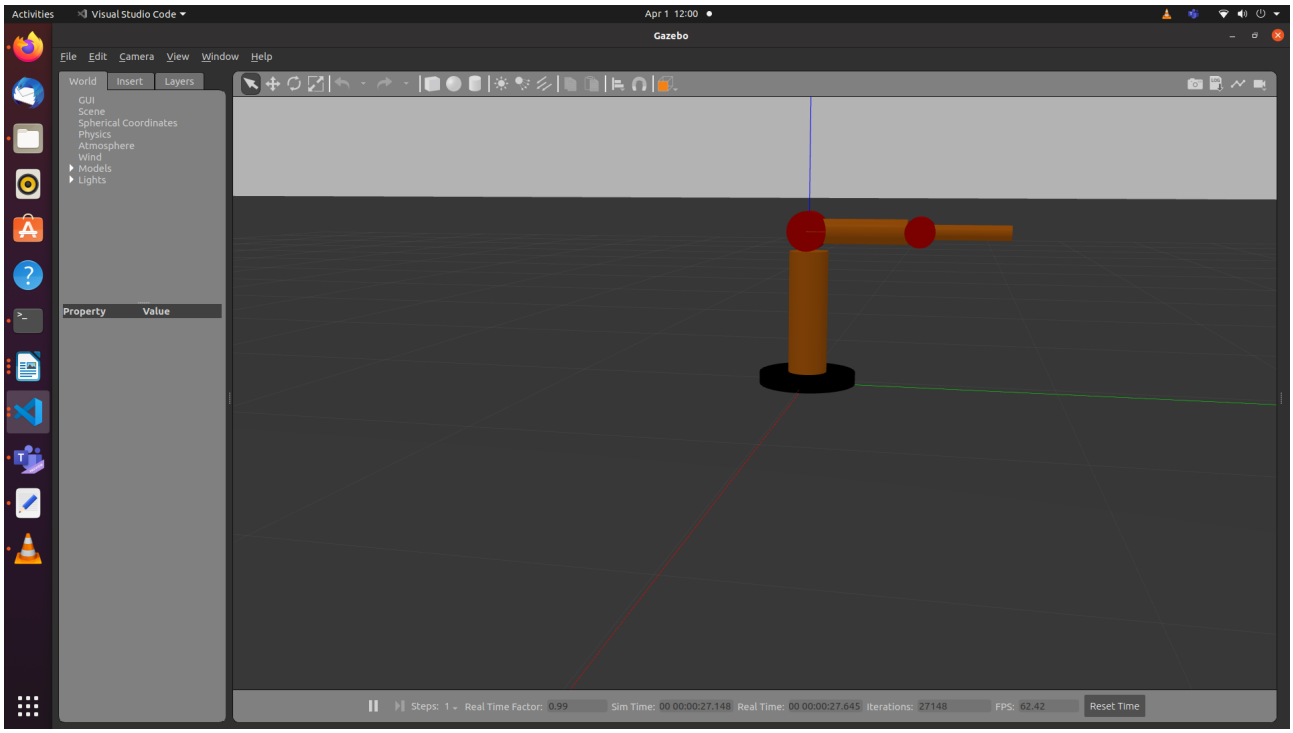
**Execute in Terminal #2**

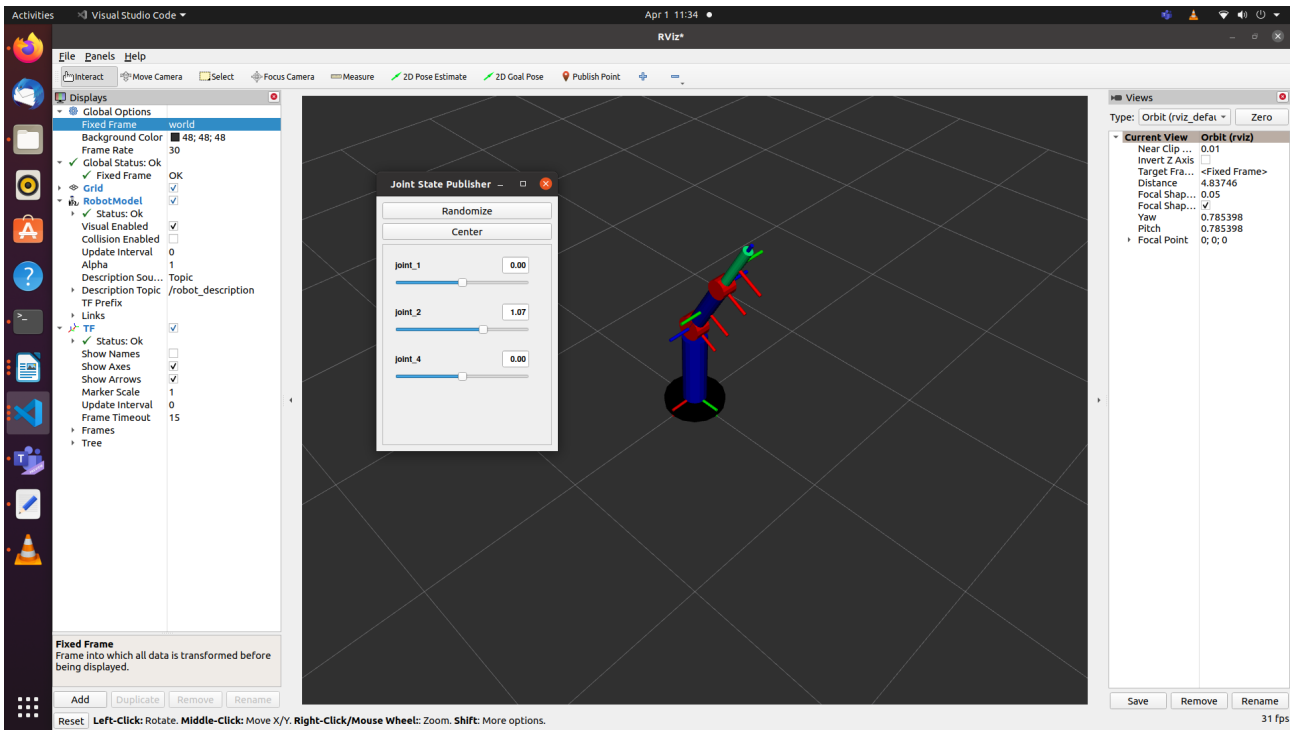
ros2 launch urdf_tutorial arm_control.launch.py

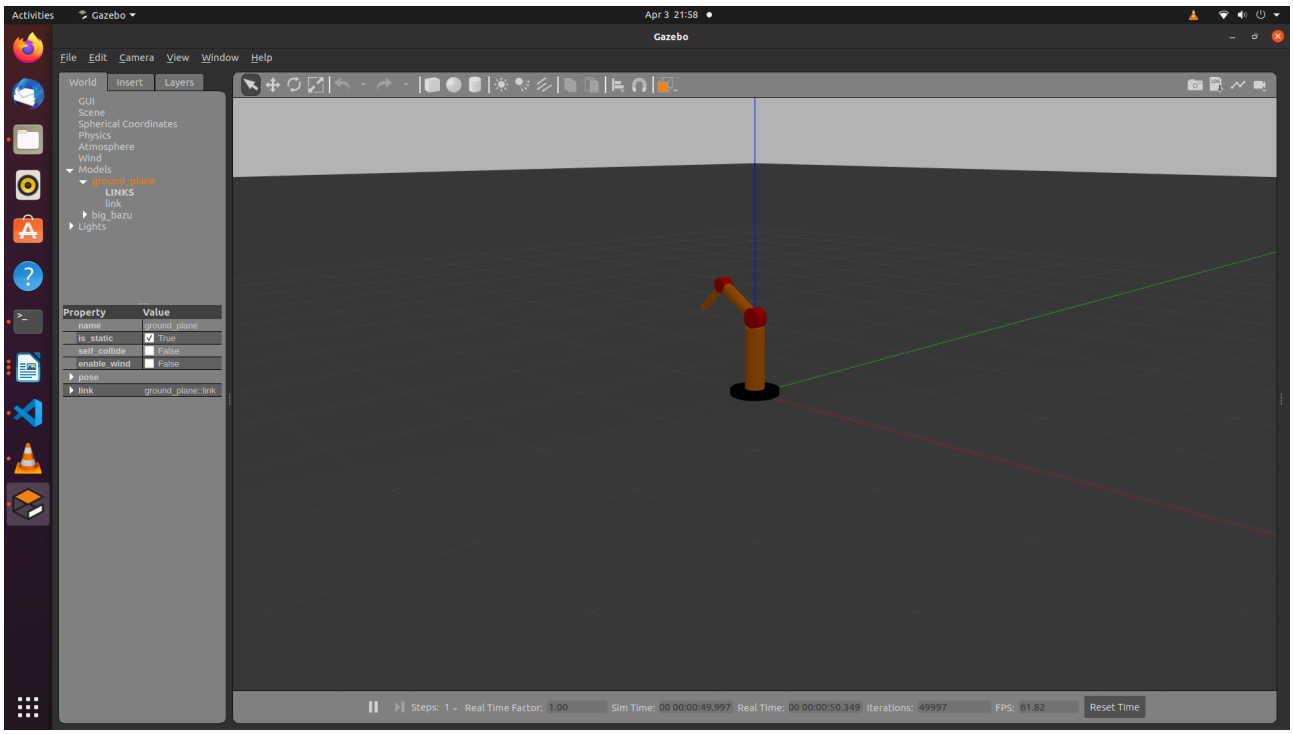
**Execute in Terminal #3**

ros2 run urdf_tutorial controller




Activities
Visual Studio Code
Apr 1 12:00
Gazebo
File Edit Camera View Window Help
World Insert Layers
GUI
Scene
Spherical Coordinates
Physics
Atmosphere
Wind
Models
Lights
Property Value
Steps: 1 Real Time Factor: 0.99 Sim Time: 00 00:00:27.148 Real Time: 00 00:00:27.645 Iterations: 27148 FPS: 62.42
Reset Time


Activities
Visual Studio Code
Apr 1 11:34
RViz*
File Panels Help
Interact
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
2D Goal Pose
Publish Point
Displays
Global Options
Fixed Frame world
Background Color 48; 48; 48
Frame Rate 30
Global Status: Ok
Fixed Frame OK
Grid
RobotModel
Status: Ok
Visual Enabled
Collision Enabled
Update Interval 0
Alpha 1
Description Sou... Topic
Description Topic /robot_description
TF Prefix
Links
TF
Status: Ok
Show Names
Show Axes
Show Arrows
Marker Scale 1
Update Interval 0
Frame Timeout 15
Frames
Tree
Fixed Frame
Frame into which all data is transformed before being displayed.
Add
Duplicate
Remove
Rename
Joint State Publisher
Randomize
Center
joint_1 0.00
joint_2 1.07
joint_4 0.00
Views
Type: Orbit (rviz_defa
Zero
Current View Orbit (rviz)
Near Clip ... 0.01
Invert Z Axis
Target Fra... <Fixed Frame>
Distance 4.83746
Focal Shap... 0.05
Focal Shap...
Yaw 0.785398
Pitch 0.785398
Focal Point 0; 0; 0
Save
Remove
Rename
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel:: Zoom. Shift: More options.
31 fps




ROS2 parameters:

Parameters help to provide the values while running the code.

ros2 param list

Edit the controller.py

```
#!/usr/bin/env python3


#colcon build --packages-select urdf_tutorial
#ros2 run urdf_tutorial controller --ros-args -p end_location:=[3.5,1.5,-1.2]

import rclpy
from rclpy.node import Node
from builtin_interfaces.msg import Duration
from trajectory_msgs.msg import JointTrajectory, JointTrajectoryPoint

class TrajectoryPublisher(Node):

    def __init__(self):
        super().__init__('trajectory_node')
        topic_ = "/joint_trajectory_controller/joint_trajectory"
        self.joints = ['joint_1', 'joint_2', 'joint_4']
        #self.goal_ =[1.5, 0.5, 1.2]
        self.declare_parameter("joint_angles", [1.5, 0.5, 1.2])
        self.goal_=self.get_parameter("joint_angles").value
```

```
        self.publisher_ = self.create_publisher(JointTrajectory, topic_, 10)
        self.timer_ = self.create_timer(1,self.timer_callback)



    def timer_callback(self):
        msg = JointTrajectory()
        msg.joint_names = self.joints
        point = JointTrajectoryPoint()
        point.positions = self.goal_
        point.time_from_start = Duration(sec=2)
        msg.points.append(point)
        self.publisher_.publish(msg)

def main(args=None):
    rclpy.init(args=args)
    node = TrajectoryPublisher()
    rclpy.spin(node)
    node.destroy_node()
    rclpy.shutdown()

if __name__ == '__main__':
    main()
```

**Execute in Terminal #1**

```
#colcon build --packages-select urdf_tutorial
```

**Execute in Terminal #2**

```
ros2 launch urdf_tutorial arm_control.launch.py
```

**Execute in Terminal #3**

```
#ros2 run urdf_tutorial controller --ros-args -p joint_angles:=[3.5,1.5,-1.2]
```

**Exercise 1: Replicate the process for UR5e robot given its urdf file.**

**Exercise 2: Write a python code to move the manipulator to end location using inverse kinematics.**

Viva Questions: Compute the inertia parameters for the each block used in the three_wheeled_robot and manipulator.

References


https://docs.ros.org/en/foxy/Tutorials/URDF/Using-URDF-with-Robot-State-Publisher.html

https://github.com/benbongalon/ros2-urdf-tutorial/tree/master/urdf_tutorial

https://github.com/cra-ros-pkg/robot_localization/tree/foxy-devel

https://github.com/ros/robot_state_publisher/tree/foxy

https://github.com/ros/joint_state_publisher/tree/foxy

http://gazebosim.org/tutorials?tut=ros_urdf