{Learn, Create, Innovate};

# ROS

*Robot Modelling/Visualisation Tools*

MCR2 Manchester Robotics

# Robot Descriptions

*URDF Files*

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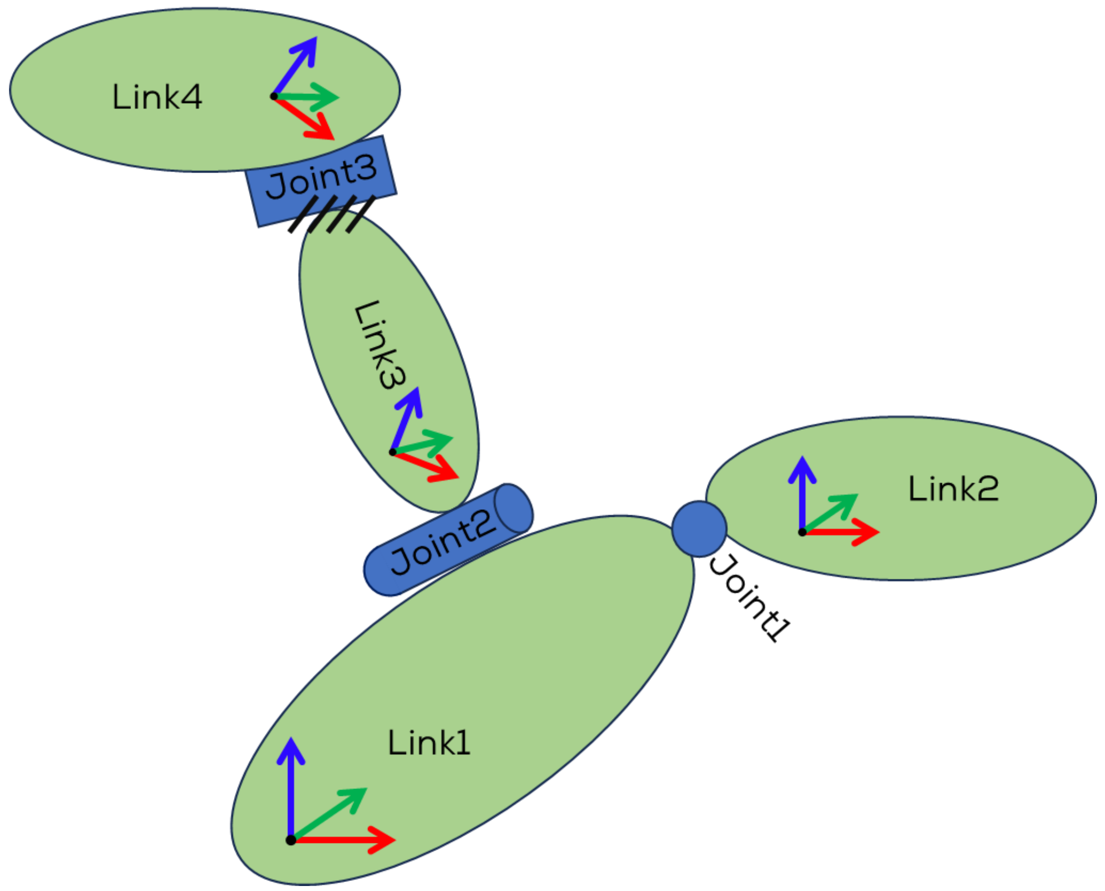
# URDF Files

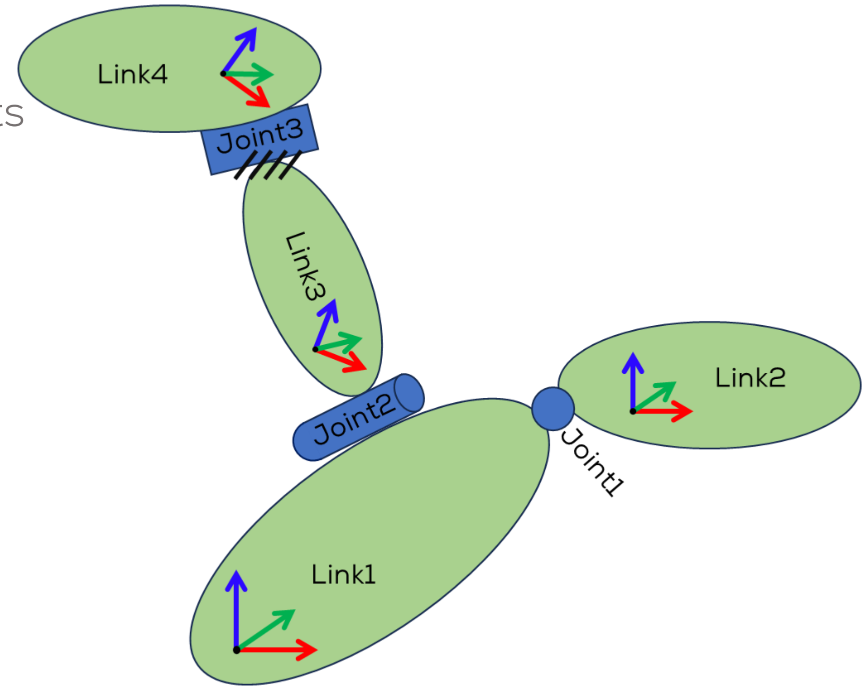
- URDF (Unified Robot Description Format) files are XML-based files used to describe a robot's structure, kinematics, dynamics, and visual appearance in the context of robotics and simulation.
- URDF is commonly used in robotics frameworks like ROS (Robot Operating System) to represent robots and their components.

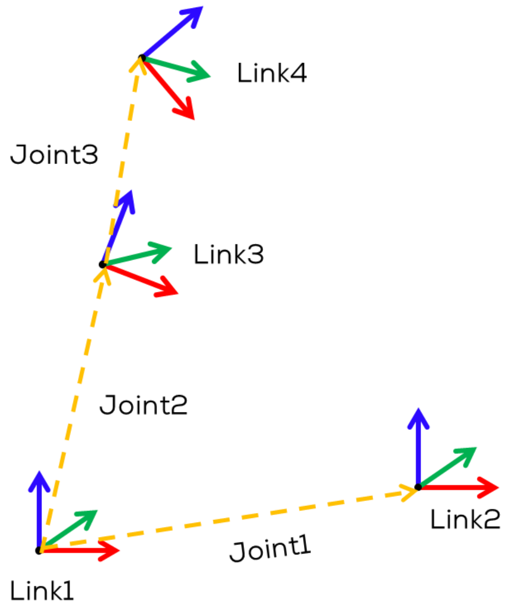


# URDF Files

- URDF files provide a standardised format to describe robot models, allowing simulation and visualisation tools to load and manipulate robots accurately.

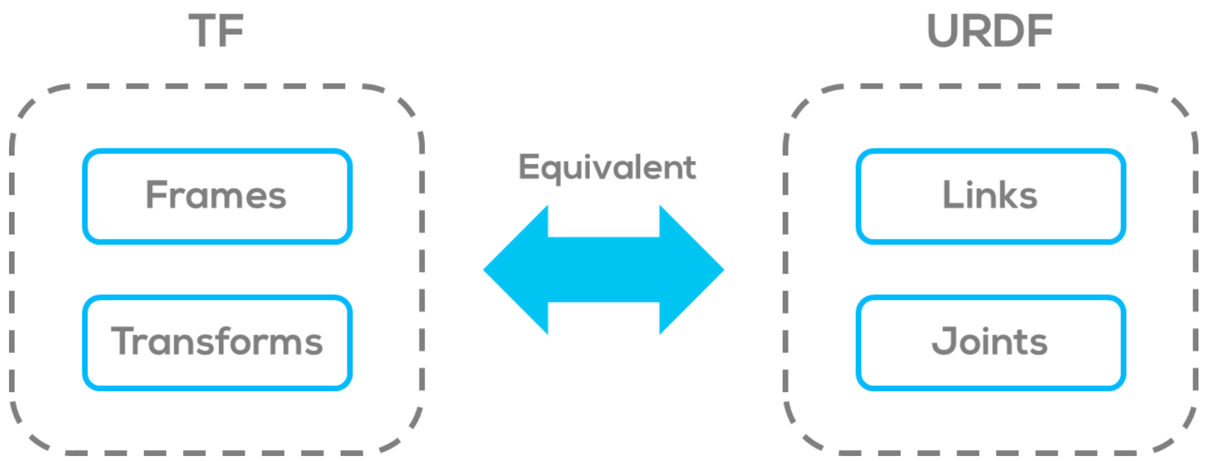
- They are widely used in the robotics community and play a crucial role in developing and integrating robotic systems.





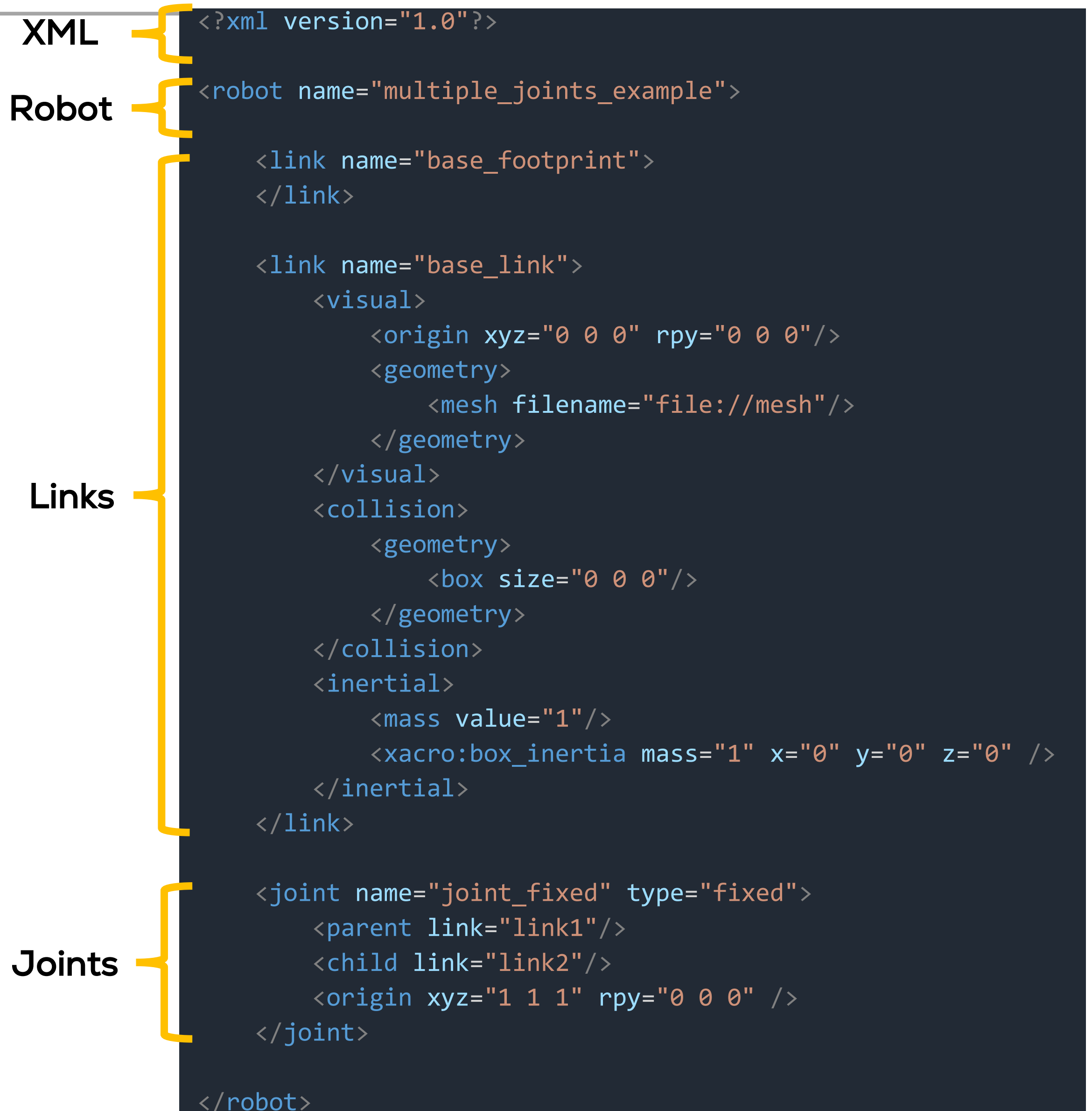
# URDF Files

- URDF describes a robot as a tree of links, that are connected by joints.
  - The links represent the physical components of the robot, and the joints represent how one link moves relative to another link, defining the location of the links in space.
- This concept can be related to the TF (Transforms) concepts of frames and links as follows
  - Frames -> Links
  - Transforms -> Joints



# Syntax

- XML Declaration: The file begins with an XML declaration that specifies the version of XML being used. For URDF, it is typically <?xml version="1.0"?>.
- Robot: The root element of the URDF file is <robot>. It encapsulates all the other elements in the file and typically includes attributes like name to specify the robot's name.
- Links represent a component or a rigid body of the robot. It describes the visual, inertial, and collision properties of the link.
- Joints represents the kinematic connection between two links. They specify the type of joint (e.g., revolute, prismatic) and its properties (e.g., limits, axis, origin).



```xml
<?xml version="1.0"?>

<robot name="multiple_joints_example">

    <link name="base_footprint">
    </link>

    <link name="base_link">
        <visual>
            <origin xyz="0 0 0" rpy="0 0 0"/>
            <geometry>
                <mesh filename="file://mesh"/>
            </geometry>
        </visual>
        <collision>
            <geometry>
                <box size="0 0 0"/>
            </geometry>
        </collision>
        <inertial>
            <mass value="1"/>
            <xacro:box_inertia mass="1" x="0" y="0" z="0" />
        </inertial>
    </link>

    <joint name="joint_fixed" type="fixed">
        <parent link="link1"/>
        <child link="link2"/>
        <origin xyz="1 1 1" rpy="0 0 0" />
    </joint>

</robot>
```

## Robot Descriptions

*Robot State Publisher*

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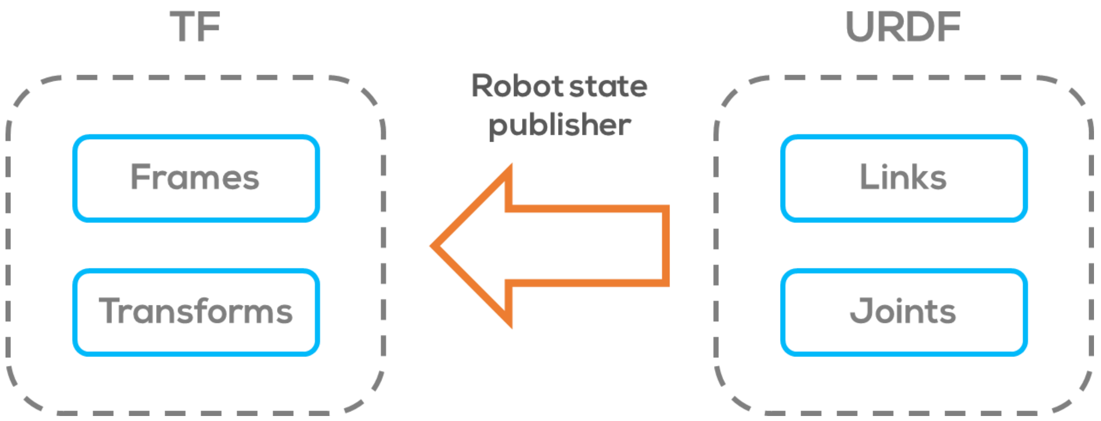
# Robot State Publisher

**Robot State Publisher**

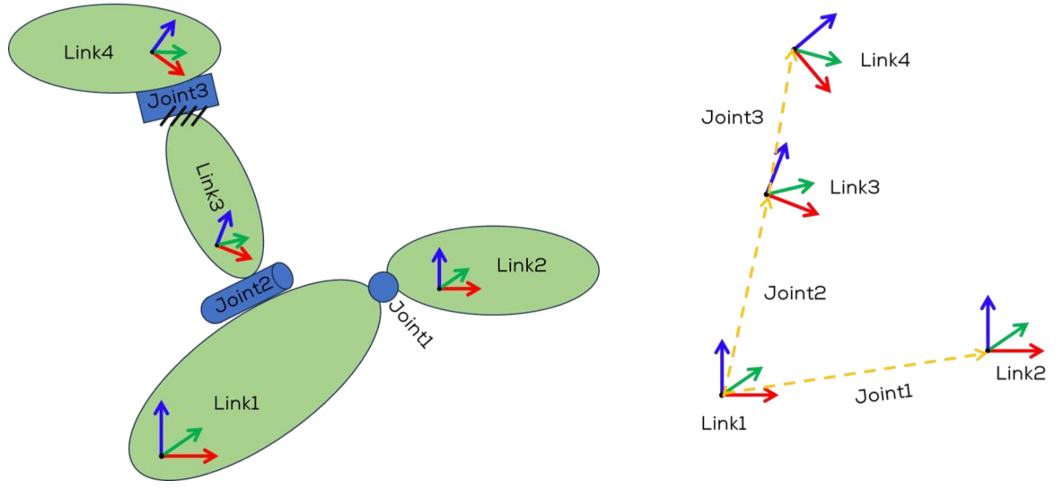
- URDF files require a translator, so that ROS can use them.
- Different translators have been developed to "translate" URDF files into TF functions (tf2 package).
- ROS has different packages to manage URDF files.
- To transform the URDF files to frames and transforms, ROS uses a package called *"robot_state_publisher"*.

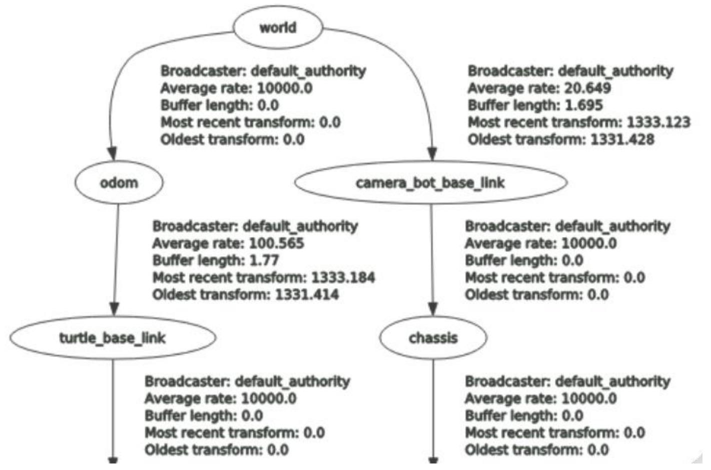


# Robot State Publisher

- Once the transforms gets published, it is available to all components in the system that also use tf2.

- The package takes the joint and links of the robot as input and publishes a transform tree model of the robot.





```
Broadcaster: default_authority
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0

Broadcaster: default_authority
Average rate: 20.649
Buffer length: 1.695
Most recent transform: 1333.123
Oldest transform: 1331.428

Broadcaster: default_authority
Average rate: 100.565
Buffer length: 1.77
Most recent transform: 1333.184
Oldest transform: 1331.414

Broadcaster: default_authority
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0

Broadcaster: default_authority
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0

Broadcaster: default_authority
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
```

## Robot State Publisher

- Usage as a ROS Node:
- “robot_state_publisher” uses the URDF specified by the parameter ”robot_description” and the joint positions from the topic ”joint_states” to calculate the forward kinematics of the robot and publish the results via tf2.

```
urdf_file_name = 'continuos_ex.urdf'
urdf = os.path.join(
    get_package_share_directory('joints_act'),
    'urdf',
    urdf_file_name)

with open(urdf, 'r') as infp:
    robot_desc = infp.read()

robot_state_pub_node = Node(
                        package='robot_state_publisher',
                        executable='robot_state_publisher',
                        name='robot_state_publisher',
                        output='screen',
                        parameters=[{'robot_description': robot_desc}],
                        arguments=[urdf]
                        )
```

## URDF

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# URDF Files: Joints

## Joints

Joints represents the kinematic connection between two links.

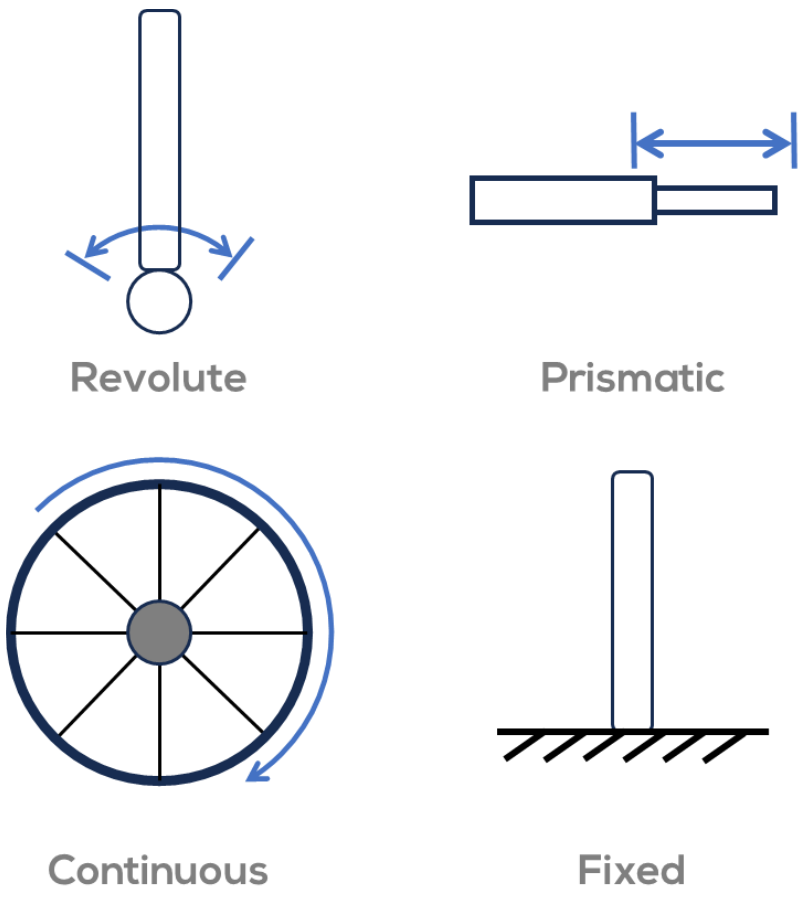
- Joints are defined within <robot> using the <joint> element. Each joint element have attributes like name, type, and contain child elements to define properties like limits, axis, and origin.

```xml
<?xml version="1.0"?>

<robot name="multiple_joints_example">

    <link name="base_footprint">
    </link>

    <link name="base_link">
        <visual>
            <origin xyz="0 0 0" rpy="0 0 0"/>
            <geometry>
                <mesh filename="file://mesh"/>
            </geometry>
        </visual>
        <collision>
            <geometry>
                <box size="0 0 0"/>
            </geometry>
        </collision>
        <inertial>
            <mass value="1"/>
            <xacro:box_inertia mass="1" x="0" y="0" z="0" />
        </inertial>
    </link>

    <joint name="joint_fixed" type="fixed">
        <parent link="link1"/>
        <child link="link2"/>
        <origin xyz="1 1 1" rpy="0 0 0" />
    </joint>

</robot>
```

Joint

# URDF Files: Joints

- Revolute – A rotational motion, on a single axis, with minimum/maximum angle limits.
- Continuous – A rotational motion, on a single axis, with no limit (e.g. a wheel).
- Prismatic – A linear sliding motion, on a single axis, with minimum/maximum position limits.
- Fixed – The child link is rigidly connected to the parent link. This is what we use for those "convenience" links.
    - *Some other joints might be available (some deprecated). Some only work on Gazebo.



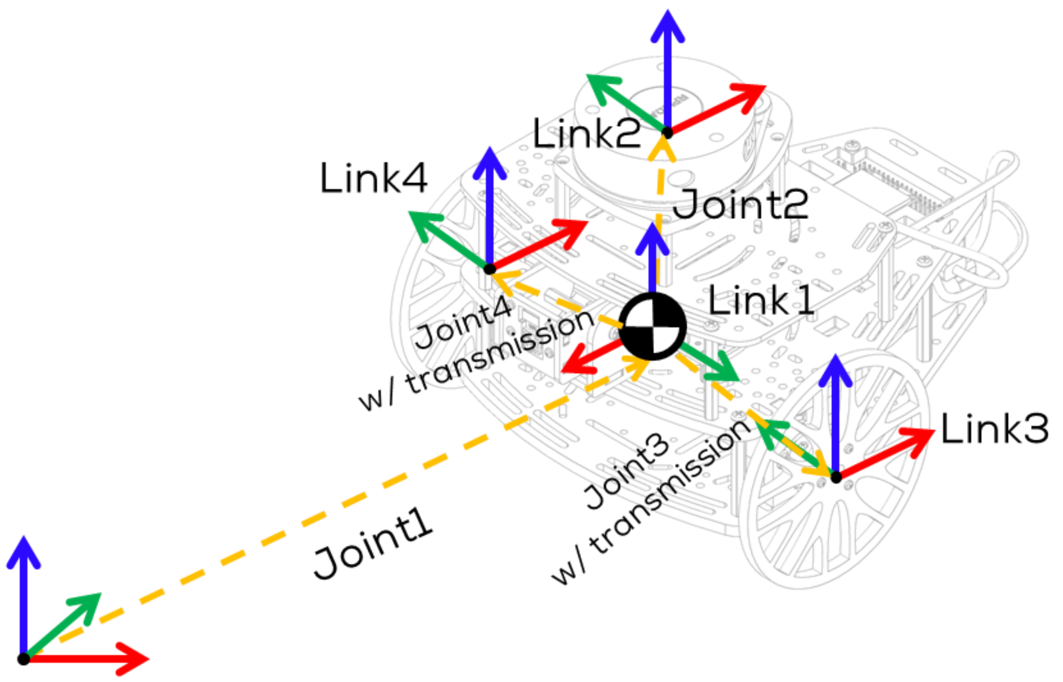
# Syntax

```
<!--Declare Joints to be used-->
<!--Declare Joint element 'name' and 'type' (revolute, continuos, prismatic, fixed)-->
<joint name="joint1" type="revolute">
    <parent link="link1"/>              <!--parent: Parent link name -->
    <child link="link2"/>               <!--child: Child link name -->
    <!--origin: This is the transform from the parent link to the child link xyz: xyz offset rpy:rotaton offset (radians)-->
    <origin xyz="0.5 1 0.5" rpy="0 0 0" />
    <!--Rotation/Translation axis for the joints(revolute,continuos/prismatic) noy used with Fixed Joints -->
    <axis xyz="0 0 1 " />
    <!--Establish the limits of a joint Lower/Upper: lower/upper limits
    for revolute/prismatic joints in rad or m, Effort: maximum joint force (torque or force)
    depend on the joint, Velocity: Max velocity of the joint (rad/s or m/s) -->
    <limit lower="-1.57" upper="1.57" effort="5.0" velocity="0.1"/>
</joint>
```

# URDF Files: Joints

## Extras

- **Transmission:** A transmission element connects a joint to an actuator, specifying how the joint motion is driven.
- **Plugins:** URDF supports plugins, allowing users to extend the capabilities of the robot description. Plugins can provide additional features like custom collision checking or dynamic properties.



## Activity 1

*Creating a simple URDF file*

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# Activity 1

1. Make a new package called “joints_act” with the following library packages

geometry_msgs, rclpy, sensor_msgs, std_msgs, tf2_ros_py, ros2launch, robot_state_publisher, joint_state_publisher

```
$ ros2 pkg create --build-type ament_python joints_act --
license Apache-2.0 --node-name joint_pub --dependencies
sensor_msgs geometry_msgs python3-numpy rclpy tf2_ros_py
ros2launch std_msgs robot_state_publisher
joint_state_publisher --description URDF Examples --
maintainer-name 'Mario Martinez' --maintainer-email
mario.mtz@manchester-robotics.com
```

2. Create a “urdf” folder inside the previously created package and a URDF file “fixed_ex.urdf” inside

```
mkdir urdf && touch urdf/fixed_ex.urdf
```

3. Paste the following code inside the “fixed_ex.urdf” file.
    - Code can be found on GitHub.

4. Create a launch file inside the package

```
mkdir launch && touch launch/fixed_launch.py
```

```xml
<?xml version="1.0"?>

<robot name="link_example">

  <link name="link1" />
  <link name="link2" />
  <link name="link3" />
  <link name="link4" />

    <joint name="joint1" type="fixed">
        <parent link="link1"/>
        <child link="link2"/>
        <origin xyz="1 2 1" rpy="0 0 0" />
    </joint>

    <joint name="joint2" type="fixed">
        <parent link="link1"/>
        <child link="link3"/>
        <origin xyz="-1 -2 -1" rpy="0 0 0" />
    </joint>

    <joint name="joint3" type="fixed">
        <parent link="link3"/>
        <child link="link4"/>
        <origin xyz="2 1 2" rpy="0 0 -1.57" />
    </joint>

</robot>
```

# Activity 1

- Open the “setup.py” file
- Add the libraries to be used

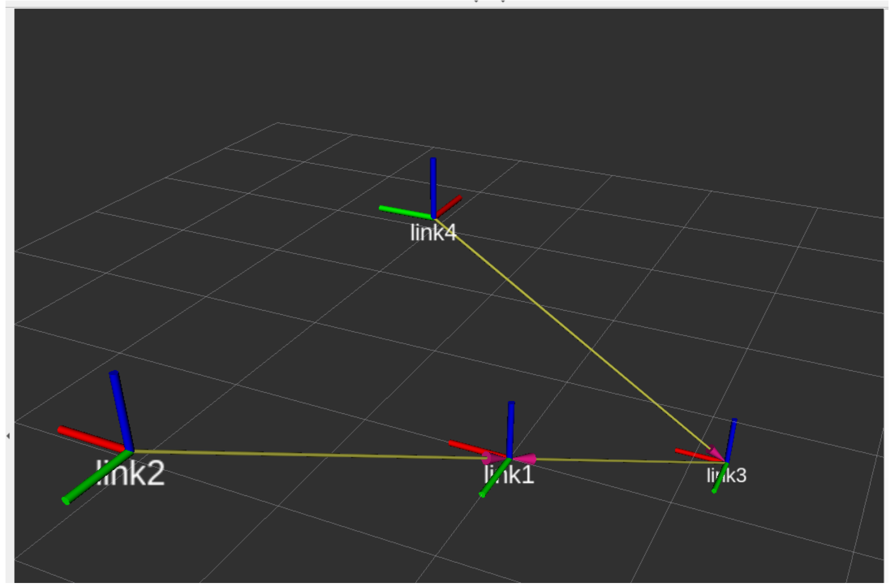
```
from setuptools import find_packages, setup
import os
from glob import glob
```

- Configure the data_files section as follows

```
data_files=[
    ('share/ament_index/resource_index/packages',
        ['resource/' + package_name]),
    ('share/' + package_name, ['package.xml']),
    (os.path.join('share', package_name, 'launch'), glob(os.path.join('launch', '*launch.[pxy][yma]*'))),
    (os.path.join('share', package_name, 'config'), glob(os.path.join('config', '*.[yma]*'))),
    (os.path.join('share', package_name, 'rviz'), glob(os.path.join('rviz', '*.rviz'))),
    (os.path.join('share', package_name, 'meshes'), glob(os.path.join('meshes', '*.stl'))),
    (os.path.join('share', package_name, 'urdf'), glob(os.path.join('urdf', '*.urdf'))),
    ],
```

# Activity 1

5. Paste the following code inside the launch file, compile and launch (give execution permissions)
6. Open RVIZ
7. Make the fixed frame to be "link 1"
8. Add the marker
   - Press "Add"
   - ››By display type››TF



```python
import os
from ament_index_python.packages import get_package_share_directory
from launch import LaunchDescription
from launch_ros.actions import Node

def generate_launch_description():

    urdf_file_name = 'fixed_ex.urdf'
    urdf = os.path.join(
        get_package_share_directory('joints_act'),
        'urdf',
        urdf_file_name)

    with open(urdf, 'r') as infp:
        robot_desc = infp.read()

    robot_state_pub_node = Node(
                            package='robot_state_publisher',
                            executable='robot_state_publisher',
                            name='robot_state_publisher',
                            output='screen',
                            parameters=[{'robot_description': robot_desc}],
                            arguments=[urdf]
                            )

    l_d = LaunchDescription([robot_state_pub_node])

    return l_d
```

## Activity 2

*Creating a movable joint using URDF*

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# Activity 2

1. Create a new “urdf” named “continuos_ex.urdf” inside the previously created package “joints_act”

```
$ touch urdf/continuous_ex.urdf
```

2. Paste the following code inside the “continuos_ex.urdf” file.
   - Code can be found on GitHub.
3. Create a launch file for this node (next slide)

```
$ touch launch/continuous_launch.py
```

5. Add the TF view
   - Press Add
   - ››By display type››TF
6. Run the tf_tree…

```
$ ros2 run rqt_tf_tree rqt_tf_tree
```

7. **Why nothing appears?!** … Because ROS does not know the state of the movable joints! (that is why ROS does not show the movable joints)

```xml
<?xml version="1.0"?>

<!--Start a Robot description-->
<robot name="continuos_joint_example">

<!--Declare Links to be used-->
  <link name="link1" />
  <link name="link2" />

<!--Declare Joints to be used-->
   <joint name="joint1" type="continuous">
        <parent link="link1"/>
        <child link="link2"/>
        <origin xyz="0.5 1 0.5" rpy="0 0 0" />
        <axis xyz="0 0 1 " />
    </joint>
</robot>
```

# Activity 2

```
import os
from ament_index_python.packages import get_package_share_directory
from launch import LaunchDescription
from launch_ros.actions import Node

def generate_launch_description():

    urdf_file_name = 'continuos_ex.urdf'
    urdf = os.path.join(
        get_package_share_directory('joints_act'),
        'urdf',
        urdf_file_name)

    with open(urdf, 'r') as infp:
        robot_desc = infp.read()

    robot_state_pub_node = Node(
                            package='robot_state_publisher',
                            executable='robot_state_publisher',
                            name='robot_state_publisher',
                            output='screen',
                            parameters=[{'robot_description': robot_desc}],
                            arguments=[urdf]
                            )

    l_d = LaunchDescription([robot_state_pub_node])
    return l_d
```

## Robot Descriptions

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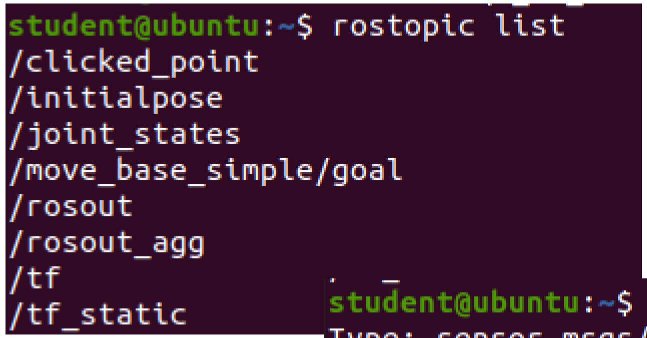
# Joint State Publisher

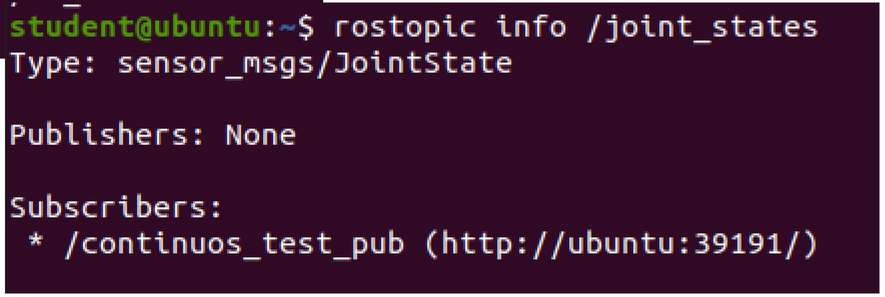
## Joint State Publisher

- ROS does not know the *"state"* of the joints in a robot i.e., position, velocity and effort.
- The Joint State Publisher is a package in Robot Operating System (ROS), designed to publish joint state information for a robot, so ROS can " know " each joint's state at a point in time.
- It's a critical component in ROS for robotics applications because it allows us to test and publish the states of the robot's joints.

- When using non-fixed joints, ROS will not publish the TF information unless they are "known"; in other words, ROS needs to know the state of the joint. To do this, the state needs to be published in the */joint_states* topic.



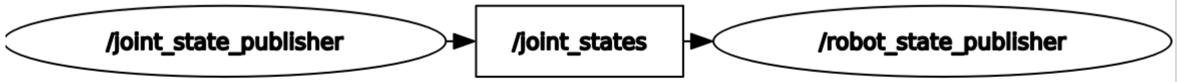
```
student@ubuntu:~$ rostopic list
/clicked_point
/initialpose
/joint_states
/move_base_simple/goal
/rosout
/rosout_agg
/tf
/tf_static
```



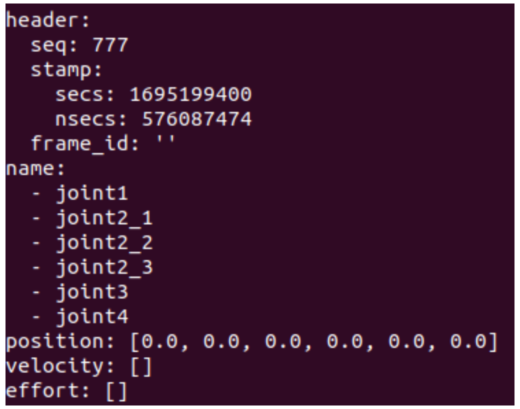
```
student@ubuntu:~$ rostopic info /joint_states
Type: sensor_msgs/JointState

Publishers: None

Subscribers:
 * /continuos_test_pub (http://ubuntu:39191/)
```

# Joint State Publisher

- This package publishes sensor_msgs/JointState messages for a robot.
- The package reads the robot_description parameter from the parameter server, finds all the non-fixed joints and publishes a JointState message with all those joints defined.
- The joint state publisher, publishes default positional values to the joints, to the robot state publisher, using the JointState message, in the /joint_state topic.



- Remember!
  - The joint state publisher is not intended to send commands to a joint (except in this activity, where is used to test our URDF file) it is intended to read and visualise the state of joints from the different robot sensors.
  - When testing our robot, in RVIZ, the joint_state_publisher allows us to make a simple test by publishing into the /joint_state topic and moving the Joint; this, however, is only for testing purposes and should not be used when reading real data!



```
header:
  seq: 777
  stamp:
    secs: 1695199400
    nsecs: 576087474
  frame_id: ''
name:
  - joint1
  - joint2_1
  - joint2_2
  - joint2_3
  - joint3
  - joint4
position: [0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
velocity: []
effort: []
```

# Activity 2

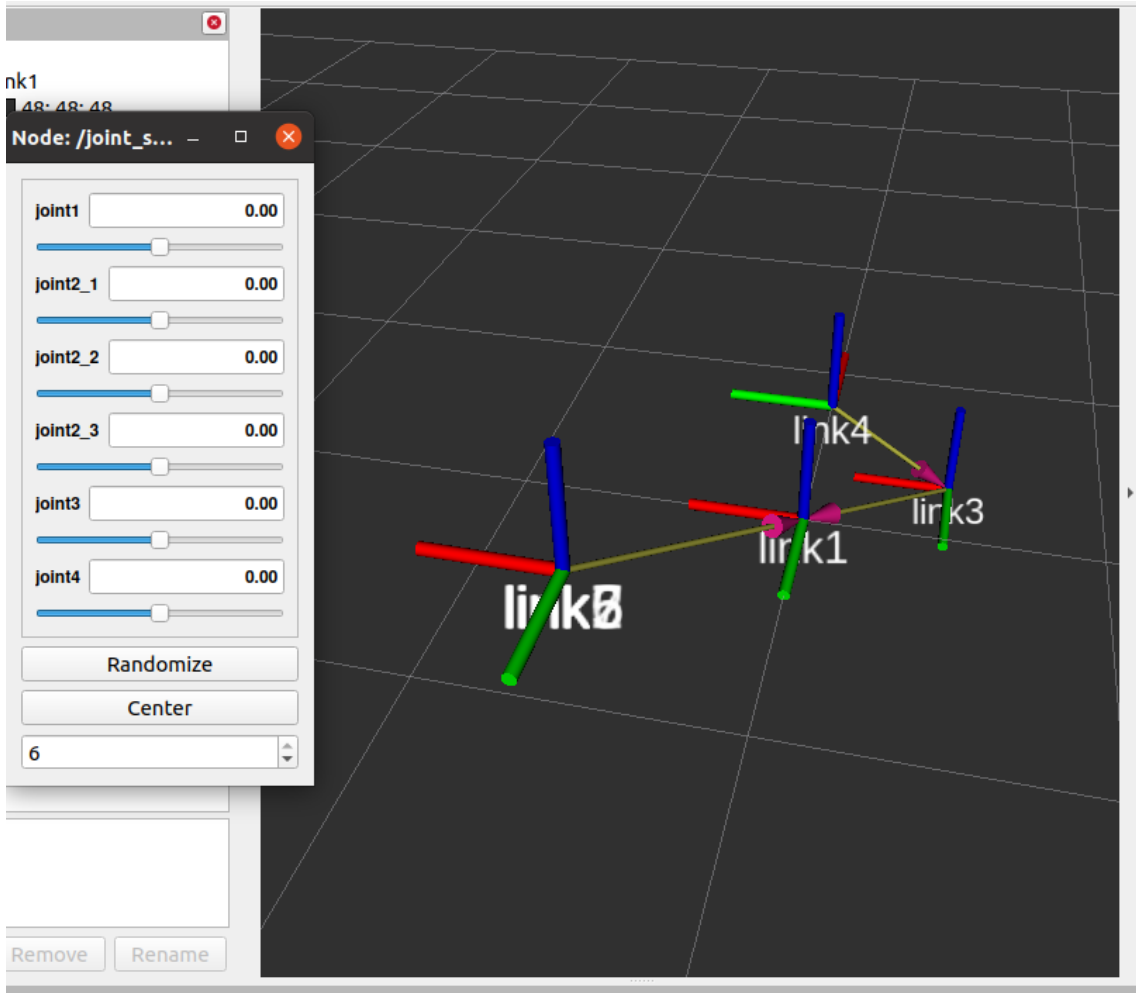
8. Install the Joint State Publisher

```
$ sudo apt install ros-<ROS_DISTRO>-joint-state-publisher-gui
#change <ROS_DISTRO> with your ros distribution e.g., “humble”
```

9. Change the launch file to add the joint state publisher

```
 # Define joint_state_publisher node (for simulation)
joint_state_publisher_node = Node(
                            package='joint_state_publisher_gui',
                            executable='joint_state_publisher_gui',
                            output='screen’
                            )

l_d = LaunchDescription([robot_state_pub_node,
joint_state_publisher_node])
```

10. Compile and relaunch the activity.
11. Use the GUI to move the joints!
12. Add More continuous joints to this activity!



Node: /joint_s...

| | |
|---|---|
| joint1 | 0.00 |
| joint2_1 | 0.00 |
| joint2_2 | 0.00 |
| joint2_3 | 0.00 |
| joint3 | 0.00 |
| joint4 | 0.00 |

# Activity 2: Extension

1. Create a new “urdf” named “joints_ex.urdf” inside the previously created package “joints_act”

```
$ touch urdf/joints_ex.urdf
```

2. Define all the different joints that are available
   - Code can be found on GitHub.
3. Create a launch file for this node (similar to the previous one), change the URDF File name at the top.

```
$ touch launch/joints_launch.py
```

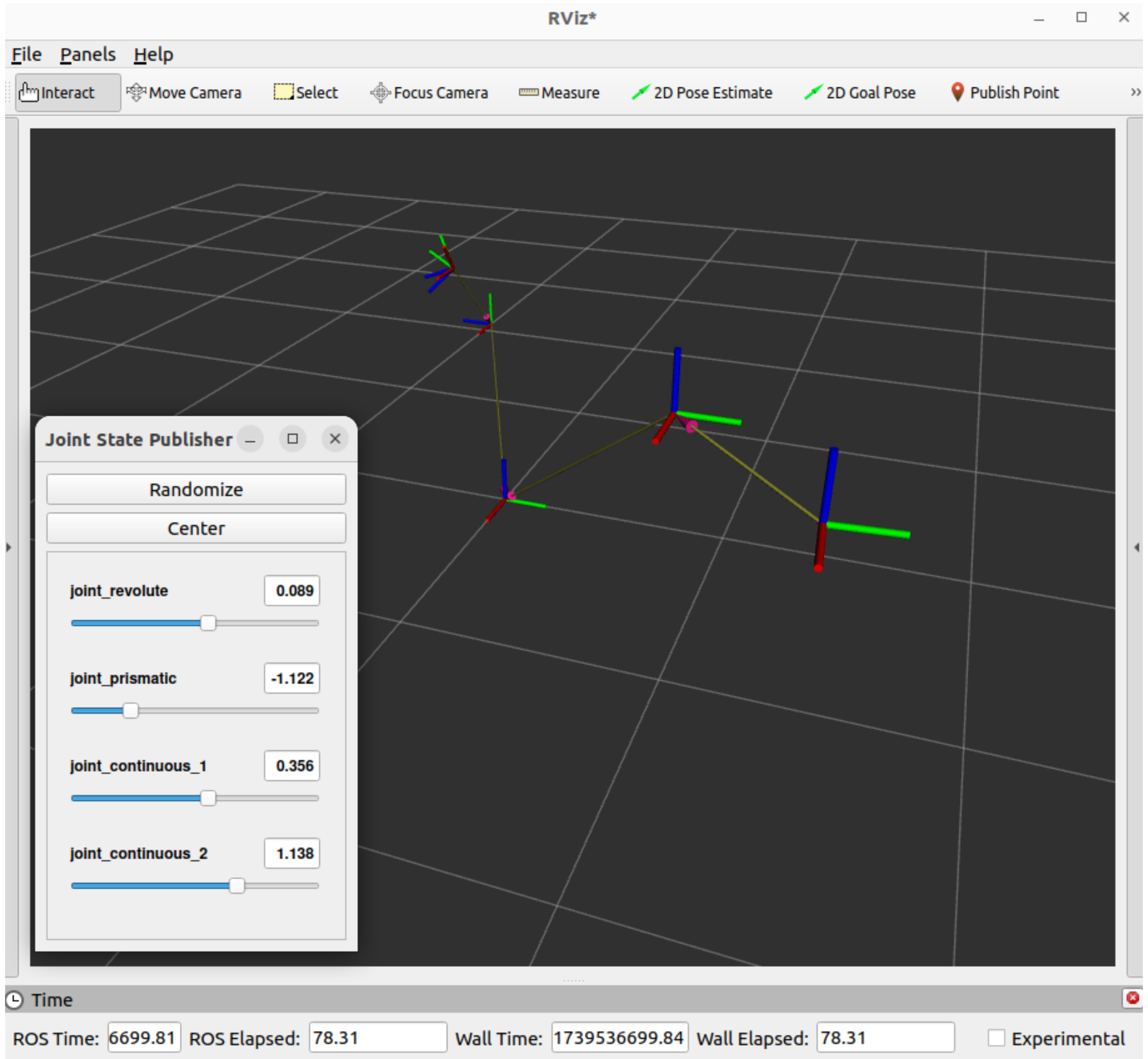
4. Add the joint_state publisher to the launch file

```
$ ros2 run rviz2 rviz2
```

5. Add the TF view
   - Press Add
   - >>By display type>>TF
6. Run the tf_tree…

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

<!--Declare Links to be used-->
  <link name="link1" />
  <link name="link2" />
  <link name="link3" />
  <link name="link4" />
  <link name="link5" />
  <link name="link6" />

<!--Declare Joints to be used-->
    <joint name="joint_fixed" type="fixed">
        <parent link="link1"/>
        <child link="link2"/>
        <origin xyz="1 1 1" rpy="0 0 0" />
    </joint>

    <joint name="joint_revolute" type="revolute">
        <parent link="link2"/>
        <child link="link3"/>
        <origin xyz="0.5 0.5 0" rpy="0 0 0" />
        <axis xyz="0 0 1" />
        <limit lower="-0.785" upper="0.785" effort="5.0" velocity="0.1"/>
    </joint>

    ... #Define the rest of the joints here ....

</robot>
```

# Activity 2: Extension


RViz*
File Panels Help
Interact Move Camera Select Focus Camera Measure 2D Pose Estimate 2D Goal Pose Publish Point
Joint State Publisher
Randomize
Center
Time
Experimental

joint_revolute 0.089
joint_prismatic -1.122
joint_continuous_1 0.356
joint_continuous_2 1.138

ROS Time: 6699.81 ROS Elapsed: 78.31 Wall Time: 1739536699.84 Wall Elapsed: 78.31

## Joint control

*Making your own Joint State Publisher*

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# Joint state publisher

- As stated previously, the robot state publisher, will not publish the joints unless something is published into the /joint_states topic.
- The joint state publisher does this by publishing positional values of the joints to the /joint_states topic using a JointState message. This allows the user to test the joints before releasing the model.
- The JointState message holds the data that describes the state of a torque-controlled joint.
- Each joint is uniquely identified by its name
- ROS associate the joint name with the correct states.
- The state of each joint (continuous,revolute or prismatic) is defined by:
  - the position of the joint (rad or m),
  - the velocity of the joint (rad/s or m/s)
  - the effort applied in the joint (Nm or N).
- The header specifies the time and frame at which the joint states were recorded.
- This message consists of a multiple arrays, one for each part o f the joint state.
- All arrays in this message should have the same size, or be em pty.

```
Header header

string[] name
float64[] position
float64[] velocity
float64[] effort
```

## Activity 3

*Making your own joint state publisher*

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# Activity 3

## Description

- In this activity, the user will create a node to control the position of the joinsts declared in the file "joints_ex.urdf".
- The position will be controlled by publishing a JointState message into the /joint_states topic.

```
# EXAMPLE
from sensor_msgs.msg import JointState

# Declare the output Messages
contJoints = JointState()

# Declare the output Messages
 self.ctrlJoints = JointState()
        self.ctrlJoints.header.stamp = self.get_clock().now().to_msg()
        self.ctrlJoints.name = ["joint_revolute", "joint_prismatic"]
        self.ctrlJoints.position = [0.0] * 2
        self.ctrlJoints.velocity = [0.0] * 2
        self.ctrlJoints.effort = [0.0] * 2
```

- For this activity, the URDF model "joints_ex.urdf" will be used. This file can be found in the course repository. (Previous activity)
- The URDF contains 4 joints with the following names

```
["joint_revolute", "joint_prismatic", "joint_continuous_1",
"joint_continuous_2"
```

- Please be aware that the JointMessage contains arrays, and they must be the same size as the number of joints to be controlled.

# Partial Code

```python
class FramePublisher(Node):

    def __init__(self):
        super().__init__('joints_publisher')

        #Publisher
        self.publisher = self.create_publisher(JointState,
'/joint_states', 10)

        #Create a Timer
        timer_period = 0.1 #seconds
        self.timer = self.create_timer(timer_period, self.timer_cb)

        #initialise Message to be published
        self.ctrlJoints = JointState()
        self.ctrlJoints.header.stamp = self.get_clock().now().to_msg()
        self.ctrlJoints.name = ["joint_revolute", "joint_prismatic",
"joint_continuous_1", "joint_continuous_2"]
        self.ctrlJoints.position = [0.0] * 4
        self.ctrlJoints.velocity = [0.0] * 4
        self.ctrlJoints.effort = [0.0] * 4

        ... #Variables
```

```python
    #Timer Callback
    def timer_cb(self):
        time = self.get_clock().now().nanoseconds/1e9

        self.ctrlJoints.header.stamp = self.get_clock().now().to_msg()
        self.ctrlJoints.position[0] = -0.785 + 2*0.785*self.i
        self.ctrlJoints.position[1] = -2+4.0*self.i
        self.ctrlJoints.position[2] = 0.5*time
        self.ctrlJoints.position[3] = 0.5*time

        ... # Rest of the code

        self.publisher.publish(self.ctrlJoints)
```

# Activity 3

1. Create a node named "continuosJoint.py" inside the previously created package "joints_act"

```
touch joints_act/joint_pub.py
```

2. Give execution permission and add it to the setup.py (if haven't done so)
3. Copy the code in GitHub for this node.
4. Make a new launch called "jointPub_launch.py" file similar to the one done for the previous activity (copy it) replace the name of the URDF file at the top.

```
touch launch/jointPub_launch.py
```

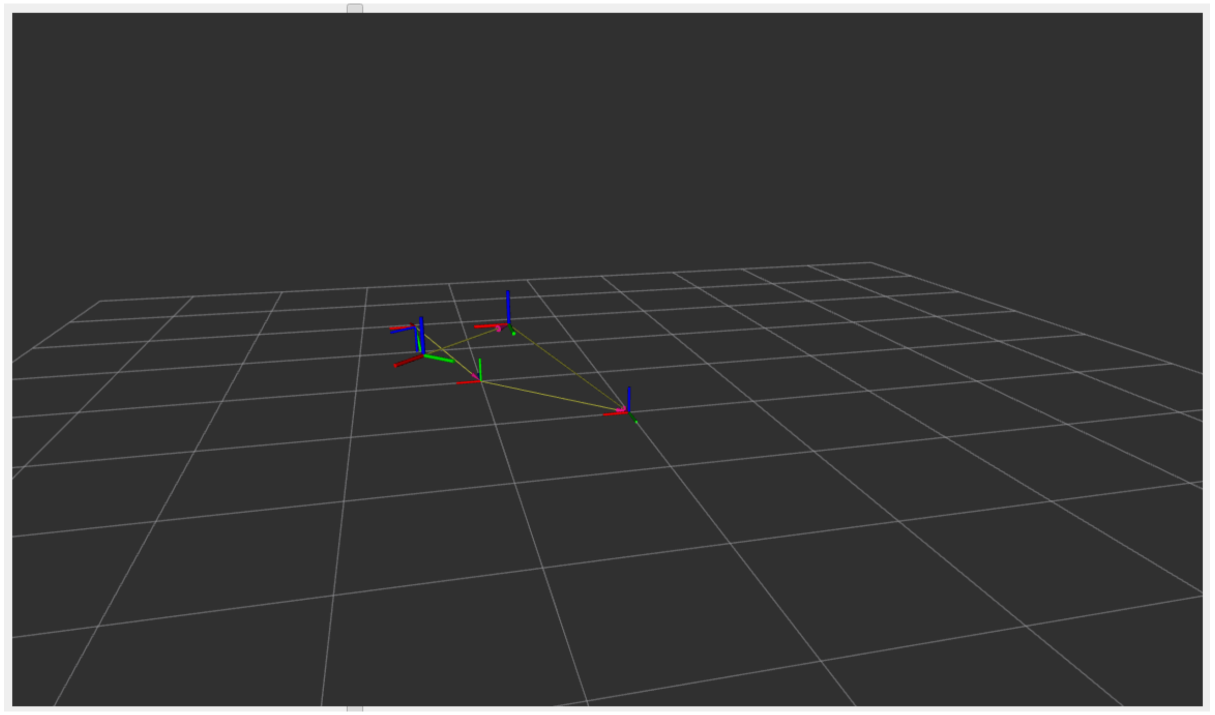
5. Give execution permissions
6. Replace the joint state publisher with your state publisher

```
# Define joint_state_publisher node (for simulation)
   joint_state_publisher_node = Node(
                                  package='joints_act',
                                  executable='joint_pub',
                                  output='screen'
                              )
```

7. Compile the node.
8. Launch the node
9. Add the TF view
   - Press Add
   - ››By display type››TF
10. Run the tf_tree…

# Activity 3

- Inside the timer of the node, the positional values for each joint (4 joints according to the URDF file) are updated using the ROS Time.
- RVIZ only handles positional values, not velocity or effort values, therefore only the position of each joint in the list of joints is being updated.
- The publishing of the message is done as a regular ROS message.

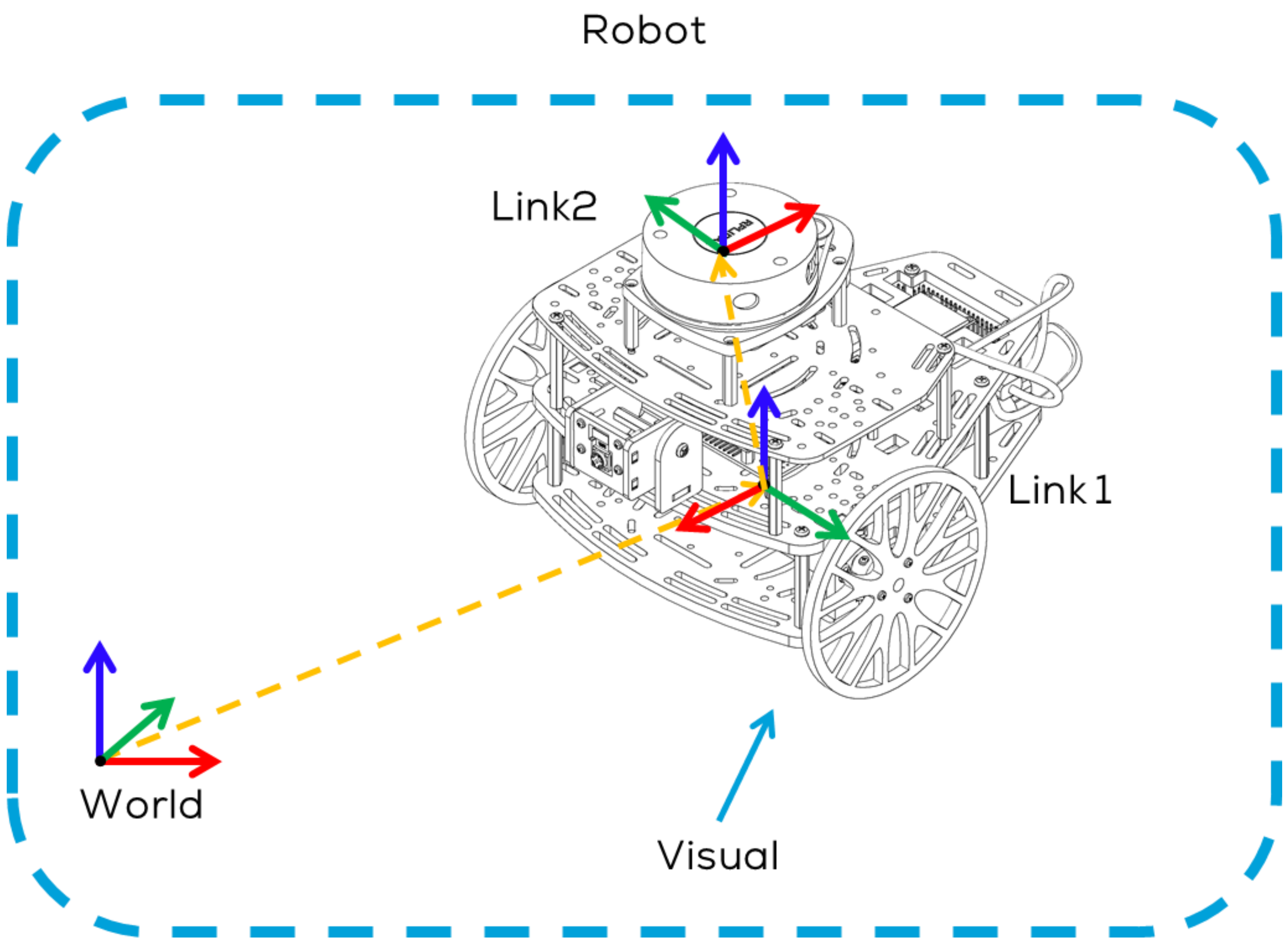


## URDF

*Links*

*{Learn, Create, Innovate};*

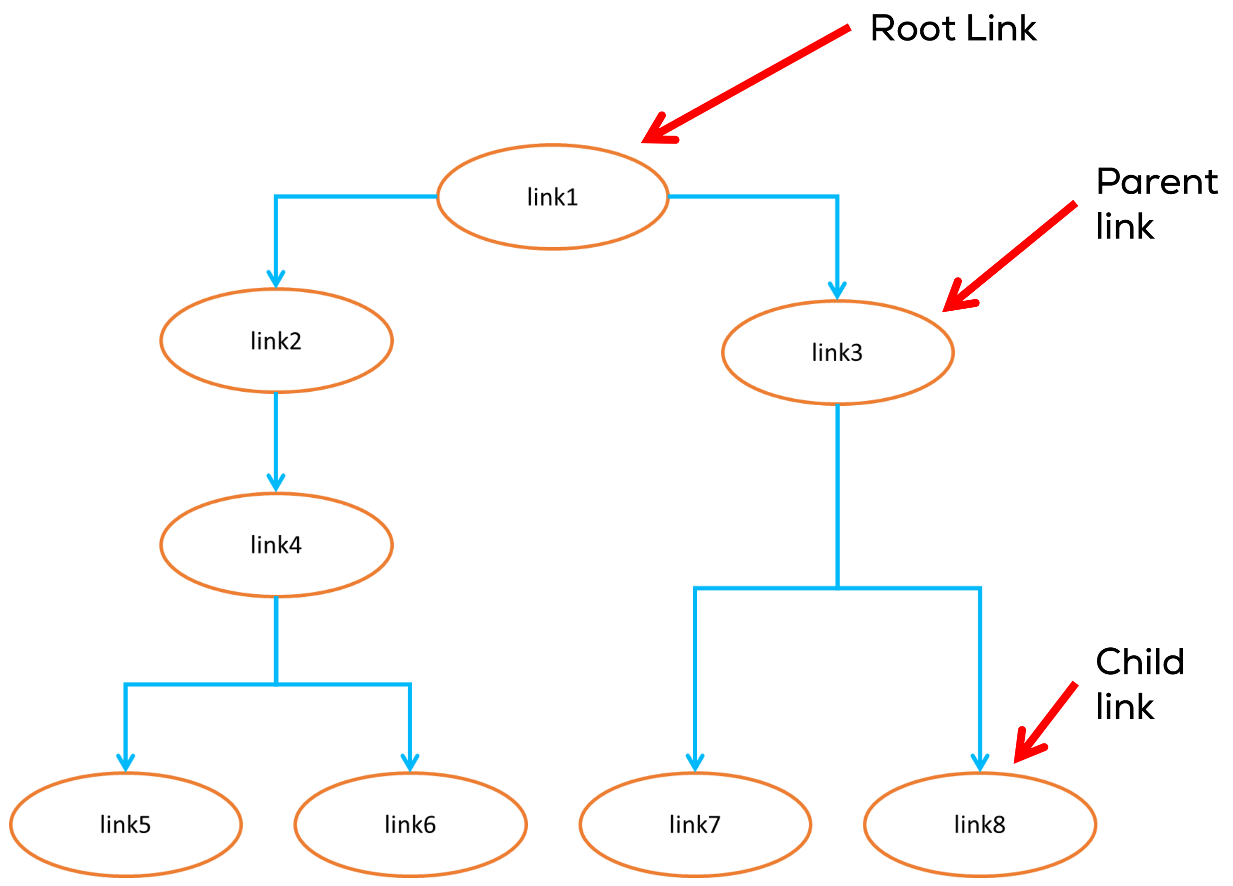
# Links



# Links

## Links description

- As stated previously, links represent a rigid body or a robot component.
- Links describe the visual, inertial, and collision properties of the link.
- Each link may have one or more visual and collision elements associated with it.
- Each link cannot have more than one parent (defined in joints).
- Root Link can have no parents.
- Only one root link is allowed per model.
- Root Link is usually modified using a joint state publisher.



# Links

## Visual

- Defines the visual appearance of a link.
- The inbuilt shapes are cylinder, box, and sphere.
- The visual can also set a mesh from a CAD file in format .dae or .stl.
- Origin: Sets the pose of the visual part relative to the link.
- Material: material properties (e.g., color, texture)

```
 <link name="wheel_left_link">
        <visual>
            <origin xyz="0 0 0" rpy="0 0 0" />
            <geometry>
                <mesh filename="file://mesh.stl"/>
            </geometry>
            <material name="yellow"/>
        </visual>
</link>
```

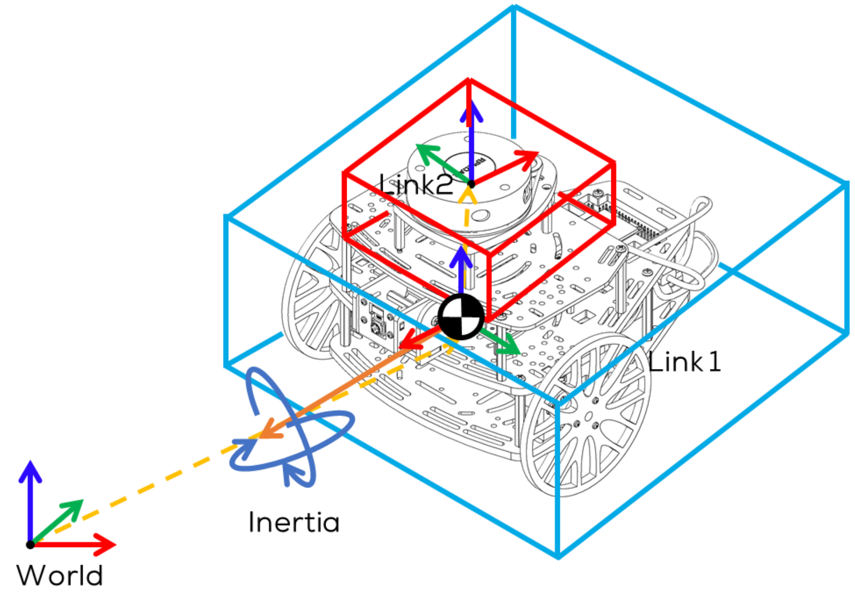
```
 <link name="link1">
    <visual>
    <origin xyz="0 0 0" rpy="0 1.57 0"/>
      <geometry>
        <cylinder length="0.4" radius="0.1" />
      </geometry>
      <material name="Grey">
        <color rgba="0.67 0.67 .67 1.0"/>
      </material>
    </visual>
  </link>
```

# Links

## Collision

- Defines the collision properties of a link.
- Collision properties can be different from the visual properties of a link (simpler collision models).
- Multiple <collision> tags can exist for the same link.
- The union of the geometry they define forms the collision representation of the link.
- Origin: Sets the pose of the visual part relative to the link frame.
- Geometry: Geometrical description of the collision body The inbuilt shapes are cylinder, box, and sphere.

```
 <link name="wheel_left_link">
       <collision>
            <origin xyz="0 0 0" rpy="0 0 0"/>
            <geometry>
                <cylinder length="1" radius="1" />
            </geometry>
        </collision>
</link>
```

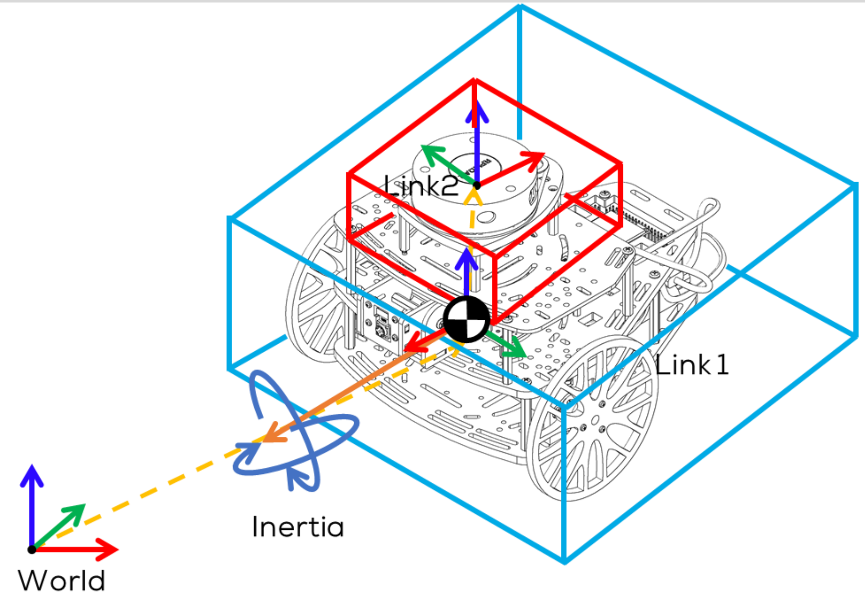


# Links

## Inertial

- Defines the link's mass, the position of its centre of mass, and its central inertia properties.
- Origin: Position and orientation of the link's centre of mass relative to the link frame "L".
- Mass: The mass of the link.
- Inertia: This link's moments of inertia ixx, iyy, izz and products of inertia ixy, ixz, iyz about C (centre of mass) for the unit vectors Ĉx, Ĉy, Ĉz fixed in the centre-of-mass frame C,  Relative to L̂x, L̂y, L̂z is specified by the rpy values in the ‹origin› tag.

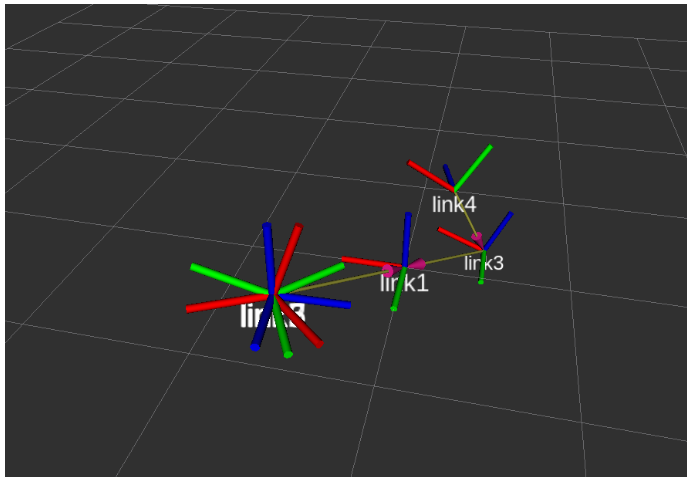
```
 <link name="wheel_left_link">
         <inertial>
            <origin xyz="0 0 0" rpy="0 0 0"/>
            <mass value="1"/>
            <inertia ixx="0.4" ixy="0.0" ixz="0.0" iyy="0.4"
            iyz="0.0" izz="0.2"/>
         </inertial>
</link>
```



# Links

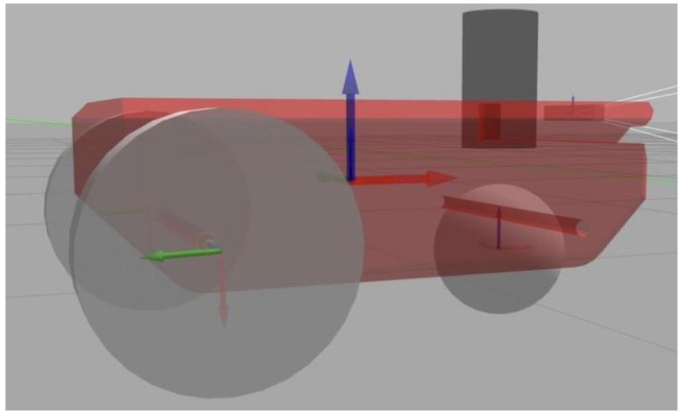
## RVIZ

- In RVIZ Links are represented by sets of coordinates.
- RVIZ only requires a name for a link.
- RVIZ only uses the information in the collision and the visual descriptions of the URDF file (both optional).



## Gazebo

- The Gazebo simulation environment, requires a plugin to transform the URDF files into SDF files (Gazebo's native file type).
- Gazebo requires information about the visual, inertial, and collision properties, alongside other physics parameters for each link, such as friction, stiffness, and damping.



# Links: Syntax

```xml
<link name="wheel_left_link">

    <visual>
        <origin xyz="0 0 0" rpy="0 0 0" />
        <geometry>
            <mesh filename="file://mesh.stl"/>
        </geometry>
        <material name="yellow"/>
    </visual>

    <collision>
        <origin xyz="0 0 0" rpy="0 0 0"/>
        <geometry>
            <cylinder length="1" radius="1" />
        </geometry>
    </collision>

    <inertial>
        <origin xyz="0 0 0" rpy="0 0 0"/>
        <mass value="1"/>
        <inertia ixx="0.4" ixy="0.0" ixz="0.0" iyy="0.4" iyz="0.0" izz="0.2"/>
    </inertial>

</link>
```

## Activities

*Activity 4 and Activity 5*

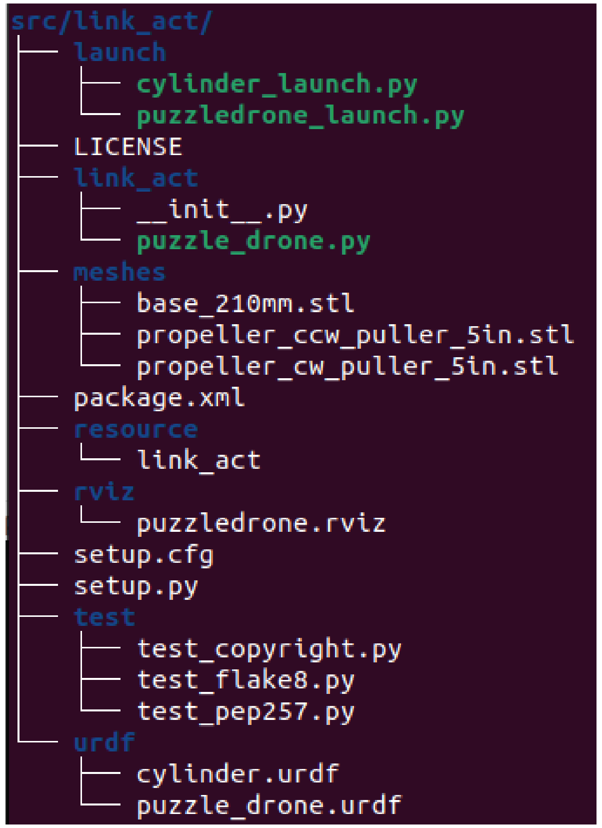
*{Learn, Create, Innovate};*

# Activity 4

1. For the following activities, make a new package called "link_act" with the following library

```
$ ros2 pkg create --build-type ament_python link_act --node-name puzzle_drone --license Apache-2.0 --dependencies sensor_msgs geometry_msgs robot_state_publisher joint_state_publisher_gui std_msgs ros2launch tf2_ros_py python3-numpy python3-transforms3d rclpy --description 'URDF Link Examples' --maintainer-name 'Mario Martinez' --maintainer-email mario.mtz@manchester-robotics.com
```

- Create the following folders inside the package
  - launch, meshes, urdf
- Create 2 launch files named inside the "launch" folder (do not forget to give executable permissions):
  - cylinder_launch.py
  - puzzledrone_launch.py
- Download from GitHub and add the three .stl files to the meshes folder
  - base_210mm.stl
  - propeller_ccw_puller_5in.stl
  - propeller_cw_puller_5in.stl
- Create two URDF Files inside the "urdf" folder
  - cylinder.urdf
  - puzzle_drone.urdf



```
src/link_act/
├── launch
│   ├── cylinder_launch.py
│   └── puzzledrone_launch.py
├── LICENSE
├── link_act
│   ├── __init__.py
│   └── puzzle_drone.py
├── meshes
│   ├── base_210mm.stl
│   ├── propeller_ccw_puller_5in.stl
│   └── propeller_cw_puller_5in.stl
├── package.xml
├── resource
│   └── link_act
├── rviz
│   └── puzzledrone.rviz
├── setup.cfg
├── setup.py
├── test
│   ├── test_copyright.py
│   ├── test_flake8.py
│   └── test_pep257.py
└── urdf
    ├── cylinder.urdf
    └── puzzle_drone.urdf
```

# Activity 1

- Open the “setup.py” file
- Add the libraries to be used

```
from setuptools import find_packages, setup
import os
from glob import glob
```

- Configure the data_files section as follows

```
data_files=[
    ('share/ament_index/resource_index/packages',
        ['resource/' + package_name]),
    ('share/' + package_name, ['package.xml']),
    (os.path.join('share', package_name, 'launch'), glob(os.path.join('launch', '*launch.[pxy][yma]*'))),
    (os.path.join('share', package_name, 'config'), glob(os.path.join('config', '*.[yma]*'))),
    (os.path.join('share', package_name, 'rviz'), glob(os.path.join('rviz', '*.rviz'))),
    (os.path.join('share', package_name, 'meshes'), glob(os.path.join('meshes', '*.stl'))),
    (os.path.join('share', package_name, 'urdf'), glob(os.path.join('urdf', '*.urdf'))),
    ],
```

## 8 SaNf Yai o

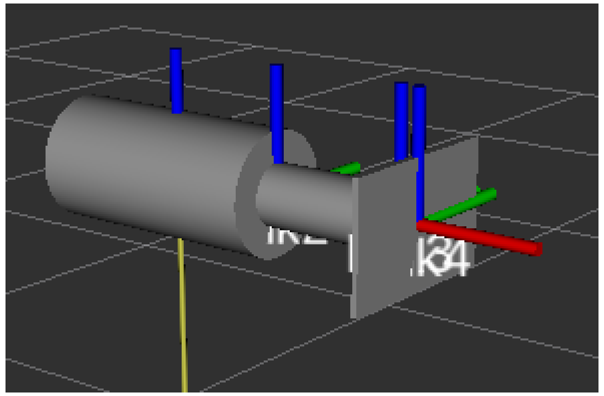
*Links in RVIZ*

{Learn, Create, Innovate};

# Activity 4

## Description

- In this activity, the user will create a link and a joint state publisher that depicts a pneumatic cylinder moving continuously.
- The position will be controlled by publishing a JointState message into the /joint_states topic.
- Open the urdf file (inside the urdf folder) named "cylinder.urdf"
- Create 5 links, and 4 joints with the information depicted in the following figure.



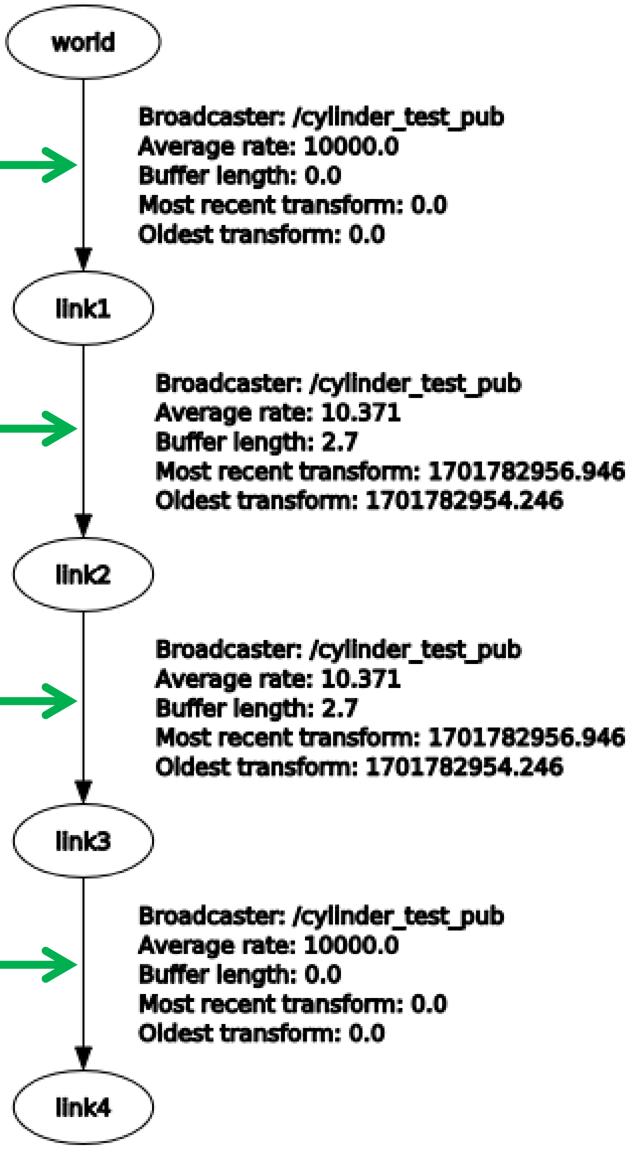
# Activity 4

```
<joint name="joint1" type="fixed">
   <origin xyz="0 0 1" rpy="0 0 0" />
   <parent link="world" />
   <child link="link1" />
 </joint>
```

```
<joint name="joint2" type="prismatic">
   <parent link="link1"/>
   <child link="link2"/>
   <origin xyz="0.1 0 0" rpy="0 0 0" />
   <axis xyz="1 0 0" />
   <limit lower="0.0" upper="0.2" effort="5.0" velocity="0.1"/>
 </joint>
```

```
<joint name="joint3" type="revolute">
   <origin xyz="0.225 0 0" rpy="0 0 0" />
   <parent link="link2" />
   <child link="link3" />
   <axis xyz="0 1 0" />
   <limit lower="-0.785" upper="0.785" effort="5" velocity="2" />
 </joint>
```

```
<joint name="joint4" type="fixed">
   <origin xyz="0.03 0 0" rpy="0 0 0" />
   <parent link="link3" />
   <child link="link4" />
 </joint>
```



```
Broadcaster: /cylinder_test_pub
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
```

```
Broadcaster: /cylinder_test_pub
Average rate: 10.371
Buffer length: 2.7
Most recent transform: 1701782956.946
Oldest transform: 1701782954.246
```

```
Broadcaster: /cylinder_test_pub
Average rate: 10.371
Buffer length: 2.7
Most recent transform: 1701782956.946
Oldest transform: 1701782954.246
```

```
Broadcaster: /cylinder_test_pub
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
```

# Activity 4

- For each link (Link1 – Link 4) use the following description in the URDF file.
- <u>The link “world” must be empty.</u>

```
 <link name="world">
    </link>

<link name="link1">
    <visual>
    <origin xyz="0 0 0" rpy="0 1.57 0"/>
      <geometry>
        <cylinder length="0.4" radius="0.1" />
      </geometry>
      <material name="Grey">
        <color rgba="0.67 0.67 .67 1.0"/>
      </material>
    </visual>
  </link>

 <link name="link2">
    <visual>
    <origin xyz="0 0 0" rpy="0 1.57 0"/>
      <geometry>
        <cylinder length="0.4" radius="0.05" />
      </geometry>
      <material name="Grey">
        <color rgba="0.67 0.67 .67 1.0"/>
      </material>
    </visual>
  </link>
```

```
<link name="link3">
   <visual>
   <origin xyz="0 0 0" rpy="0 1.57 1.57"/>
     <geometry>
       <cylinder length="0.1" radius="0.025" />
     </geometry>
     <material name="Grey">
       <color rgba="0.67 0.67 .67 1.0"/>
     </material>
   </visual>
 </link>

<link name="link4">
   <visual>
   <origin xyz="0 0 0" rpy="0 0 0"/>
     <geometry>
       <box size="0.01 0.3 0.2" />
     </geometry>
     <material name="Grey">
       <color rgba="0.67 0.67 .67 1.0"/>
     </material>
   </visual>
 </link>
```

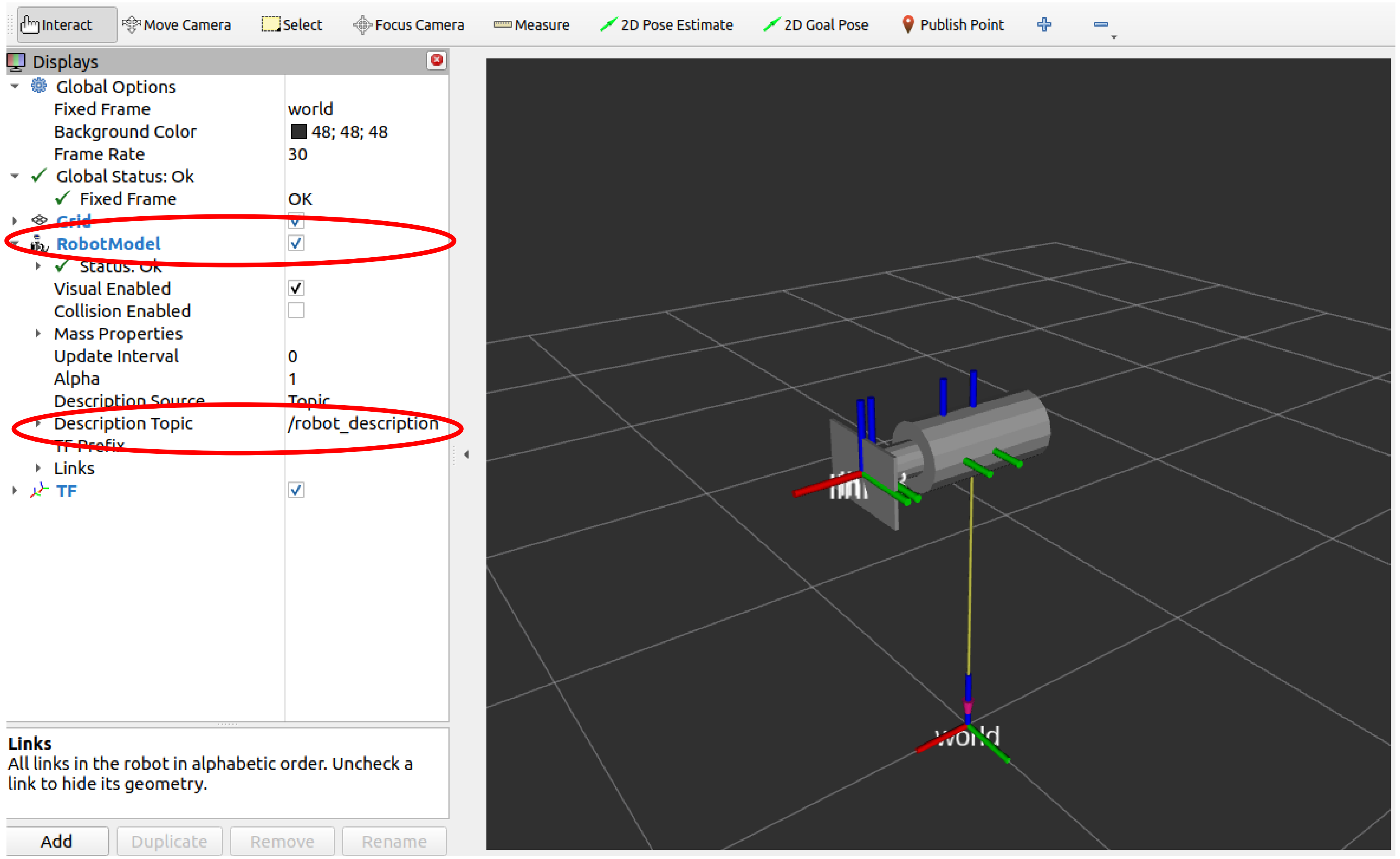
# Activity 4

## Testing the model

- Open the “cylinder_launch.py” and add the following.
- Save it and give executable permissions if you haven’t done so.
- Make a lunch file and use the “robot_state_publisher” to publish the information about the state of the cylinder.
- Use the Joint State Controller GUI  in the launch file to verify if the model is working properly.
- To visualise the model in RVIZ select “world” as Fixed Frame.
- In RVIZ press “Add››By display type››RobotModel”. In the RobotModel select s “Description Topic” “/robot_description”.

```
import os
from ament_index_python.packages import get_package_share_directory
from launch import LaunchDescription
from launch_ros.actions import Node

def generate_launch_description():

    urdf_file_name = 'cylinder.urdf'
    urdf = os.path.join(
        get_package_share_directory('link_act'),
        'urdf',
        urdf_file_name)

    with open(urdf, 'r') as infp:
        robot_desc = infp.read()

    robot_state_pub_node = Node(
                            package='robot_state_publisher',
                            executable='robot_state_publisher',
                            name='robot_state_publisher',
                            output='screen',
                            parameters=[{'robot_description': robot_desc}],
                            arguments=[urdf]
                            )

 # Define joint_state_publisher node (for simulation)
    joint_state_publisher_node = Node(
                                package='joint_state_publisher_gui',
                                executable='joint_state_publisher_gui',
                                output='screen'
                            )

    l_d = LaunchDescription([robot_state_pub_node, joint_state_publisher_node])
    return l_d
```

# Activity 4



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 | |
| Mass Properties | |
| Update Interval | 0 |
| Alpha | 1 |
| Description Source | Topic |
| Description Topic | /robot_description |
| TF Prefix | |
| Links | |
| TF | ✓ |

**Links**
All links in the robot in alphabetic order. Uncheck a link to hide its geometry.

## 8 SdNf Ydi p

*Putting It All Together*

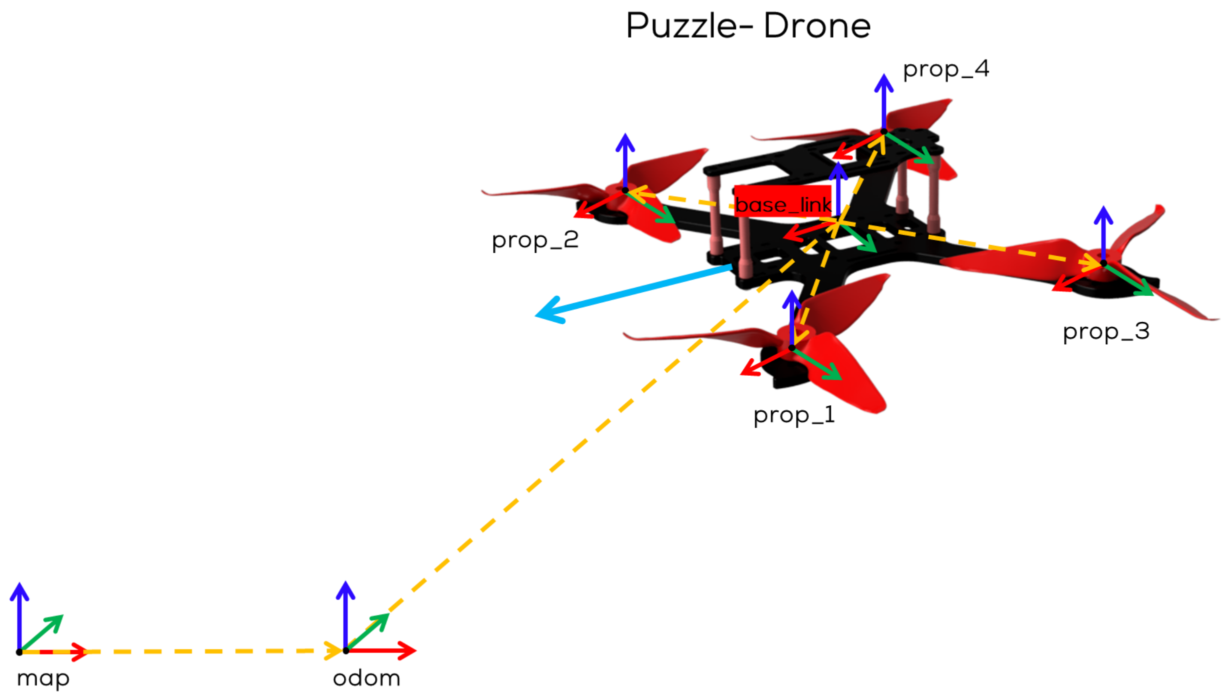
*{Learn, Create, Innovate};*

Manchester **Robotics**

# Activity 5

## Description

- In this activity, the user will create a link and a joint state publisher that depicts the Puzzledrone.
- The propellers will be controlled by publishing a JointState message into the /joint_states topic.
- To decrease the complexity and decrease computational power, only the basic parts od the Puzzle Drone will be modelled (excl. motors, cables, PCB, etc.)
- The activity is divided into three sections: URDF, Joint State Publisher and Launch File.

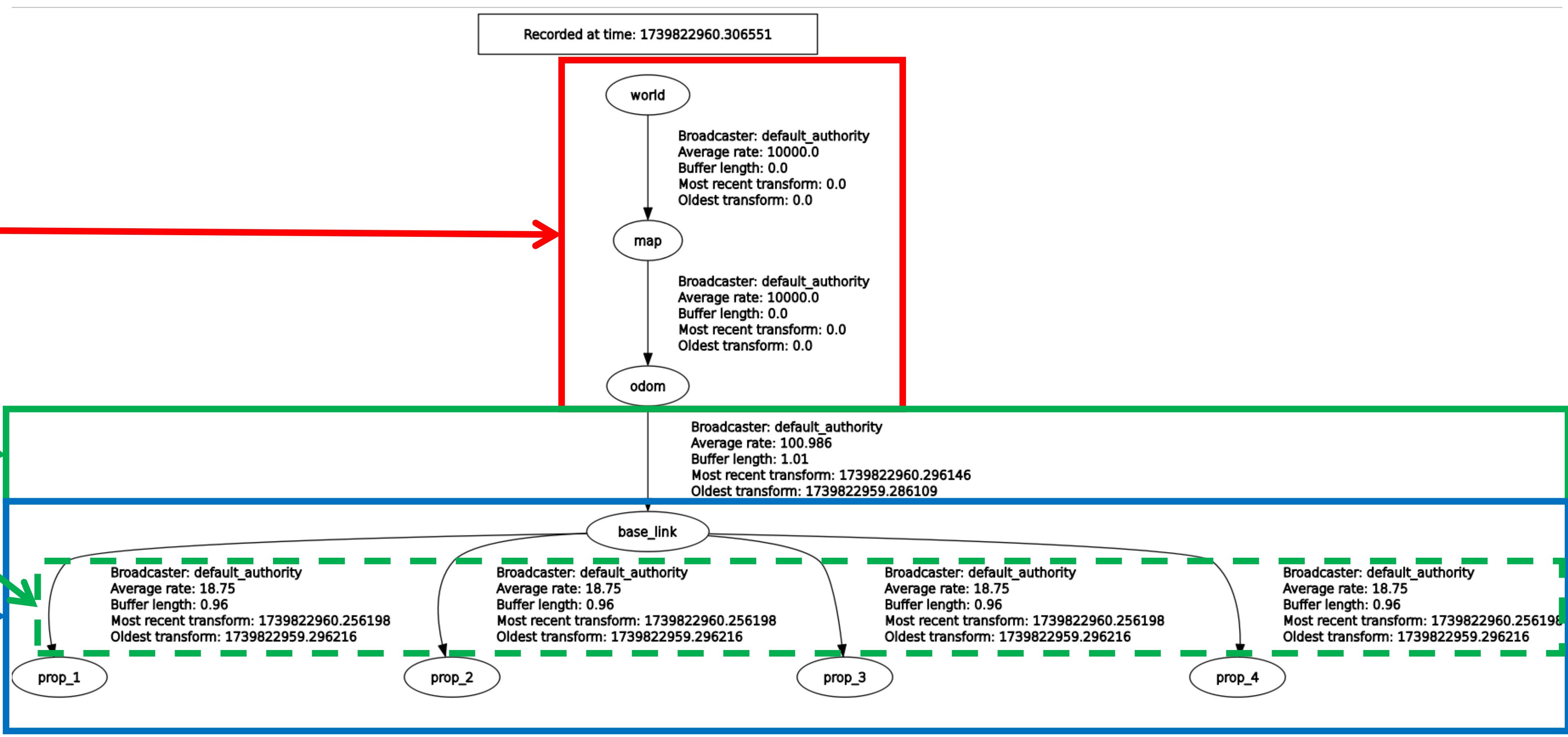


# Activity 5

Static Transforms and links to be defined in the launch file

Dynamic Transforms, to be defined and joints to be updated on the node "puzzle_drone.py" (joint_state_pub)

Dynamic (continuous) joints and links to be defined on URDF File



```
Recorded at time: 1739822960.306551

world -> map
Broadcaster: default_authority
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0

map -> odom
Broadcaster: default_authority
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0

odom -> base_link
Broadcaster: default_authority
Average rate: 100.986
Buffer length: 1.01
Most recent transform: 1739822960.296146
Oldest transform: 1739822959.286109

base_link -> prop_1
Broadcaster: default_authority
Average rate: 18.75
Buffer length: 0.96
Most recent transform: 1739822960.256198
Oldest transform: 1739822959.296216

base_link -> prop_2
Broadcaster: default_authority
Average rate: 18.75
Buffer length: 0.96
Most recent transform: 1739822960.256198
Oldest transform: 1739822959.296216

base_link -> prop_3
Broadcaster: default_authority
Average rate: 18.75
Buffer length: 0.96
Most recent transform: 1739822960.256198
Oldest transform: 1739822959.296216

base_link -> prop_4
Broadcaster: default_authority
Average rate: 18.75
Buffer length: 0.96
Most recent transform: 1739822960.25619
Oldest transform: 1739822959.296216
```

# Activity 5: URDF

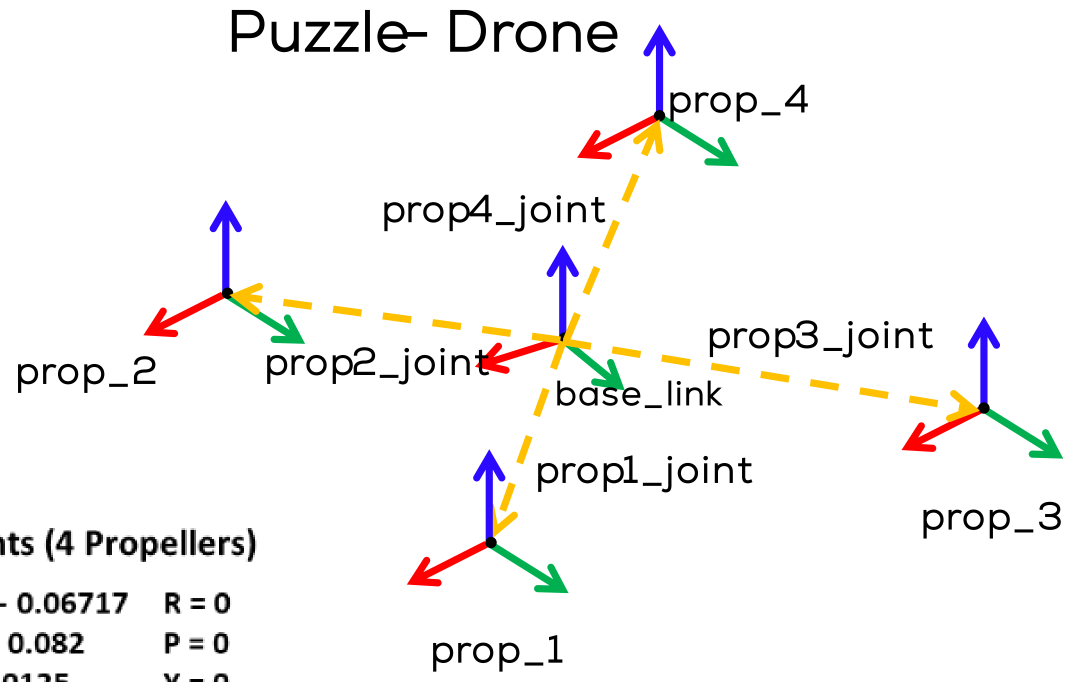
## Instructions

- Use the package previously created in Activity 4.
- Open the urdf file (inside the urdf folder) named "puzzle_drone.urdf"
- Create the links and joints of the using the following information.
- The information about the joints is described in the figure.
- An example on how to define two links and a join is presented in the following slide, the complete exercise can be found in GitHub.

- Create five links using the following information:

| Link name | Mesh to attach | Adjusted Mesh Pose |
|---|---|---|
| base_link | base_210mm.stl | x=0<br>y=0<br>z=-0.0205<br>r=1.57<br>p= 0.0<br>yaw=1.57 |
| prop_1 | propeller_ccw_puller_5in.stl | z=-0.004 |
| prop_2 | propeller_cw_puller_5in.stl | z=-0.004 |
| prop_3 | propeller_ccw_puller_5in.stl | z=-0.004 |
| prop_4 | propeller_cw_puller_5in.stl | z=-0.004 |

# Activity 5: URDF



**Joints (4 Propellers)**

| | |
|---|---|
| X= +/- 0.06717 | R = 0 |
| Y=+/- 0.082 | P = 0 |
| Z= -0.0125 | Y = 0 |

```
...
<link name="base_link">
    <visual>
        <origin xyz="0 0 -0.0205" rpy="1.57 0 1.57"/>
        <geometry>
            <mesh filename="package://link_act/meshes/base_210mm.stl"/>
        </geometry>
        <material name="yellow">
            <color rgba="0.8 0.8 0.05 1.0"/>
        </material>
    </visual>
</link>

<link name="prop_1">
    <visual>
        <origin xyz="0 0 -0.004" rpy="0 0 0"/>
        <geometry>
            <mesh filename="package://link_act/meshes/propeller_ccw_puller_5in.stl"/>
        </geometry>
        <material name="yellow">
            <color rgba="0.8 0.8 0.05 1.0"/>
        </material>
    </visual>
</link>
    ...
<joint name="prop1_joint" type="continuous">
    <parent link="base_link"/>
    <child link="prop_1"/>
    <origin xyz="0.06717 0.082 -0.0125" rpy="0 0 0"/>
    <axis xyz="0 0 1"/>
</joint>
```

# Activity 5: Joint State Publisher

- Make a Ros2 Node, that broadcast a dynamic transform from the “odom” frame to the “base_link” frame. The transform can vary in time to make the drone describe a circular trajectory.
- Publish the states of the joints "prop1_joint", "prop2_joint", "prop3_joint", "prop4_joint” in the /joint_states topic so that the propellers act like they are rotating.
- The following slide shows the template for the Joint State Puiblisher

```
#Initialise Message to be published

self.ctrlJoints = JointState()
self.ctrlJoints.header.stamp = self.get_clock().now().to_msg()
self.ctrlJoints.name = ["prop1_joint", "prop2_joint",
"prop3_joint", "prop4_joint"]
self.ctrlJoints.position = [0.0] * 4
self.ctrlJoints.velocity = [0.0] * 4
self.ctrlJoints.effort = [0.0] * 4
```

# Activity 5: Joint State Publisher

```python
import rclpy
from rclpy.node import Node
from tf2_ros import TransformBroadcaster
from geometry_msgs.msg import TransformStamped
from visualization_msgs.msg import Marker
import transforms3d
import numpy as np

class DronePublisher(Node):

    def __init__(self):
        super().__init__('frame_publisher')

        #Drone Initial Pose
        self.intial_pos_x = 1.0
        self.intial_pos_y = 1.0
        self.intial_pos_z = 1.0
        self.intial_pos_yaw = np.pi/2
        self.intial_pos_pitch = 0.0
        self.intial_pos_roll = 0.0

        #Angular velocity for the pose change and propellers
        self.omega = 0.5
        self.omega_prop = 100.0

        #Define Transformations
        self.define_TF()
```

```python
        #Create Transform Boradcasters

        #Create Publishers

        #Create Joint State to be Published

        #Create a Timer
        timer_period = 0.01 #seconds
        self.timer = self.create_timer(timer_period, self.timer_cb)

    #Timer Callback
    def timer_cb(self):
        #Callback to be filled

    def define_TF(self):
        #Create Trasnform Messages here

def main(args=None):
    rclpy.init(args=args)
    node = DronePublisher()
    try:
        rclpy.spin(node)
    except KeyboardInterrupt:
        pass
    finally:
        if rclpy.ok():  # Ensure shutdown is only called once
            rclpy.shutdown()
        node.destroy_node()

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

# Activity 5: Joint State Publisher

```
def define_TF(self):
    #Create Trasnform Messages
    self.base_link_tf = TransformStamped()
    self.base_link_tf.header.stamp = self.get_clock().now().to_msg()
    self.base_link_tf.header.frame_id = 'odom'
    self.base_link_tf.child_frame_id = 'base_link'
    self.base_link_tf.transform.translation.x = self.intial_pos_x
    self.base_link_tf.transform.translation.y = self.intial_pos_y
    self.base_link_tf.transform.translation.z = self.intial_pos_z
    q = transforms3d.euler.euler2quat(self.intial_pos_roll,
self.intial_pos_pitch, self.intial_pos_yaw)
    self.base_link_tf.transform.rotation.x = q[1]
    self.base_link_tf.transform.rotation.y = q[2]
    self.base_link_tf.transform.rotation.z = q[3]
    self.base_link_tf.transform.rotation.w = q[0]
```

- The transform will be declared as follows
- All transforms will be defined inside the function "define_TF"
- The transforms and joints will be updated using a timer.
- The following slides contain the full code, the code can also be found on GitHub.

# Activity 5: Joint State Publisher

```python
import rclpy
from rclpy.node import Node
from tf2_ros import TransformBroadcaster
from geometry_msgs.msg import TransformStamped
from sensor_msgs.msg import JointState
import transforms3d
import numpy as np

class DronePublisher(Node):

    def __init__(self):
        super().__init__('frame_publisher')

        #Drone Initial Pose
        self.intial_pos_x = 1.0
        self.intial_pos_y = 1.0
        self.intial_pos_z = 1.0
        self.intial_pos_yaw = np.pi/2
        self.intial_pos_pitch = 0.0
        self.intial_pos_roll = 0.0

        #Angular velocity for the pose change and propellers
        self.omega = 0.5
        self.omega_prop = 100.0

        #Define Transformations
        self.define_TF()
```

```python
        #initialise Message to be published
        self.ctrlJoints = JointState()
        self.ctrlJoints.header.stamp = self.get_clock().now().to_msg()
        self.ctrlJoints.name = ["prop1_joint", "prop2_joint", "prop3_joint", 
"prop4_joint"]
        self.ctrlJoints.position = [0.0] * 4
        self.ctrlJoints.velocity = [0.0] * 4
        self.ctrlJoints.effort = [0.0] * 4

        #Create Transform Boradcasters
        self.tf_br_base = TransformBroadcaster(self)
        #Publisher
        self.publisher = self.create_publisher(JointState, '/joint_states', 10)
        #Create a Timer
        timer_period = 0.01 #seconds
        self.timer = self.create_timer(timer_period, self.timer_cb)
```

# Activity 5: Joint State Publisher

```python
    #Timer Callback
    def timer_cb(self):
        time = self.get_clock().now().nanoseconds/1e9
        #Create Trasnform Messages
        self.base_link_tf.header.stamp = self.get_clock().now().to_msg()
        self.base_link_tf.transform.translation.x = self.intial_pos_x +
0.5*np.cos(self.omega*time)
        self.base_link_tf.transform.translation.y = self.intial_pos_y +
0.5*np.sin(self.omega*time)
        self.base_link_tf.transform.translation.z = self.intial_pos_z
        q = transforms3d.euler.euler2quat(self.intial_pos_roll,
self.intial_pos_pitch, self.intial_pos_yaw+self.omega*time)
        self.base_link_tf.transform.rotation.x = q[1]
        self.base_link_tf.transform.rotation.y = q[2]
        self.base_link_tf.transform.rotation.z = q[3]
        self.base_link_tf.transform.rotation.w = q[0]

        self.ctrlJoints.header.stamp = self.get_clock().now().to_msg()
        self.ctrlJoints.position[0] = self.omega_prop*time
        self.ctrlJoints.position[1] = -self.omega_prop*time
        self.ctrlJoints.position[2] = self.omega_prop*time
        self.ctrlJoints.position[3] = -self.omega_prop*time

        self.tf_br_base.sendTransform(self.base_link_tf)
        self.publisher.publish(self.ctrlJoints)
```

```python
    def define_TF(self):
        #Create Trasnform Messages
        self.base_link_tf = TransformStamped()
        self.base_link_tf.header.stamp = self.get_clock().now().to_msg()
        self.base_link_tf.header.frame_id = 'odom'
        self.base_link_tf.child_frame_id = 'base_link'
        self.base_link_tf.transform.translation.x = self.intial_pos_x
        self.base_link_tf.transform.translation.y = self.intial_pos_y
        self.base_link_tf.transform.translation.z = self.intial_pos_z
        q = transforms3d.euler.euler2quat(self.intial_pos_roll,
self.intial_pos_pitch, self.intial_pos_yaw)
        self.base_link_tf.transform.rotation.x = q[1]
        self.base_link_tf.transform.rotation.y = q[2]
        self.base_link_tf.transform.rotation.z = q[3]
        self.base_link_tf.transform.rotation.w = q[0]

def main(args=None):
    rclpy.init(args=args)
    node = DronePublisher()
    try:
        rclpy.spin(node)
    except KeyboardInterrupt:
        pass
    finally:
        if rclpy.ok():  # Ensure shutdown is only called once
            rclpy.shutdown()
        node.destroy_node()
if __name__ == '__main__':
    main()
```

# Activity 5: Launch File

- Open the previously created launch file "puzzledrone_launch.py"
- Define two static transforms
  - world -> map (same pose)
  - map -> odom `[x= 2, y=1, z=-0.0, r=0, p=0.0, yaw=0]`

```
static_transform_node = Node(
                            package='tf2_ros',
                            executable='static_transform_publisher',
                            arguments = ['--x', '2', '--y', '1', '--z', '0.0',
                                         '--yaw', '0.0', '--pitch', '0', '--roll', '0.0',
                                         '--frame-id', 'map', '--child-frame-id', 'odom']
                            )

static_transform_node_2 = Node(
                            package='tf2_ros',
                            executable='static_transform_publisher',
                            arguments = ['--x', '0', '--y', '0', '--z', '0.0',
                                         '--yaw', '0.0', '--pitch', '0', '--roll', '0.0',
                                         '--frame-id', 'world', '--child-frame-id', 'map']
                            )
```

- Add the robot state publisher

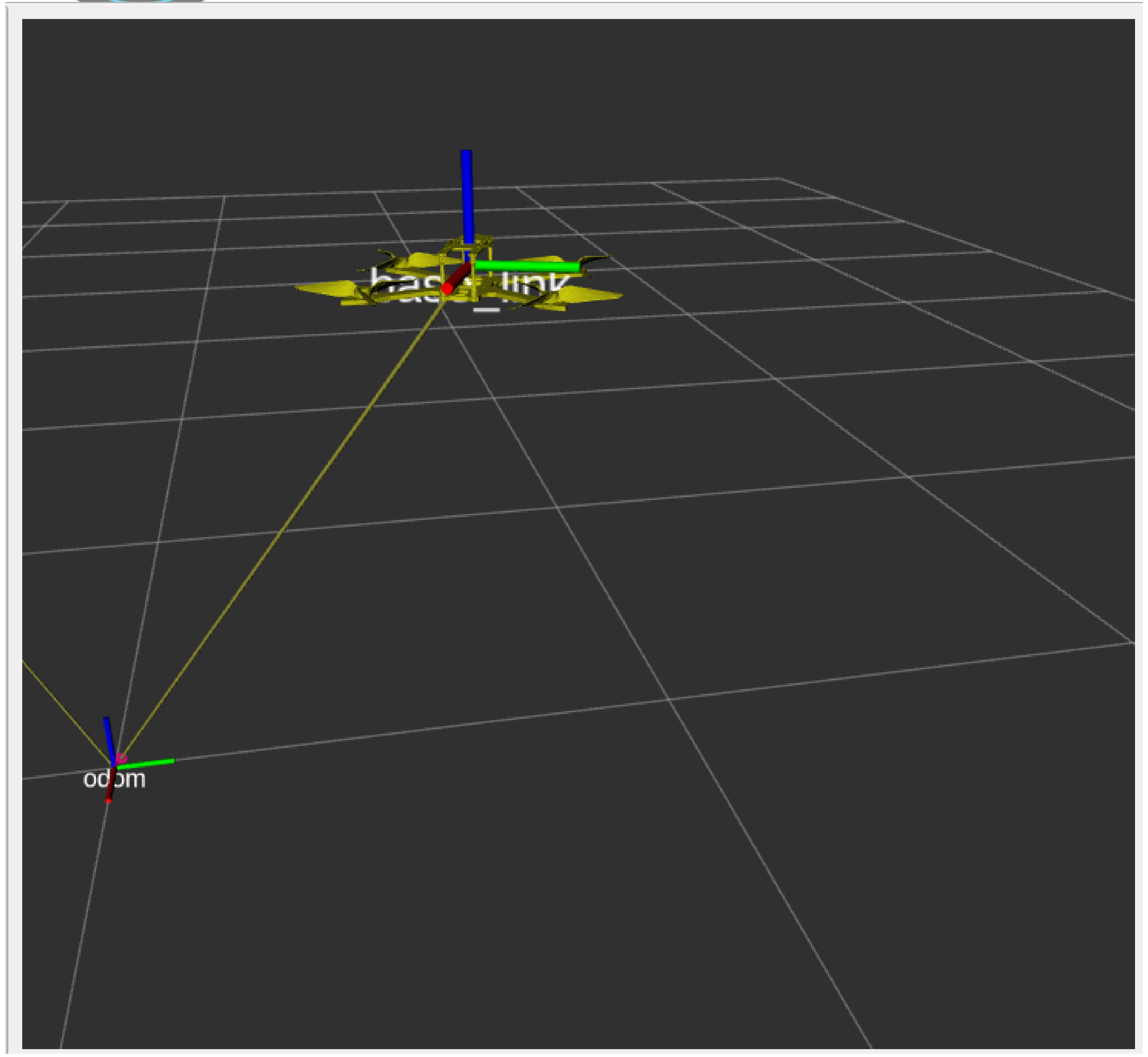
```
urdf_file_name = 'puzzle_drone.urdf'
urdf = os.path.join(
    get_package_share_directory('link_act'),
    'urdf',
    urdf_file_name)

with open(urdf, 'r') as infp:
    robot_desc = infp.read()

robot_state_pub_node = Node(
                        package='robot_state_publisher',
                        executable='robot_state_publisher',
                        name='robot_state_publisher',
                        output='screen',
                        parameters=[{'robot_description': robot_desc}],
                        arguments=[urdf]
                        )
```

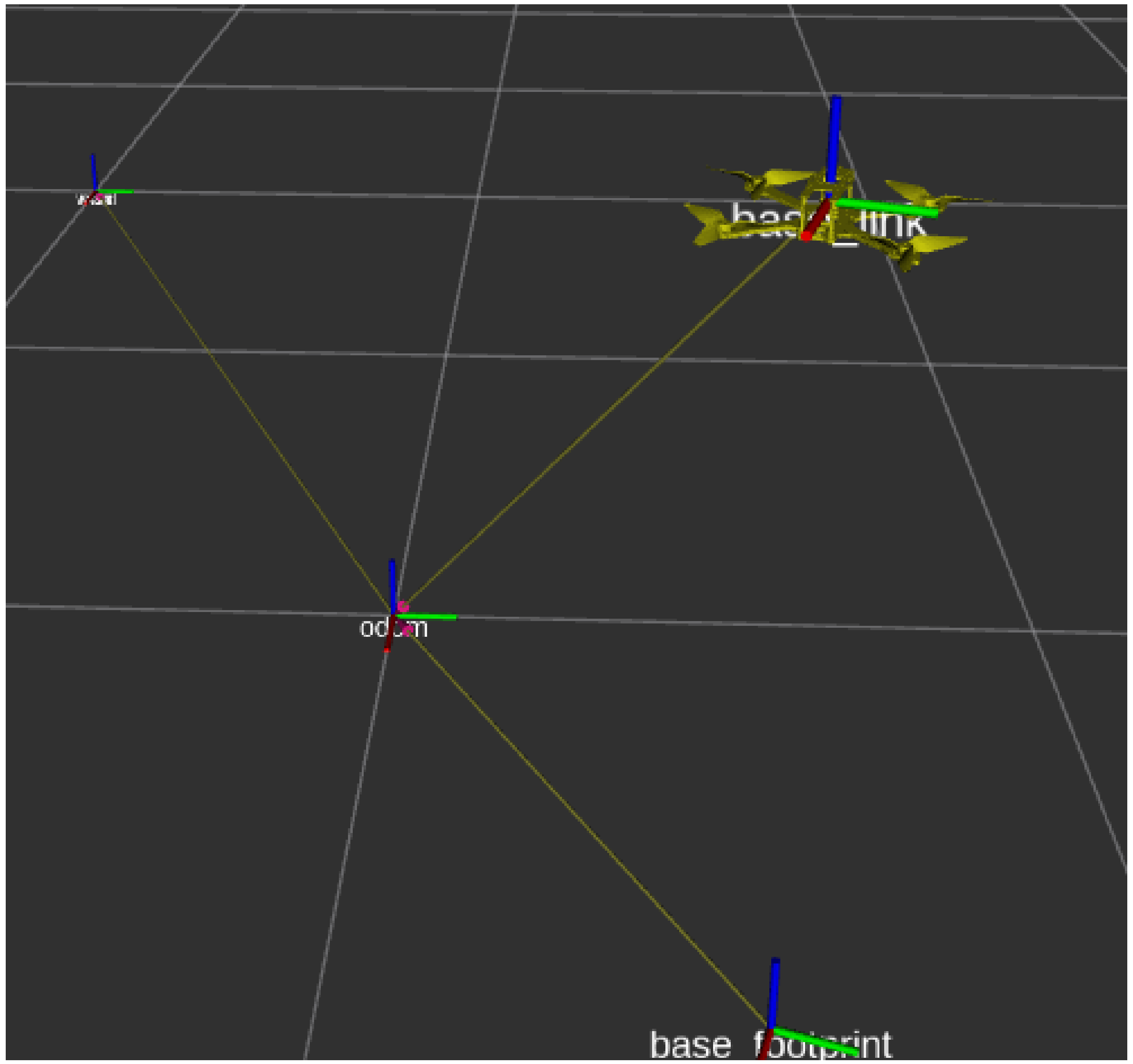
## Activity 5: Launch File

- Add the newly developed “puzzle_drone.py” node to the launch file.
- You can add RVIZ and TF_Tree to verify the transforms.
- The full Launch File can be found in GitHub.
- Build the package
- Launch the package
- Add the TF’s to RVIZ

- To visualise the model in RVIZ select “world” as Fixed Frame.
- In RVIZ press “Add››By display type››RobotModel”. In the RobotModel select s “Description Topic” “/robot_description”.

# Activity 5: Results





## Thank you

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