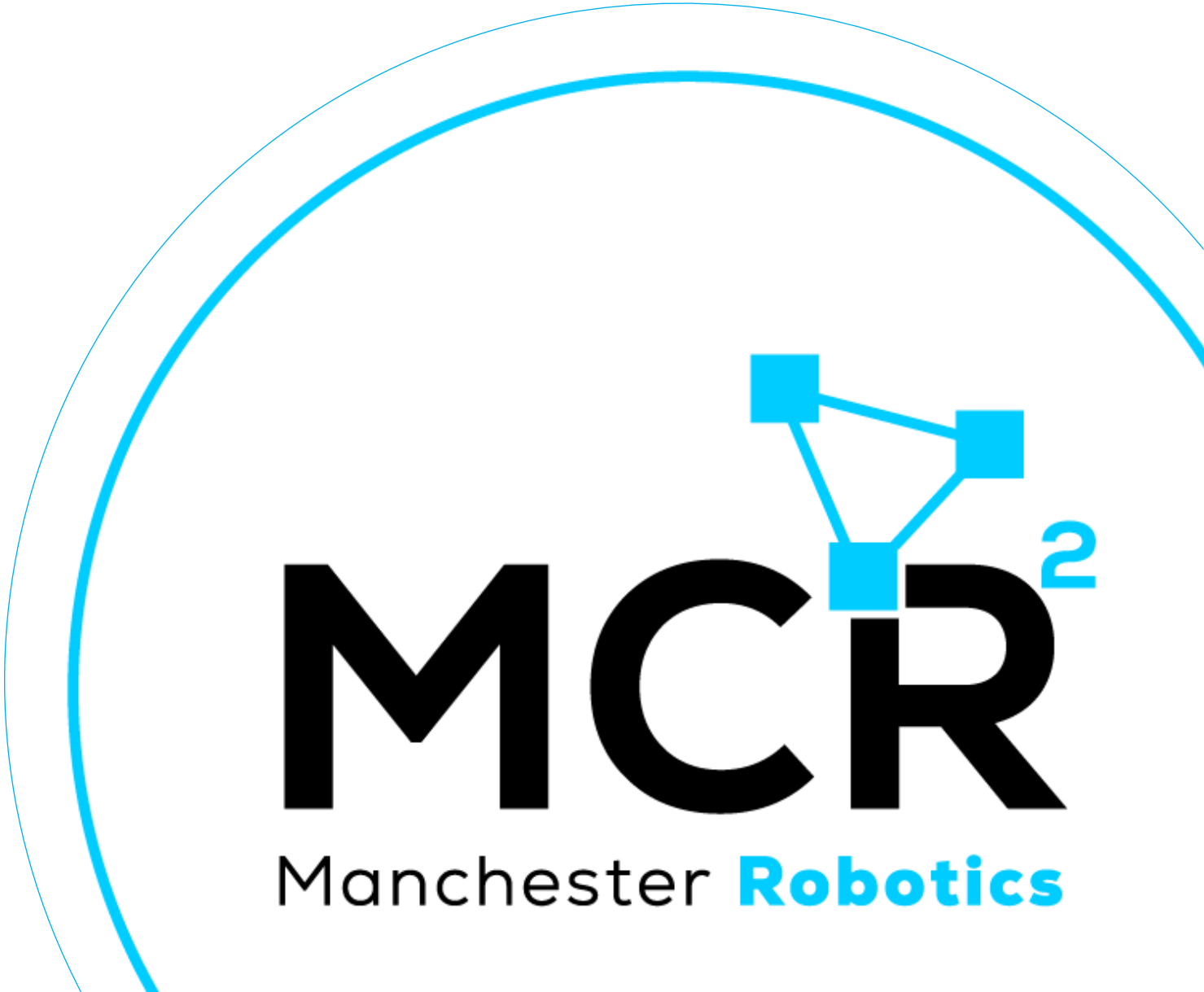
{Learn, Create, Innovate};

ROS

Visualisation Tools

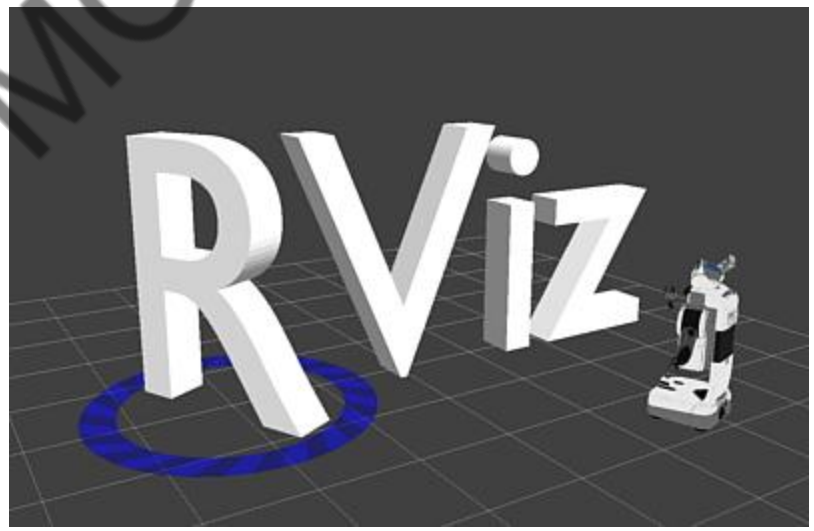


RVIZ

What is RVIZ?

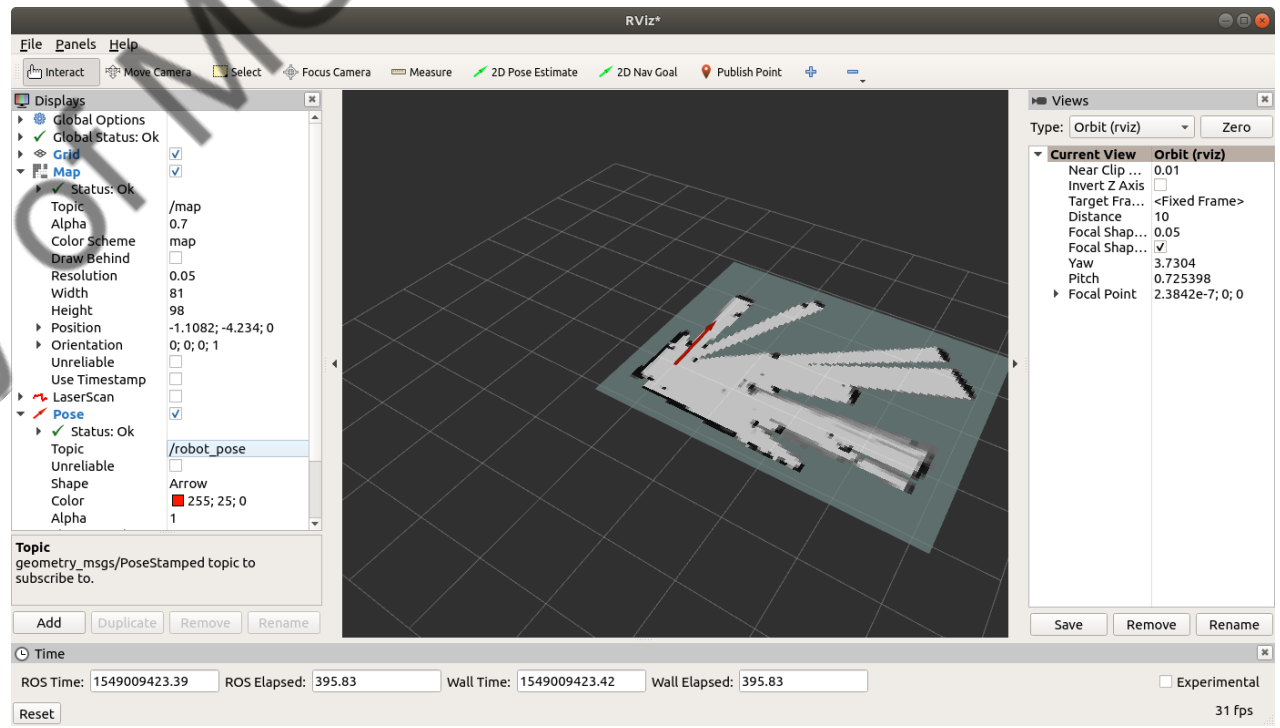
- RVIZ (ROS Visualization)
- Is a 3D visualisation environment
- Made to simplify debugging using visual tools.
- RVIZ allows the user to see what the robot is seeing, thinking and doing.

  "See the world through the robot's eyes."



RVIZ

- There are two main ways of putting data into RVIZ.
  - Via messages, where it understands sensors and state information, like laser scans, point clouds, cameras, and coordinate frames.
    - They have specialised displays to let the user configure how to view that information.
  - Information markers, letting the user send cubes, arrows and lines coloured however you want.
- The combination of sensor data and custom visualisation markers makes RVIZ a powerful tool for robotic development.



RVIZ

Quick Start (USB camera)

- Download the rospackage usb_cam

```
sudo apt install ros-<$DISTRO>-usb-cam
```

- Run the node

```
ros2 run usb_cam usb_cam_node_exe
```

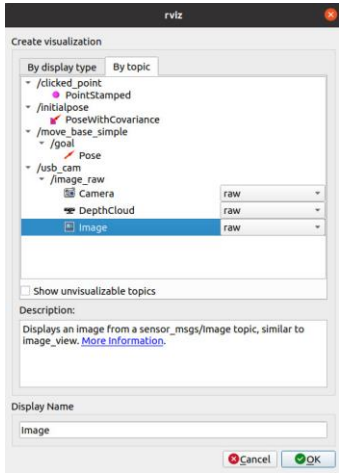
- Check that the topics are being published

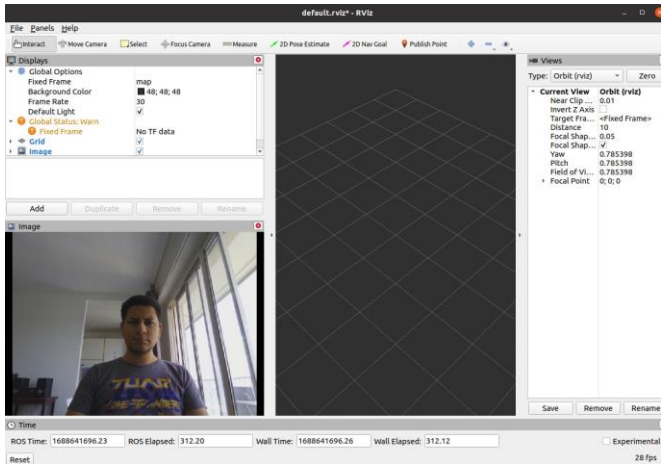
```
ros2 topic list
```

- Start RVIZ

```
ros2 run rviz2 rviz2
```

- Press the “add” button
- Go to the tab ”By topic”
- Add the topic Camera, located under the topics /usb_cam -> /image_raw





RVIZ

Markers

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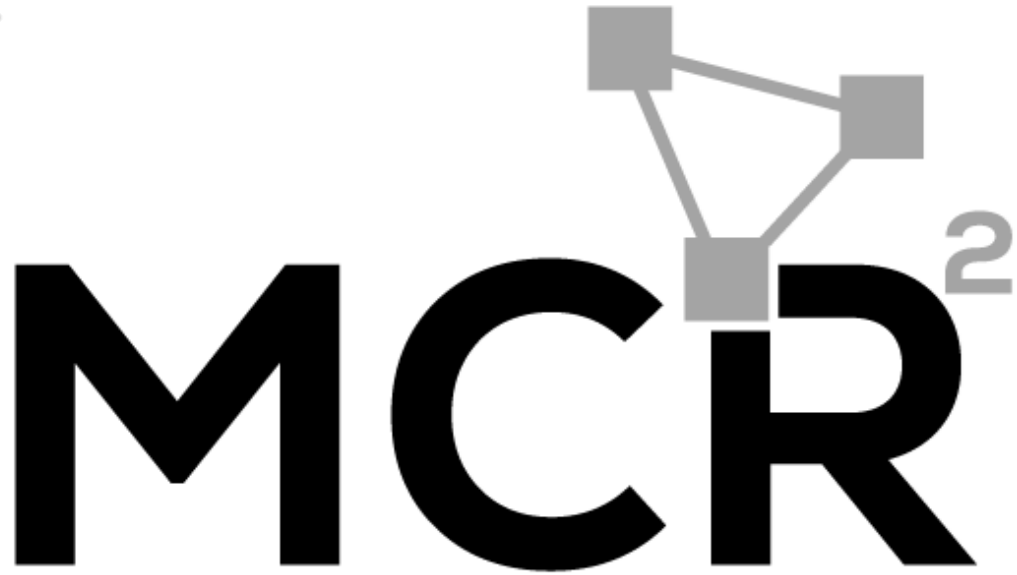
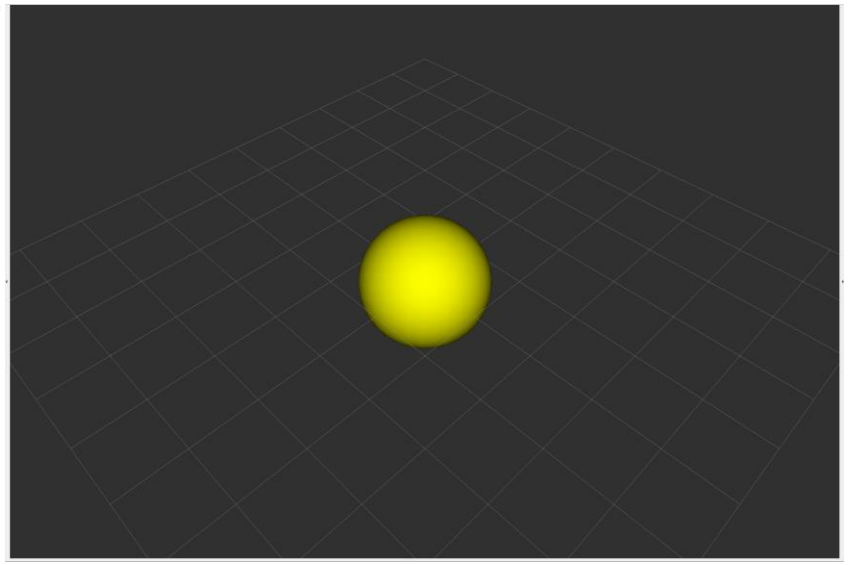


Markers

What are markers?

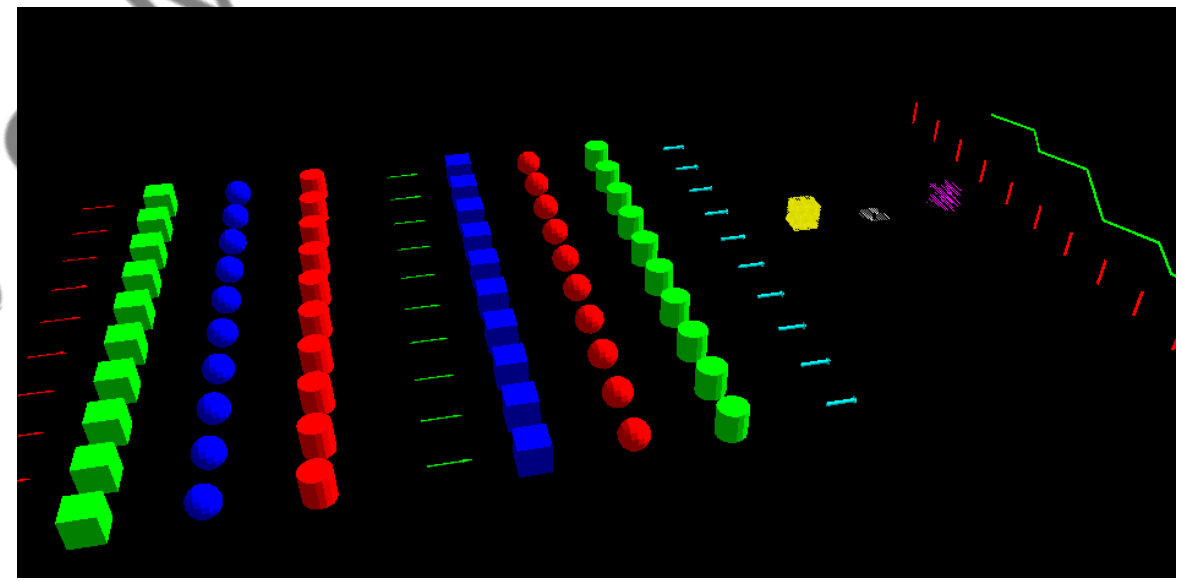
- One of the key features of RViz is the ability to visualize markers.
- Markers are graphical objects that represent different types of data in the 3D space.
- They can display points, lines, meshes, text, and more.
- Markers are typically published as ROS messages and can be subscribed to by RViz for visualisation.
- RViz provides a user-friendly interface for adding, configuring, and visualizing markers.



Markers

Type of markers?

- There are different types of markers that help us to visualise information in RViz.
- The basic markers are points, cubes, spheres, arrows, and lines.
- The user can set up and define its own markers and make them move.



Markers

- Markers are defined as ROS messages (composed of submessages) in which the user inputs the type of marker, configuration and characteristics. More information here and here

```
uint8 ARROW=0, uint8 CUBE=1, uint8 SPHERE=2, uint8 CYLINDER=3, uint8 LINE_STRIP=4
uint8 LINE_LIST=5, uint8 CUBE_LIST=6, uint8 SPHERE_LIST=7, uint8 POINTS=8, uint8 TEXT_VIEW_FACING=9, uint8 MESH_RESOURCE=10,
uint8 TRIANGLE_LIST=11

uint8 ADD=0, uint8 MODIFY=0, uint8 DELETE=2,
uint8 DELETEALL=3

Header header                       # header for time/frame information
string ns                           # Namespace to place this object in... used in conjunction with id to create a unique name for the object
int32 id                          # object ID useful in conjunction with the namespace for manipulating and deleting the object later
int32 type                        # Type of object
int32 action                        # 0 add/modify an object, 1 (deprecated), 2 deletes an object, 3 deletes all objects
geometry_msgs/Pose pose                 # Pose of the object
geometry_msgs/Vector3 scale             # Scale of the object 1,1,1 means default (usually 1 meter square)
std_msgs/ColorRGBA color            # Color [0.0-1.0]
duration lifetime                   # How long the object should last before being automatically deleted.  0 means forever
bool frame_locked                   # If this marker should be frame-locked, i.e. retransformed into its frame every timestep

#Only used if the type specified has some use for them (eg. POINTS, LINE_STRIP, ...)
geometry_msgs/Point[] points
#Only used if the type specified has some use for them (eg. POINTS, LINE_STRIP, ...)
#number of colors must either be 0 or equal to the number of points
#NOTE: alpha is not yet used
std_msgs/ColorRGBA[] colors

# NOTE: only used for text markers
string text

# NOTE: only used for MESH_RESOURCE markers
string mesh_resource
bool mesh_use_embedded_materials
```

Markers

Key Aspects

- When using Markers three key aspects must be taken into consideration.

Header

- Header Message: in this section the user define the marker frame and the time stamp.
- Markers must be attached to a frame of reference!

```
Header header # header for time/frame information
```

```
chassis = Marker()

chassis.header.frame_id = "base_link"
chassis.header.stamp = self.get_clock().now().to_msg()
```

Pose

- Pose Message, in this section the user define the pose (position and orientation) of the marker with respect to the frame of reference stated on the Header ("base_link"). The position is given by a point and the orientation by a quaternion.

```
geometry_msgs/Pose pose  # Pose of the object
```

```
chassis.pose.position.x = 0.205/2
chassis.pose.position.y = 0.0
chassis.pose.position.z = 0.0
chassis.pose.orientation.x = 0.0
chassis.pose.orientation.y = 0.0
chassis.pose.orientation.z = 0.0
chassis.pose.orientation.w = 1.0
```

Markers

Key Aspects

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Header

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- Markers must be attached to a frame of reference!

```
Header header # header for time/frame information
```

```
chassis = Marker()

chassis.header.frame_id = "base_link"
chassis.header.stamp = self.get_clock().now().to_msg()
```

Pose

- Pose Message, in this section the user define the pose (position and orientation) of the marker with respect to the frame of reference stated on the Header ("base_link"). The position is given by a point and the orientation by a quaternion.
- If the pose varies through time, it will be done w.r.t the header's frame of reference.

```
geometry_msgs/Pose pose  # Pose of the object
```

```
chassis.pose.position.x = 0.205/2
chassis.pose.position.y = 0.0
chassis.pose.position.z = 0.0
chassis.pose.orientation.x = 0.0
chassis.pose.orientation.y = 0.0
chassis.pose.orientation.z = 0.0
chassis.pose.orientation.w = 1.0
```

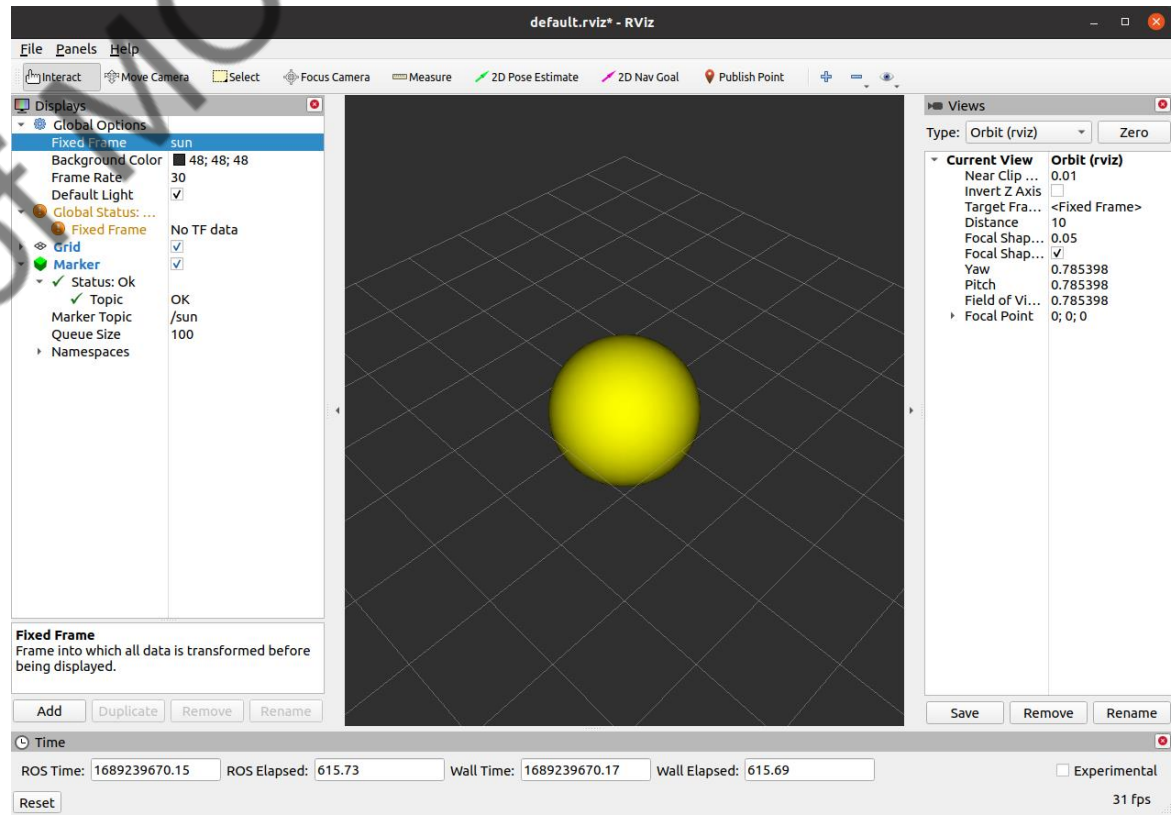
Markers

Scale

- Vector3 message in this section the user defines the Scale/Size of the object in each of its dimension's x,y,z.

```
geometry_msgs/Vector3 scale # Scale of the object
 1,1,1 means default (usually 1 meter square)
```

```
chassis.scale.x = 0.205
chassis.scale.y = 0.41
chassis.scale.z = 0.2
```



Activity 1

Markers

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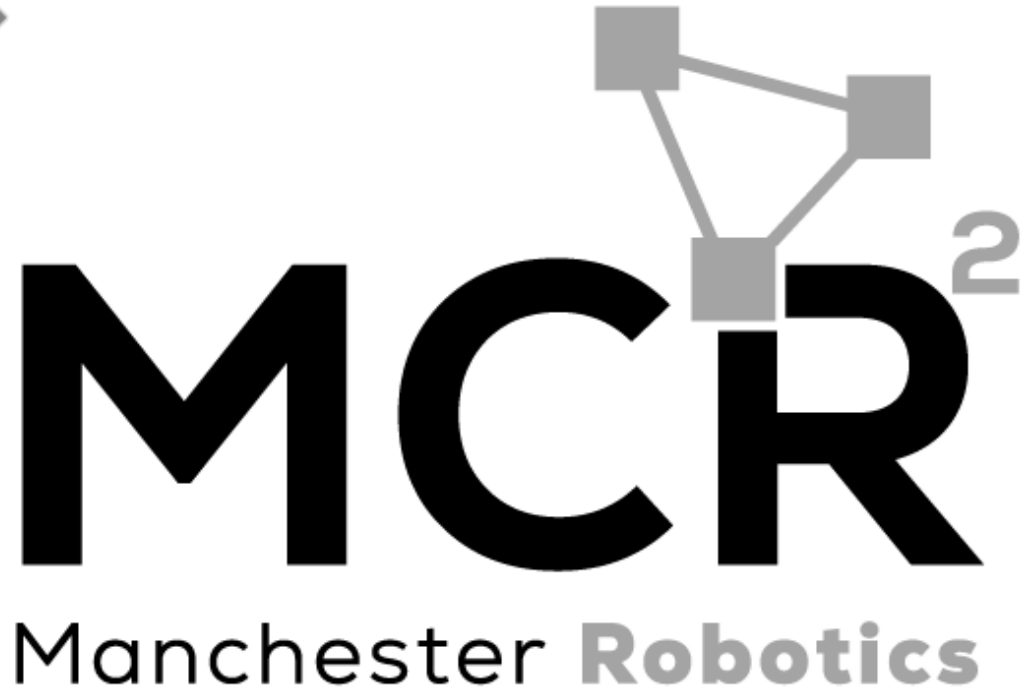


Marker Generator

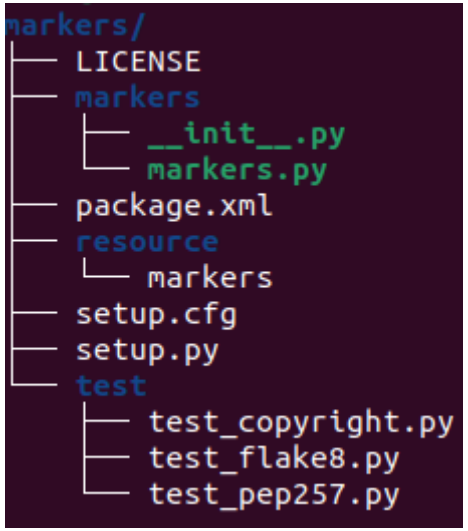
Declaring a Static Transform from Launch File

- Make a package called “markers” and a node called “markers.py” with the following dependencies:
  - geometry_msgs, python3-numpy, rclpy, tf2_ros_py, ros2launch, std_msgs python3-transforms3d visualization_msgs

```
$ ros2 pkg create --build-type ament_python markers --license
Apache-2.0 --node-name markers --dependencies geometry_msgs
python3-numpy rclpy tf2_ros_py ros2launch std_msgs python3-
transforms3d visualization_msgs --description TF2_Examples --
maintainer-name "Mario Martinez" --maintainer-email
mario.mtz@manchester-robotics.com
```

- Do not forget to give executable permissions to the newly created files

```
$ chmod +x markers/markers/*
```



Marker Generator

- Make a launch folder and a launch file called "simple_marker_launch.py"

```
#replace "YOUR_WS" with the name of tour workspace

$ cd ~/<YOUR_WS>/src/markers
$ mkdir launch
$ touch simple_marker_launch.py
$ chmod +x markers/launch/*
```

- Change the "setup.py" to find the launch files

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

package_name = 'tf_examples'

setup(
    name=package_name,
    version='0.0.0',
    packages=find_packages(exclude=['test']),
    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]*'))),
    ],
    install_requires=['setuptools'],
    zip_safe=True,
    maintainer='Mario Martinez',
    maintainer_email='mario.mtz@manchester-robotics.com',
    description='TF2_Examples',
    license='Apache-2.0',
    tests_require=['pytest'],
    entry_points={
        'console_scripts': [
            'static_tf = tf_examples.static_tf:main'
        ],
    },
)
```


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

 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]*'))),
    ],
```

Marker Generator

- Open the file *markers.py*
- Define a new marker called marker in the constructor.

```
# Message Declaration
self.marker = Marker()
```

- Define its publisher

```
self.publisher = self.create_publisher(Marker, '/marker', 10)
```

- Initialise the marker (if needed) on the constructor
  - For this exercise the marker is defined w.r.t "map" frame.
- Define a timer to update the marker pose (next slide)
- Publish the marker

```
        #Variables to be used
        self.omega = 0.5
        self.intial_pos_x = 0.0
        self.intial_pos_y = 0.0
        self.intial_pos_z = 1.0

        #initialise the marker(the pose and orientation will be
changed on the callback function)
        self.marker = Marker()
        self.marker.header.frame_id = "map"
        self.marker.header.stamp = self.get_clock().now().to_msg()
        self.marker.id = 0
        self.marker.type = Marker.CUBE
        self.marker.action = Marker.ADD
        self.marker.pose.position.x = self.intial_pos_x
        self.marker.pose.position.y = self.intial_pos_y
        self.marker.pose.position.z = self.intial_pos_z
        self.marker.pose.orientation.x = 0.0
        self.marker.pose.orientation.y = 0.0
        self.marker.pose.orientation.z = 0.0
        self.marker.pose.orientation.w = 1.0
        self.marker.scale.x = 0.2
        self.marker.scale.y = 0.5
        self.marker.scale.z = 0.2
        self.marker.color.r = 1.0
        self.marker.color.g = 1.0
        self.marker.color.b = 0.0
        self.marker.color.a = 1.0
```

```python
import rclpy
from rclpy.node import Node
from visualization_msgs.msg import Marker
import transforms3d
import numpy as np
from rclpy.duration import Duration

class MarkersPublisher(Node):
    def __init__(self):
        super().__init__('marker_publisher')
        self.publisher = self.create_publisher(Marker, '/marker', 10)

        #Variables to be used
        self.omega = 0.5
        self.intial_pos_x = 0.0
        self.intial_pos_y = 0.0
        self.intial_pos_z = 1.0

       #initialise the marker
        self.marker = Marker()
        self.marker.header.frame_id = "map"
        self.marker.header.stamp = self.get_clock().now().to_msg()
        self.marker.id = 0
        self.marker.type = Marker.CUBE
        self.marker.action = Marker.ADD
        self.marker.pose.position.x = self.intial_pos_x
        self.marker.pose.position.y = self.intial_pos_y
        self.marker.pose.position.z = self.intial_pos_z
        self.marker.pose.orientation.x = 0.0
        self.marker.pose.orientation.y = 0.0
        self.marker.pose.orientation.z = 0.0
        self.marker.pose.orientation.w = 1.0
        self.marker.scale.x = 0.2
        self.marker.scale.y = 0.5
        self.marker.scale.z = 0.2
        self.marker.color.r = 1.0
        self.marker.color.g = 1.0
        self.marker.color.b = 0.0
        self.marker.color.a = 1.0
        timer_period = 0.1 #seconds
        self.timer = self.create_timer(timer_period, self.timer_cb)
        self.i = 0

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

        q = transforms3d.euler.euler2quat(0, 1.57, self.omega*time)
        self.marker.header.stamp = self.get_clock().now().to_msg()
        self.marker.pose.position.x = self.intial_pos_x + 0.5*np.sin(self.omega*time)
        self.marker.pose.position.y = self.intial_pos_y + 0.5*np.cos(self.omega*time)
        self.marker.pose.position.z = self.intial_pos_z
        self.marker.pose.orientation.x = q[1]
        self.marker.pose.orientation.y = q[2]
        self.marker.pose.orientation.z = q[3]
        self.marker.pose.orientation.w = q[0]

        self.publisher.publish(self.marker)

def main(args=None):
    rclpy.init(args=args)
    node = MarkersPublisher()
    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()
```

Marker Generator

- Compile the program

```
cd ~/<YOUR_WS>

colcon build

source install/setup.bash
```

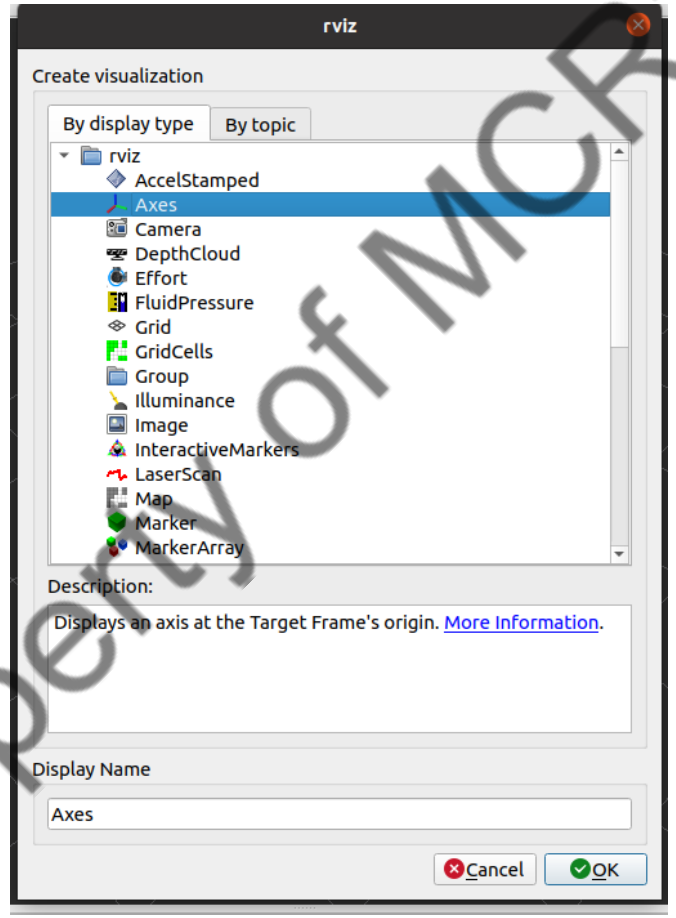
- Run the node

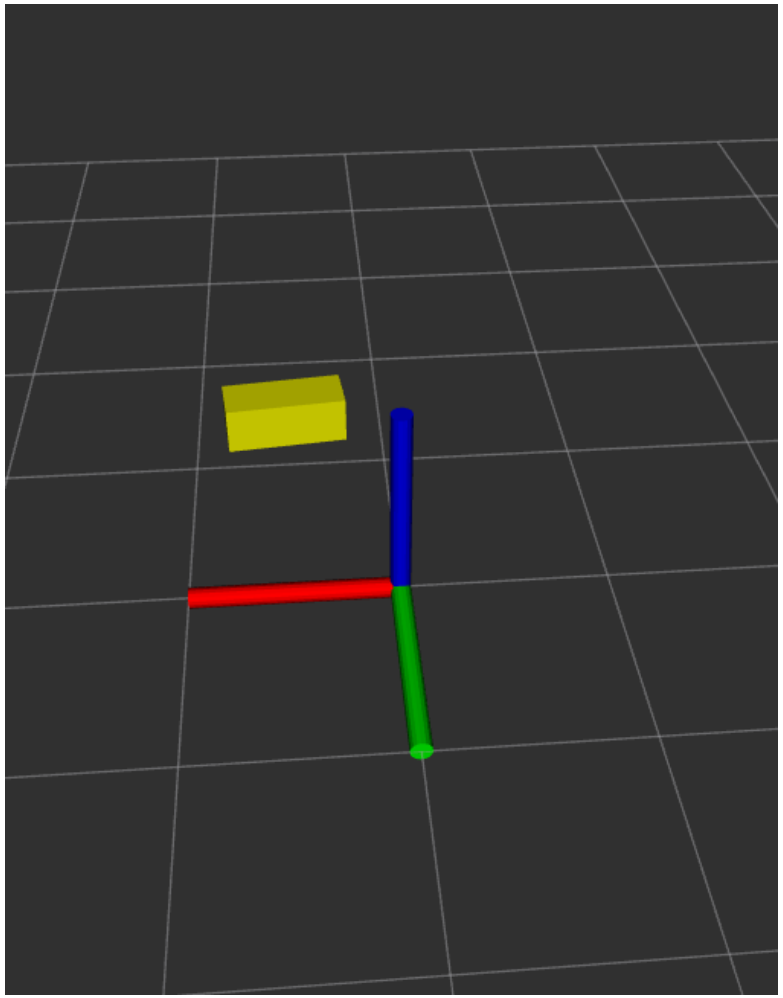
```
ros2 run markers markers
```

- Start RViz

```
ros2 run rviz2 rviz2
```

- Add the marker
  - Press Add
  - ››By topic››/marker›› marker
- Change the fixed frame on top of RViz to “map”
- Visualise the Fixed Frame by adding “Axes” from the “Add” Menu

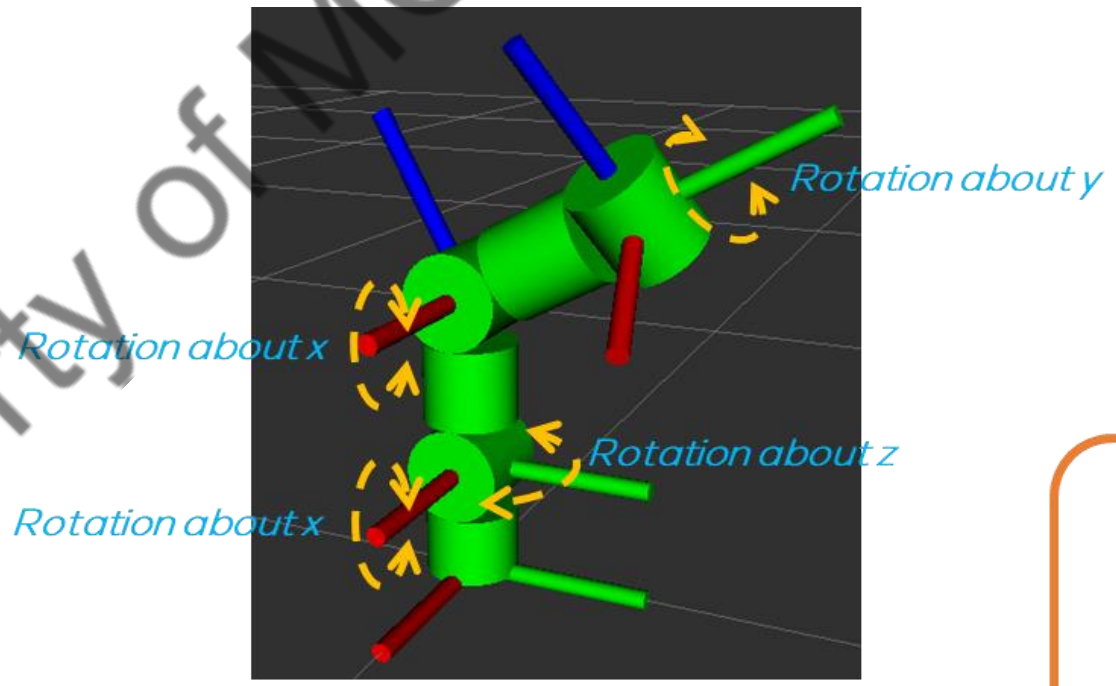


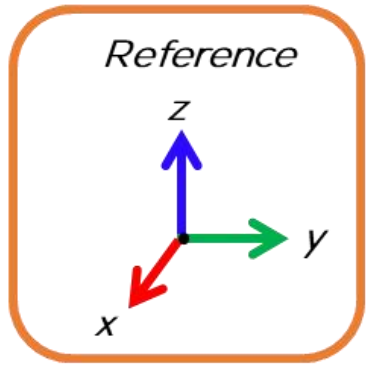


Markers and Transforms

Scale

- One of the best practices in ROS is to attach markers to frames of reference at their origin.
- The movement of the markers should be performed by the frames of reference rather than by the marker itself.
- In other words, the frame must move while the marker is attached to its centre.
- In the previous example the marker was moving around a frame of reference (not recoomended), better to declare a frame, move the frame and keep the marker attached to its origin.





Activity 2

Multiple Markers

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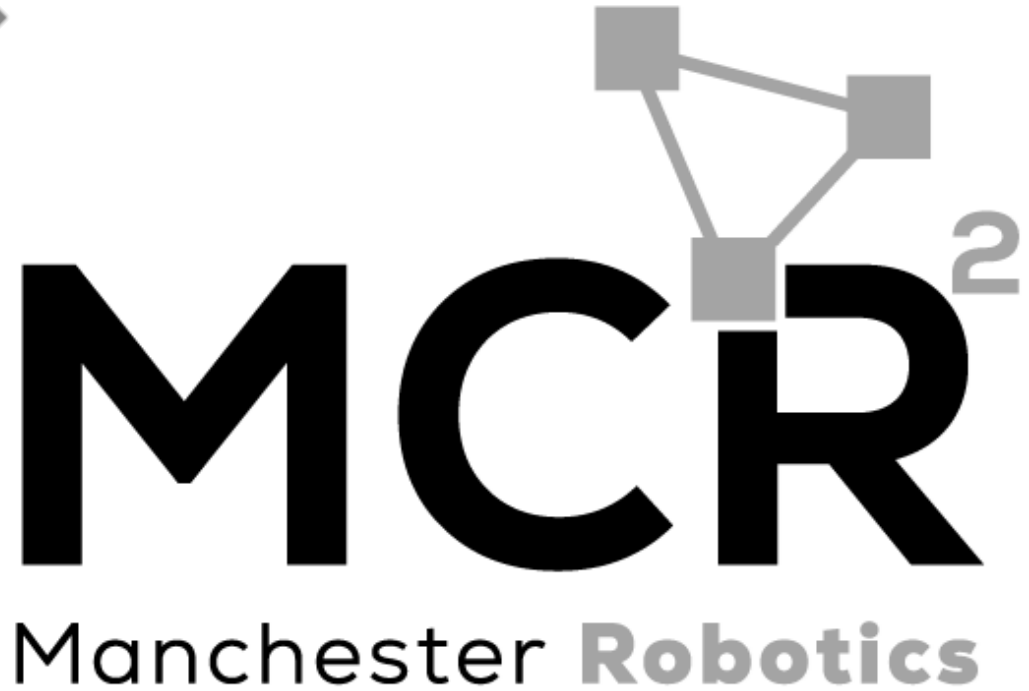
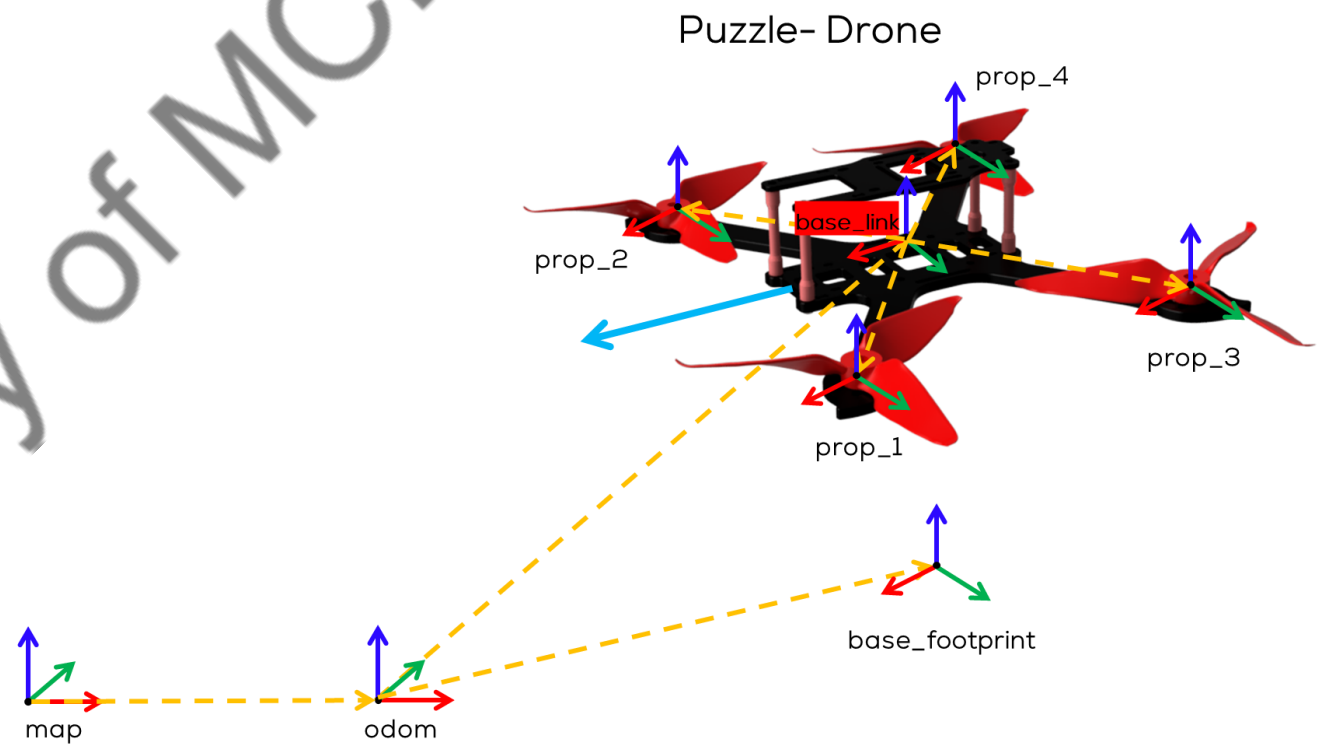


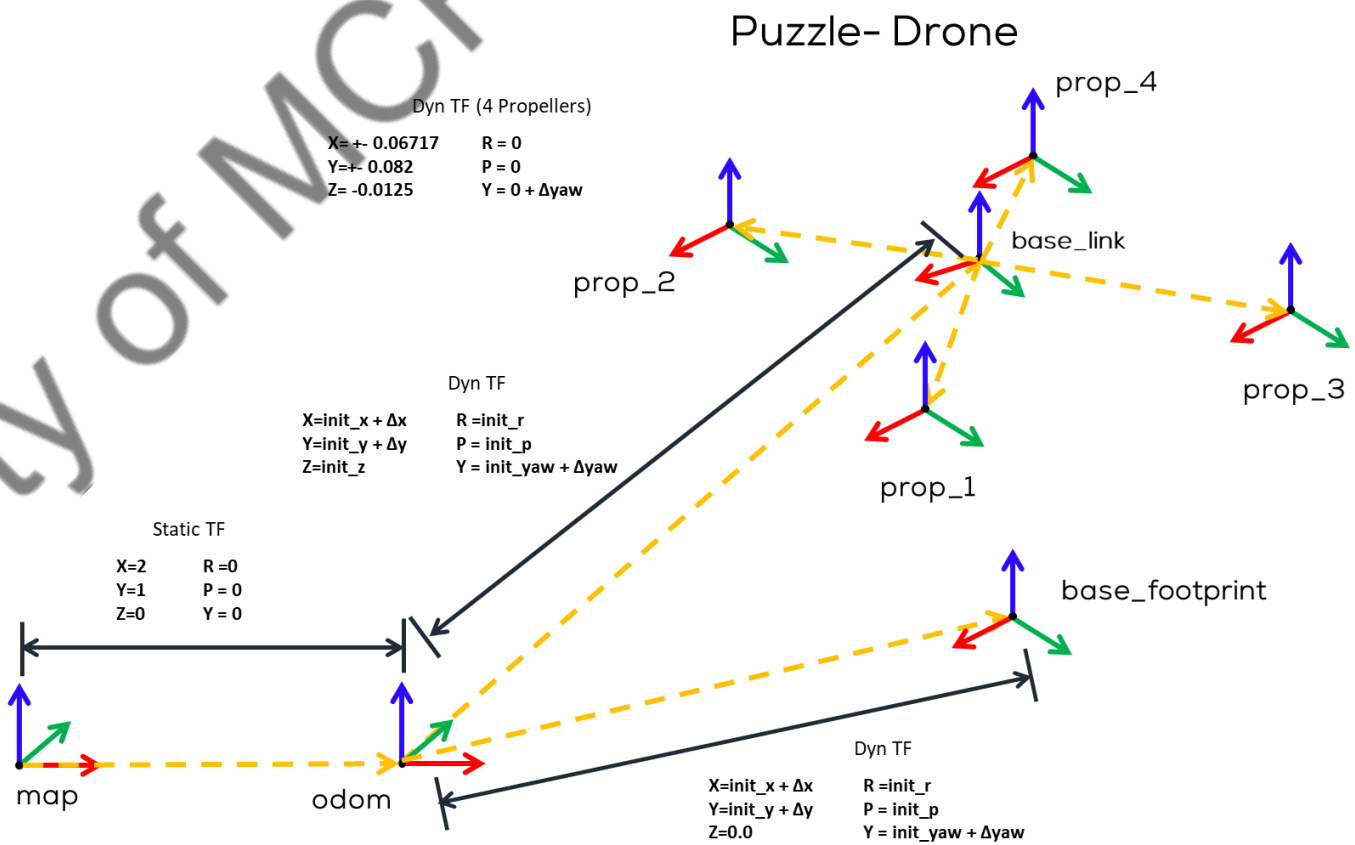
Multiple Markers

- In this activity a simple Puzzle Drone will be modelled.
- 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 transforms will be set up as follows.
- The markers will be attached to each one of the transforms.
- For this case, a “mesh” type marker will be used.



Multiple Markers

- The following coordinates will be used to define the Drone as Transforms.
- Once the transforms are defined, the markers will be set up to lay on top of the transforms.
- The user should manipulate/control the transforms only, not the Markers.
- For this exercise, the basic on how to define transforms and markers will be shown.
- For this activity, the full code is on GitHub (too long to be on a ppt.)



Multiple Markers

- Make a new node called “PuzzleDrone.py” inside the “markers” package developed previously.

```
$ touch ~/<YOUR_WS>/src/markers/markers/PuzzleDrone.py
```

- Make a launch file called “puzzledrone_launch.py”

```
$ mkdir ~/<YOUR_WS>/src/markers/launch
$ touch ~/<YOUR_WS>/src/markers/launch/puzzledrone_launch.py
```

- Give execution permission to both files
- Modify the previously created “setup.py” 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'))),
    ],
```

Multiple Markers

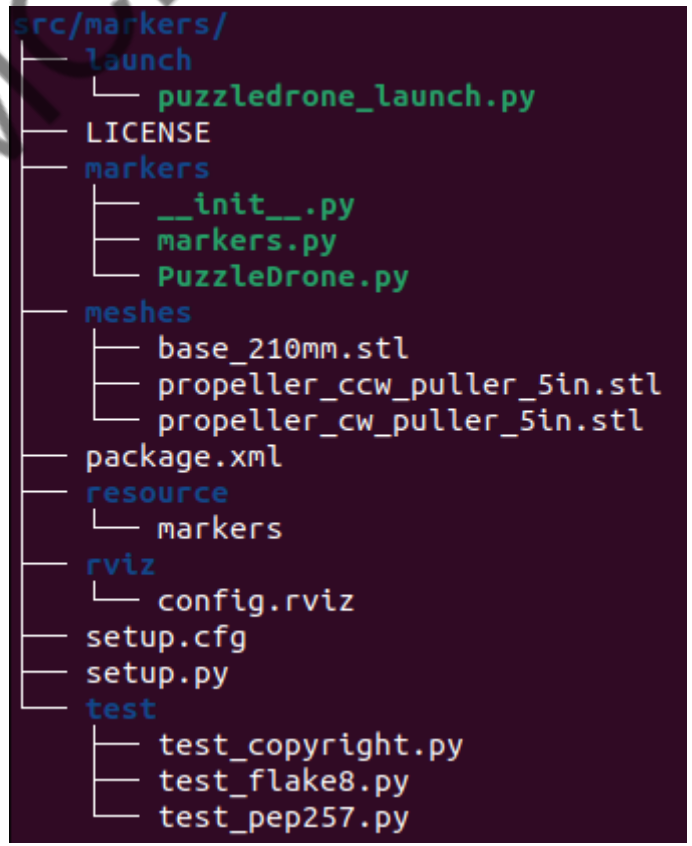
- Make a “meshes” directory in the package “markers”

```
$ mkdir ~/<YOUR_WS>/src/markers/meshes
```

- Download inside the folder ”meshes” the three “.stl” files in GitHub.

```
base_210mm.stl
propeller_ccw_puller_5in.stl
propeller_cw_puller_5in.stl
```

- The folder tree should look as in the image
- Open the “PuzzleDrone.py”
- Type the following code (node initialisation)



Multiple Markers

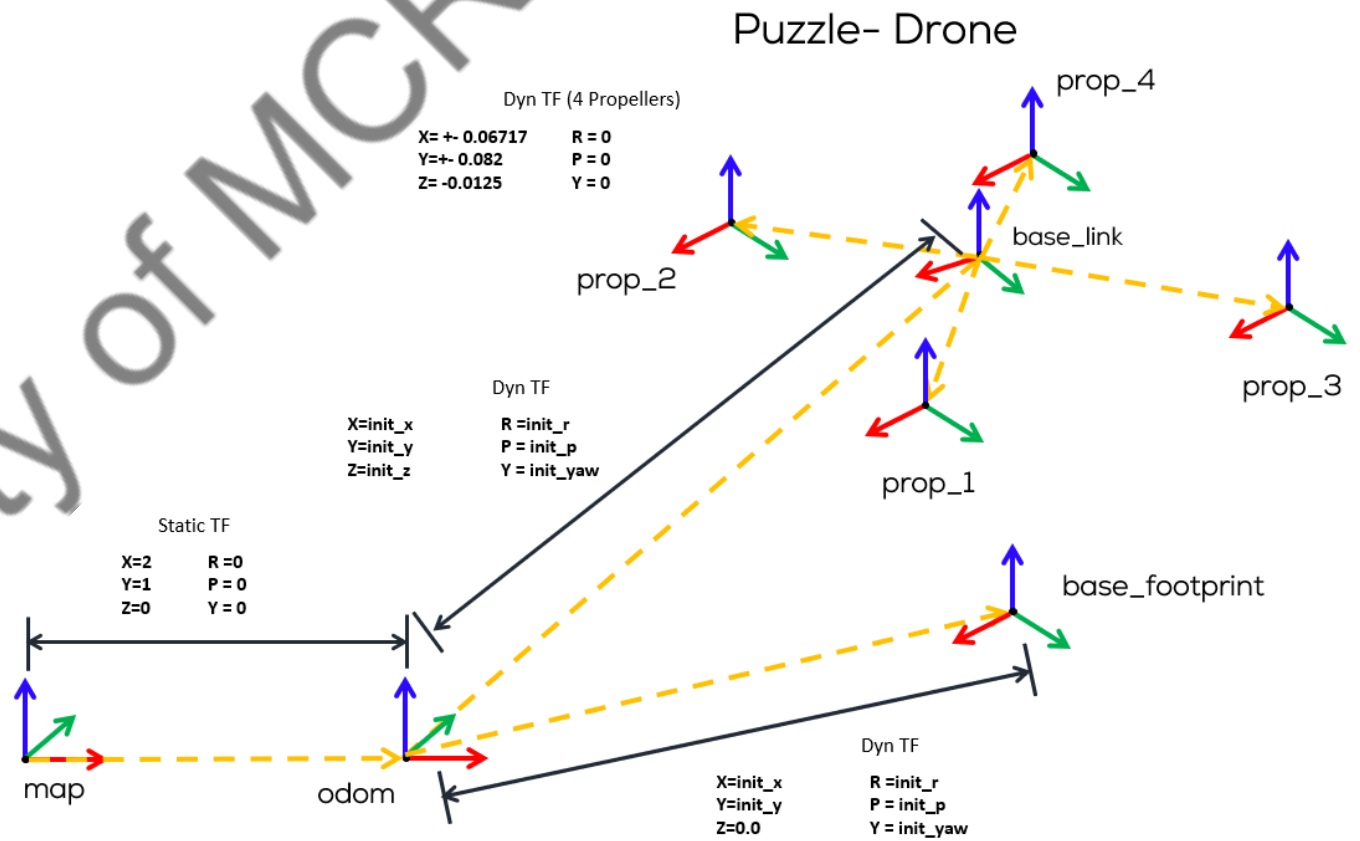
```python
import rclpy
from rclpy.node import Node
from tf2_ros import TransformBroadcaster
from geometry_msgs.msg import TransformStamped
from visualization_msgs.msg import Marker
import transforms3d
import numpy as np

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()
        #Define Markers
        self.define_markers()
```

```python
        #Create Transform Boradcasters

        #Create Markers Publishers

        #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_markers(self):
        #Initialise the markers here

    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()
```

Transforms

- Each transform will be declared as follows
- All transforms will be defined inside the function “define_TF”

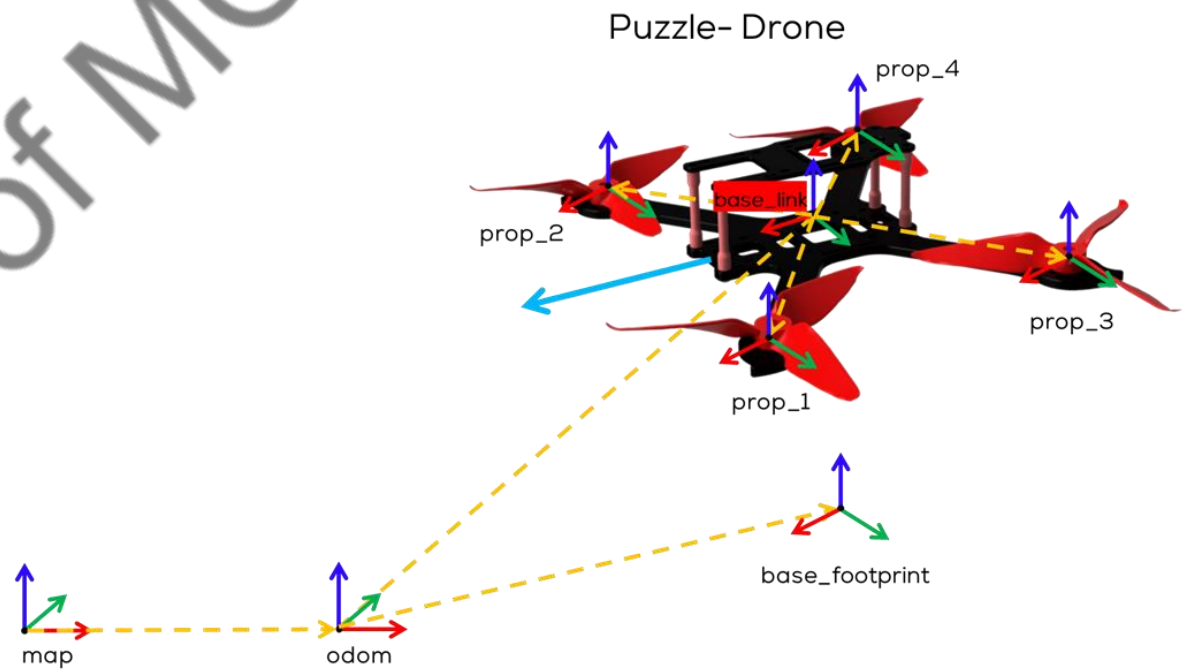
```
def define_TF(self):
    #Create Trasnform Messages
    self.base_footprint_tf = TransformStamped()
    self.base_footprint_tf.header.stamp = self.get_clock().now().to_msg()
    self.base_footprint_tf.header.frame_id = 'odom'
    self.base_footprint_tf.child_frame_id = 'base_footprint'
    self.base_footprint_tf.transform.translation.x = self.intial_pos_x
    self.base_footprint_tf.transform.translation.y = self.intial_pos_y
    self.base_footprint_tf.transform.translation.z = 0.0
    q_foot = transforms3d.euler.euler2quat(self.intial_pos_roll,
self.intial_pos_pitch, self.intial_pos_yaw)
    self.base_footprint_tf.transform.rotation.x = q_foot[1]
    self.base_footprint_tf.transform.rotation.y = q_foot[2]
    self.base_footprint_tf.transform.rotation.z = q_foot[3]
    self.base_footprint_tf.transform.rotation.w = q_foot[0]


... #Define the rest of the transforms
```



Multiple Markers

- The same as with Transforms, the markers must be defined.
- Each marker will be related to a frame and to a mesh (in this case simple marker will not be used)

Marker	Frame/link to attach	Mesh to attach
base	base_link	base_210mm.stl
prop1	prop_1	propeller_ccw_puller_5in.stl
prop2	prop_2	propeller_cw_puller_5in.stl
prop3	prop_3	propeller_ccw_puller_5in.stl
prop4	prop_4	propeller_cw_puller_5in.stl



Multiple Markers

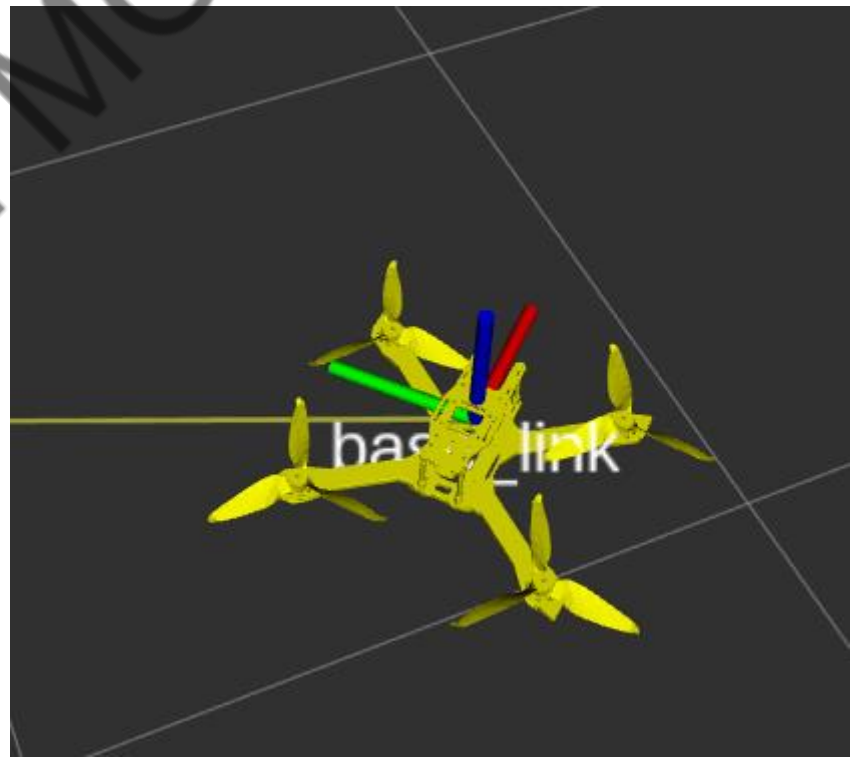
```python
def define_markers(self):

    #initialise the marker
    self.base = Marker()
    self.base.header.frame_id = "base_link"
    self.base.header.stamp = self.get_clock().now().to_msg()
    self.base.id = 0
    self.base.type = Marker.MESH_RESOURCE
    self.base.mesh_resource = "package://markers/meshes/base_210mm.stl"
    self.base.action = Marker.ADD
    self.base.pose.position.x = 0.0
    self.base.pose.position.y = 0.0
    self.base.pose.position.z = -0.0205
    q_base_marker = transforms3d.euler.euler2quat(1.57, 0.0, 1.57)
    self.base.pose.orientation.x = q_base_marker[1]
    self.base.pose.orientation.y = q_base_marker[2]
    self.base.pose.orientation.z = q_base_marker[3]
    self.base.pose.orientation.w = q_base_marker[0]
    self.base.scale.x = 1.0
    self.base.scale.y = 1.0
    self.base.scale.z = 1.0
    self.base.color.r = 1.0
    self.base.color.g = 1.0
    self.base.color.b = 0.0
    self.base.color.a = 1.0
... #Define the rest of the Markers
```

- Some markers requires a small adjustment, because the coordinate frame of the .stl file is not the same as the coordinate frame in ROS.
- In the example the position and orientations of the markers changed to make the coordinate of the .stl to match with the one defined by ROS standards.

Marker	Adjusted Pose
base	x= 0, y=0, z=-0.0205, r=1.57, p= 0.0, yaw=1.57
prop1	x= 0, y=0, z=-0.004, r=0.0, p= 0.0, yaw=0.0
prop2	x= 0, y=0, z=-0.004, r=0.0, p= 0.0, yaw=0.0
prop3	x= 0, y=0, z=-0.004, r=0.0, p= 0.0, yaw=0.0
prop4	x= 0, y=0, z=-0.004, r=0.0, p= 0.0, yaw=0.0

Multiple Markers

- Update the dynamic transforms and the time stamp of the markers.
- The “TF’s” must be updated inside the timer callback.
- For the “markers” only the timestamp must be updated, since they are fixed to a Frame.
- The user must always control the Frames, not the markers.
- If using meshes, the tessellation in the stl files must be as low quality as possible to save computing power for other ROS Tasks (This is just to visualise!)



Multiple Markers

```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()
        #Define Markers
        self.define_markers()

        #Create Transform Boradcasters
        self.tf_br_base = TransformBroadcaster(self)
        ... #Define the other broadcasters for each transform

        #Create Markers Publishers
        self.base_marker_pub = self.create_publisher(Marker, '/base_marker', 10)
        ... #Define the other publishers for each marker

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

    #Timer Callback
    def timer_cb(self):

        time = self.get_clock().now().nanoseconds/1e9

        #Update the time stamp of each marker
        self.base.header.stamp = self.get_clock().now().to_msg()
        ... #Update the time stamp of th other markers

        #Update the Transforms
        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]
        ... #Update the other TF's

        self.tf_br_base.sendTransform(self.base_link_tf)
        ... #Broadcast the other TF's

        self.base_marker_pub.publish(self.base)
        ... #Publish the Other Markers
```

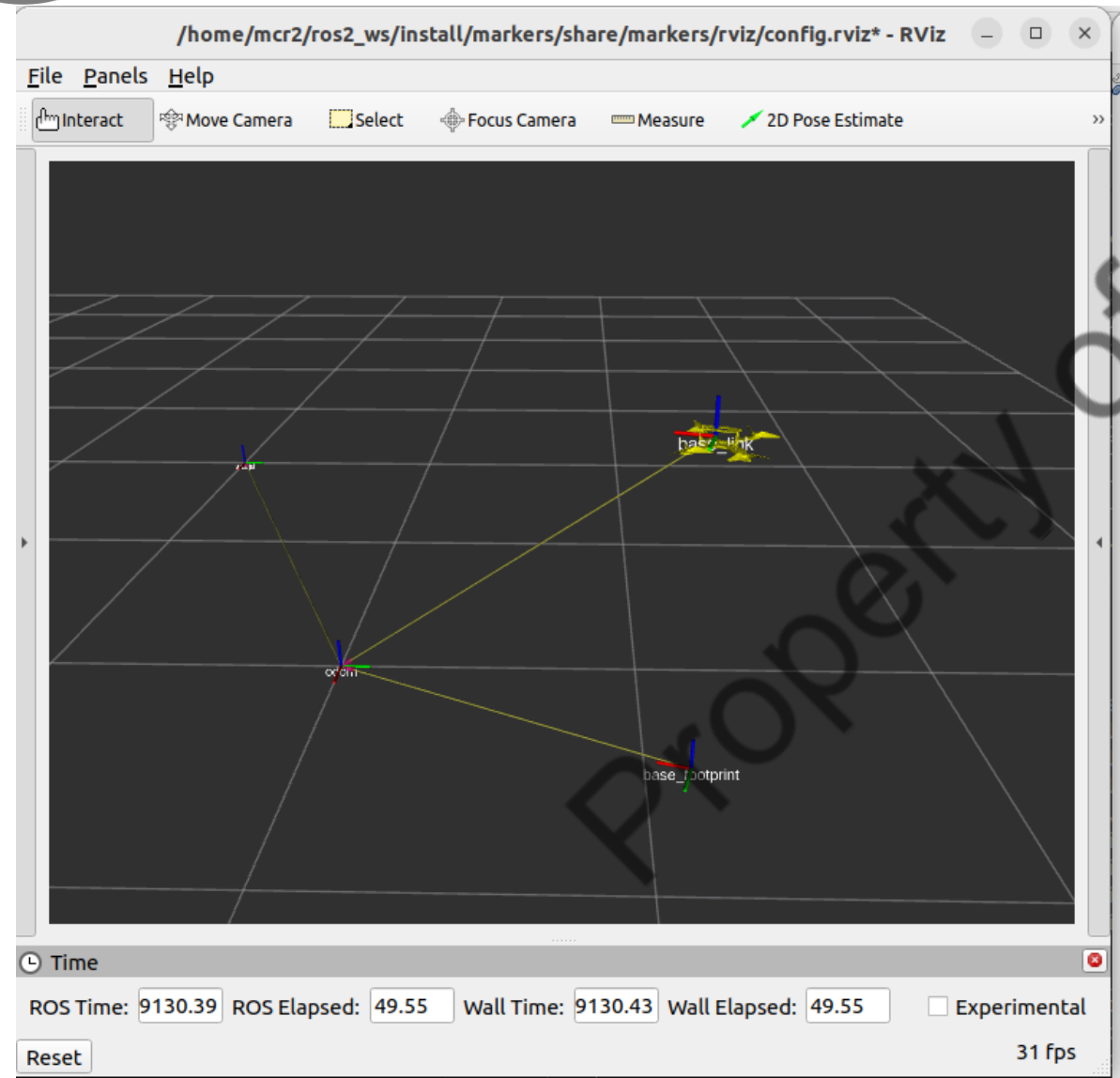
Multiple Markers

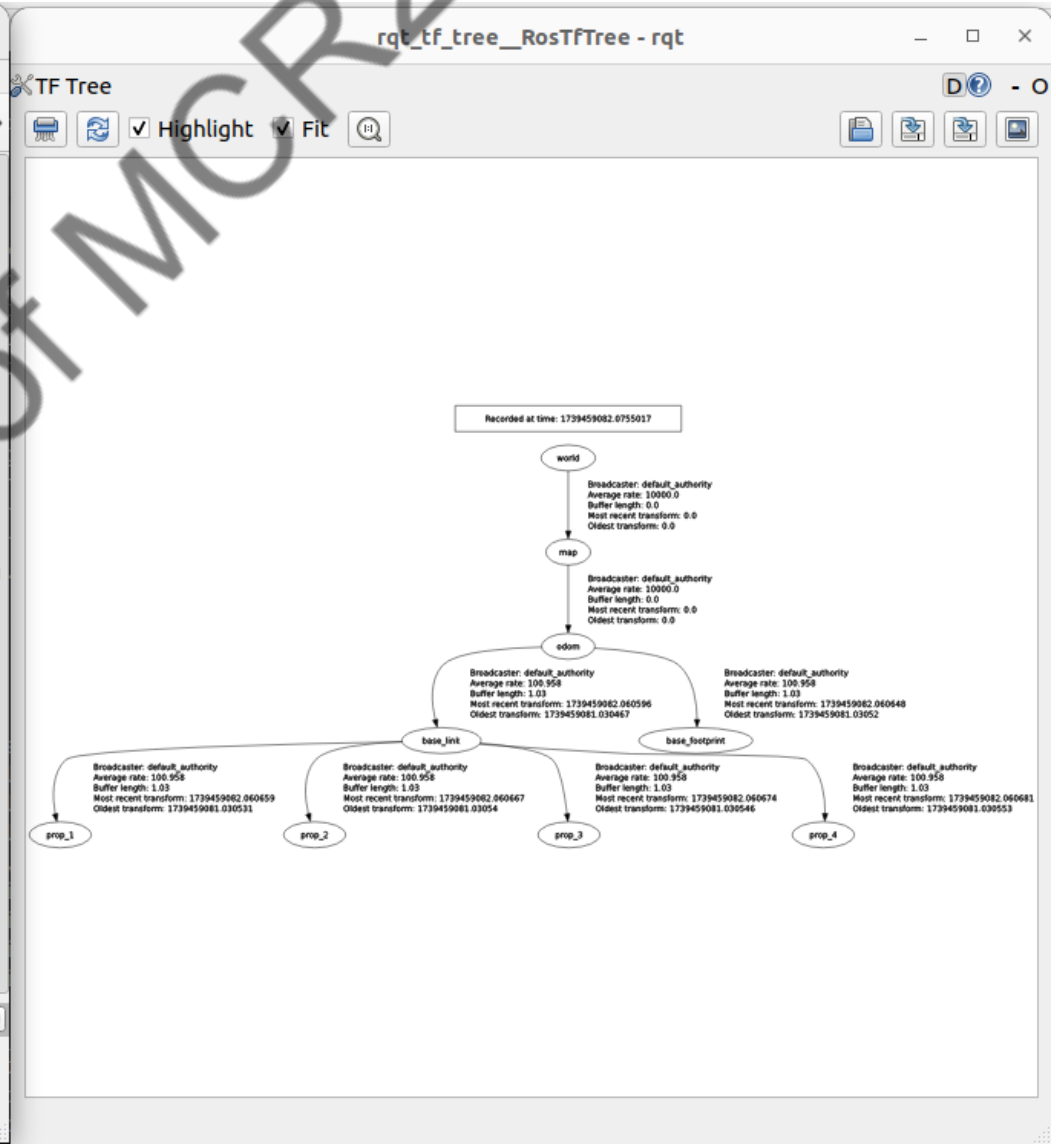
- Open the launch file previously done.
- Define two static transforms
  - world -> map (same pose)
  - map -> odom `[x= 2, y=1, z=-0.0, r=0, p=0.0, yaw=0]`

```
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 "PuzzleDrone" node to the launch file.
- You can add RVIZ and TF_Tree to verify the transforms.
- Build the package
- Launch the package
- Add the TF's to RVIZ and the Markers

Results





Thank you

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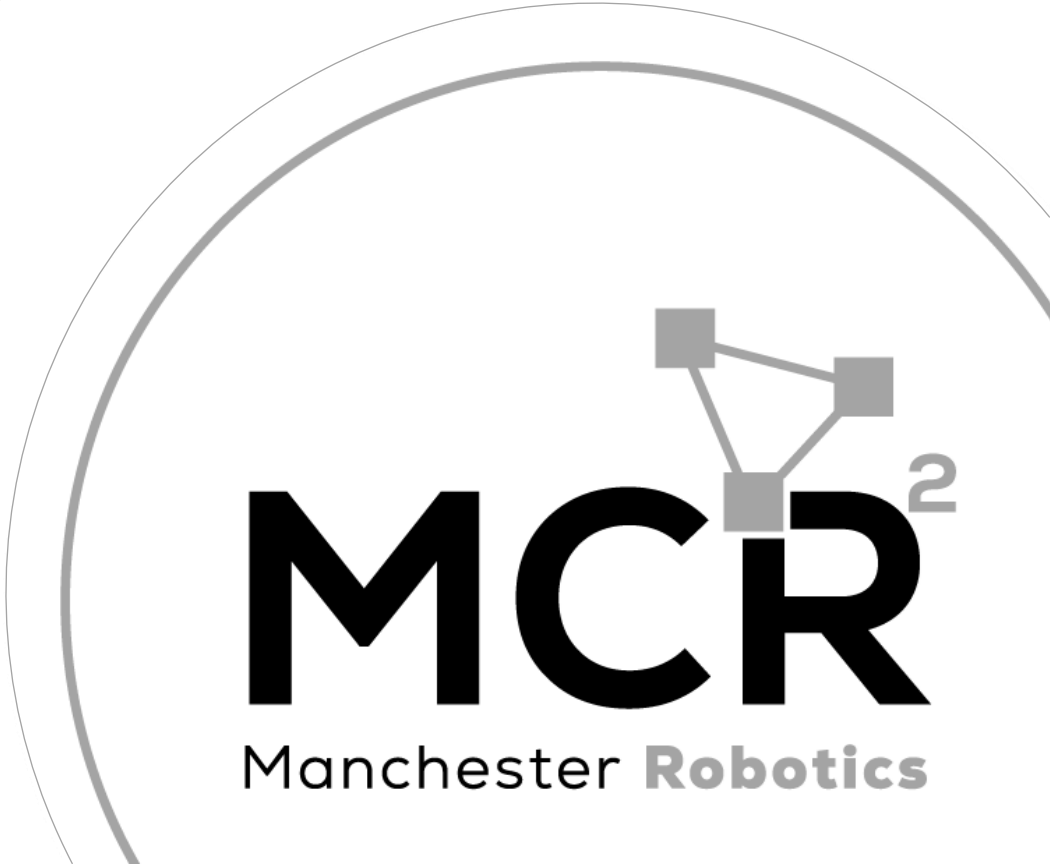

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