ROS/Gazebo

Getting Started - Installation

- Install ROS
- Install Simulator_Gazebo package

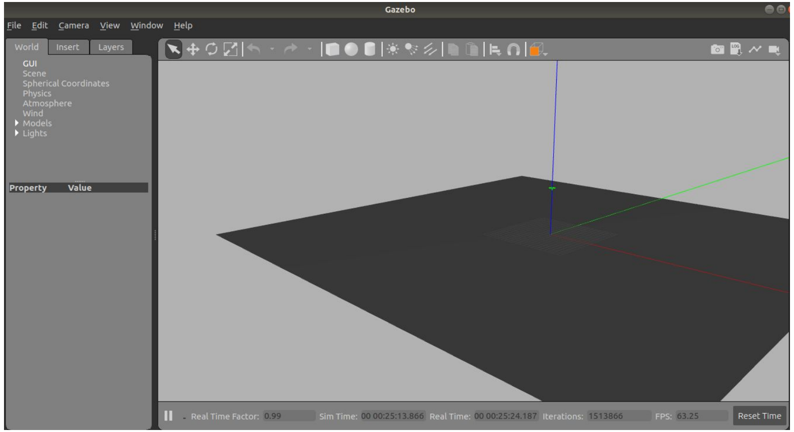
```
$ sudo apt-get install ros-melodic-simulators
```

- IF ROS is configured properly, you can launch gazebo by running the following command:

```
$ roslaunch gazebo_ros empty_world.launch
```

- You can see the launch file within the gazebo_ros package:

```
$ roscd gazebo_ros
$ cat launch/empty_world.launch
```



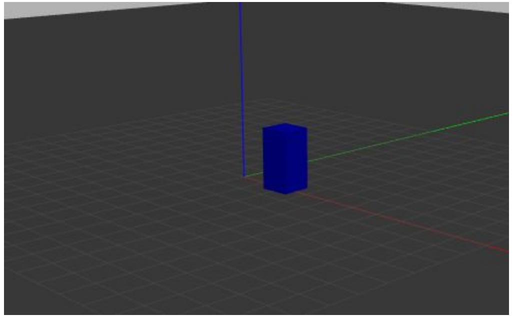
Creating and Spawning Custom URDF Objects in Simulation

```
<robot name="simple_box">
  <link name="my_box">
    <inertial>
      <origin xyz="2 0 0" />
      <mass value="1.0" />
      <inertia  ixx="1.0" ixy="0.0"  ixz="0.0"
iyy="100.0"  iyz="0.0"  izz="1.0" />
    </inertial>
    <visual>
      <origin xyz="2 0 1"/>
      <geometry>
        <box size="1 1 2" />
      </geometry>
    </visual>
    <collision>
      <origin xyz="2 0 1"/>
      <geometry>
        <box size="1 1 2" />
      </geometry>
    </collision>
  </link>
  <gazebo reference="my_box">
    <material>Gazebo/Blue</material>
  </gazebo>
</robot>
```

- Create a file called ‘object.urdf’ and copy the content shown on the the left and save it in the current directory.
- Use the following command to spawn (load) this object into our Gazebo empty world environment.

```
$ rosrun gazebo_ros spawn_model `pwd`/object.urdf
-urdf -z 1 -model my_object
```

- It spawns a blue box into the gazebo environment.



Building and Controlling a Mobile Robot in Gazebo

- Objectives
  - Building a simulated mobile robot from a scratch
  - Controlling the robot motion from ROS
  - Visualizing with RViz
  - Adding Sensors to the robot
  - Autonomous Navigation of the Robot

- Prerequisites:
  - Working ROS and Gazebo installation
  - Catkin Workspace '~/catkin_ws' is created
  - Tested on Ubuntu 18.04 with ROS-Melodic with Gazebo version 9.0

- Credits:
  - Generation Robots Blog
  - Moorerobots.com Blog

Building the Robot

- Create 3 ros packages inside the ~/catkin_ws/src folder

```
$ catkin_create_pkg skbot_gazebo gazebo_ros
$ catkin_create_pkg skbot_description
$ catkin_create_pkg skbot_control
```

- Create your own world

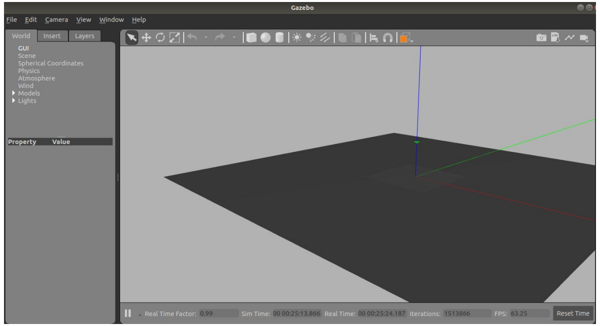
```
$ roscd skbot_gazebo
$ mkdir launch worlds
$ cd worlds
$ gedit skbot.world
```

It has a ground and basic illumination source as shown in the

```
<?xml version="1.0.7" ?>
<sdf version="1.4">
  <world name="myworld">

    <include>
      <uri> model://sun </uri>
    </include>

    <include>
      <uri> model://ground_plane </uri>
    </include>

  </world>
</sdf>
```

- You can download the package for this section using the following command:

```
$ git clone -b master https://github.com/swagatk/gazebo_expts.git
```



- Create a launch file to load this world into the gazebo simulator:

```
$ roscd skbot gazebo/launch
$ gedit skbot_world.launch
```

  And insert the following:

```
<launch>
  <include file="$(find gazebo_ros)/launch/empty_world.launch">
      <arg name="world_name" value="$(find skbot_gazebo)/worlds/skbot.world"/>
      <arg name="gui" value="true"/>
  </include>
</launch>
```

- This gazebo environment can now be loaded using the following command:

```
$ roslaunch skbot_gazebo skbot_world.launch
```

- Create a Robot Model
  - Robot models are described using an XML file called Universal Robot Description Format (URDF) which is the native format for describing all elements of a robot. Xacro (XML macro) is an XML macro language that is useful for making shorter and clearer robot descriptions.
  - Robot description files are created inside the ‘skbot_description’ folder

    $ roscd skbot_description
    $ mkdir urdf
    $ cd urdf
    $ gedit skbot.xacro

    The basic structure of this file looks as follows.

```
<?xml version="1.0"?>
<robot name="skbot" xmlns:xacro="http://www.ros.org/wiki/xacro">
   <!-- put robot description here -->
 </robot>
```

XACRO Concepts:

- `xacro:include` import content from other files. This helps in dividing the content in different xacros and merge them using xacro:include

- `xacro:property` is used to define constant variables and use them later using `${property_name}`

- `xacro:macro` are macros with variable values. These are like functions which help in reusing the same piece of code at multiple places with new set of variables passed to the macro.

- `xmlns:xacro="http://www.ros.org/wiki/xaco "` specifies that a particular file will use xacro.

File: skbot.xacro

```
<?xml version="1.0"?>
<robot name="skbot" xmlns:xacro="http://www.ros.org/wiki/xacro">

  <xacro:property name="PI" value="3.1415926535897931"/>
  <xacro:property name="chassisHeight" value="0.1"/>
  <xacro:property name="chassisLength" value="0.4"/>
  <xacro:property name="chassisWidth" value="0.2"/>
  <xacro:property name="chassisMass" value="50"/>

  <xacro:property name="wheelWidth" value="0.05"/>
  <xacro:property name="wheelRadius" value="0.1"/>
  <xacro:property name="wheelPos" value="0.25"/>
  <xacro:property name="wheelMass" value="5"/>

  <xacro:property name="casterRadius" value="0.05"/>
  <xacro:property name="casterMass" value="5"/>
  <xacro:property name="cameraSize" value="0.05"/>
  <xacro:property name="cameraMass" value="0.1"/>

  <xacro:include filename="$(find skbot_description)/urdf/skbot.gazebo" />
  <xacro:include filename="$(find skbot_description)/urdf/materials.xacro" />
  <xacro:include filename="$(find skbot_description)/urdf/macros.xacro" />
```

Define variables to be used by various macros.

Include other files

Rectangular Base for the robot

```
  <link name="chassis">
    <pose> 0 0 0.1 0 0 0 </pose>
    <collision>
      <origin xyz="0 0 ${wheelRadius}" rpy="0 0 0"/>
      <geometry>
        <box size="${chassisLength} ${chassisWidth} ${chassisHeight}"/>
      </geometry>
    </collision>
    <visual>
      <origin xyz="0 0 ${wheelRadius}" rpy="0 0 0"/>
      <geometry>
        <box size="${chassisLength} ${chassisWidth} ${chassisHeight}"/>
      </geometry>
      <material name="orange"/>
    </visual>
    <inertial>
      <origin xyz="0 0 ${wheelRadius}" rpy="0 0 0"/>
      <mass value="${chassisMass}"/>
      <box_inertia m="${chassisMass}" x="${chassisLength}" y="${chassisWidth}" z="${chassisHeight}"/>
    </inertial>
  </link>
</robot>
```

Defined in materials.xacro file

Defined in macros.xacro file

- Collision tags are used by the collision detection engine
- Visual tags are used by the visual rendering engine
- Inertial tags are used by physics engine.

File: skbot.gazebo

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

  <gazebo reference="chassis">
    <material>Gazebo/Orange</material>
  </gazebo>

</robot>
```

File: materials.xacro

```xml
<?xml version="1.0"?>
<robot>
  <material name="black">
    <color rgba="0.0 0.0 0.0 1.0"/>
  </material>
  <material name="blue">
    <color rgba="0.0 0.0 0.8 1.0"/>
  </material>
  <material name="green">
    <color rgba="0.0 0.8 0.0 1.0"/>
  </material>
  <material name="grey">
    <color rgba="0.2 0.2 0.2 1.0"/>
  </material>
  <material name="orange">
    <color rgba="${255/255} ${108/255} ${10/255} 1.0"/>
  </material>
  <material name="white">
    <color rgba="1.0 1.0 1.0 1.0"/>
  </material>
</robot>
```

File: macros.xacro

```
<?xml version="1.0"?>
<robot>
  <macro name="cylinder_inertia" params="m r h">
    <inertia  ixx="${m*(3*r*r+h*h)/12}" ixy = "0" ixz = "0"
      iyy="${m*(3*r*r+h*h)/12}" iyz = "0"
      izz="${m*r*r/2}"
    />
  </macro>
  <macro name="box_inertia" params="m x y z">
    <inertia  ixx="${m*(y*y+z*z)/12}" ixy = "0" ixz = "0"
      iyy="${m*(x*x+z*z)/12}" iyz = "0"
      izz="${m*(x*x+z*z)/12}"
    />
  </macro>
  <macro name="sphere_inertia" params="m r">
    <inertia  ixx="${2*m*r*r/5}" ixy = "0" ixz = "0"
      iyy="${2*m*r*r/5}" iyz = "0"
      izz="${2*m*r*r/5}"
    />
  </macro>
</robot>
```

All formulas, repetitive functions could be defined in this file using macro tags.

File:skbot_world.launch

```
<launch>
  <include file="$(find gazebo_ros)/launch/empty_world.launch">
      <arg name="world_name" value="$(find
skbot_gazebo)/worlds/skbot.world"/>
      <arg name="gui" value="true"/>
  </include>

  <!-- urdf xml robot description loaded on the Parameter Server, converting
the xacro into a proper urdf file-->
  <param name="robot description" command="$(find xacro)/xacro.py '$(find
skbot_description)/urdf/ skbot.xacro'" />

  <!-- push robot description to factory and spawn robot in gazebo -->
  <node name="skbot_spawn" pkg="gazebo_ros" type="spawn_model"
output="screen"
  args="-urdf -param robot_description -model  skbot " />

  </launch>
```

```
$ roslaunch skbot skbot_gazebo skbot_world.launch
```

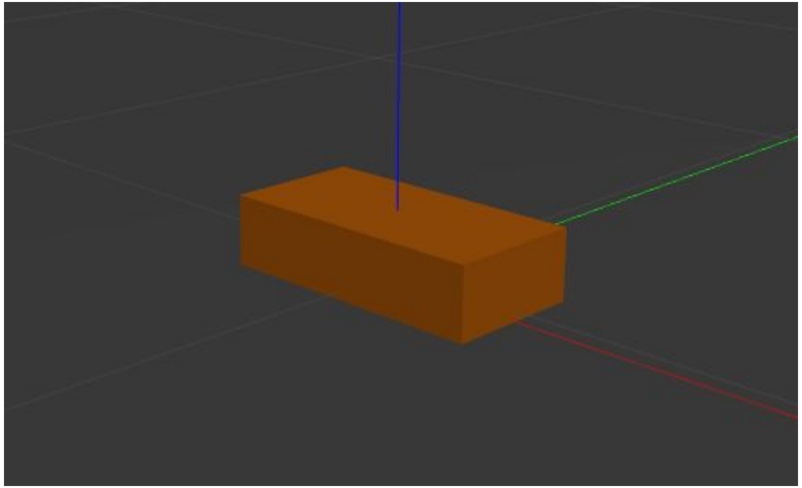
- We should see an orange box in in our empty world Gazebo environment as shown in the adjacent image.

- The next step is to add caster wheels and other two main wheels to the robot chassis.

- We make modifications to the main URDF file "`skbot.xacro`" after the chassis link definition within the <robot> </robot> tags.

- We also define another macro called <wheel> inside the `macros.xacro` file to keep the main URDF file clean and concise.

- We will add a gazebo reference related to caster wheels in the `skbot.gazebo` file.



```xml
<joint name="fixed" type="fixed">
  <parent link="chassis"/>
  <child link="caster_wheel"/>
</joint>

<link name="caster_wheel">
  <collision>
    <origin xyz="${casterRadius-chassisLength/2} 0 ${casterRadius-chassisHeight+wheelRadius}" rpy="0 0 0"/>
    <geometry>
      <sphere radius="${casterRadius}"/>
    </geometry>
  </collision>
  <visual>
    <origin xyz="${casterRadius-chassisLength/2} 0 ${casterRadius-chassisHeight+wheelRadius}" rpy="0 0 0"/>
    <geometry>
      <sphere radius="${casterRadius}"/>
    </geometry>
    <material name="red"/>
  </visual>
  <inertial>
    <origin xyz="${casterRadius-chassisLength/2} 0 ${casterRadius-chassisHeight+wheelRadius}" rpy="0 0 0"/>
    <mass value="${casterMass}"/>
    <sphere_inertia m="${casterMass}" r="${casterRadius}"/>
  </inertial>
</link>
<wheel lr="left" tY="1"/>
<wheel lr="right" tY="-1"/>
</robot>
```

Add to the skbot.xacro file after the chassis link.

Defined in macros.xacro file

Additions to file: macros.xacro

```xml
<macro name="wheel" params="lr tY">
  <link name="${lr}_wheel">
    <collision>
      <origin xyz="0 0 0" rpy="0 ${PI/2} ${PI/2}" />
      <geometry>
        <cylinder length="${wheelWidth}" radius="${wheelRadius}"/>
      </geometry>
    </collision>
    <visual>
      <origin xyz="0 0 0" rpy="0 ${PI/2} ${PI/2}" />
      <geometry>
        <cylinder length="${wheelWidth}" radius="${wheelRadius}"/>
      </geometry>
      <material name="white"/>
    </visual>
    <inertial>
      <origin xyz="0 0 0" rpy="0 ${PI/2} ${PI/2}" />
      <mass value="${wheelMass}"/>
      <cylinder_inertia m="${wheelMass}" r="${wheelRadius}" h="${wheelWidth}"/>
    </inertial>
  </link>

  <gazebo reference="${lr}_wheel">
    <mu1 value="1.0"/>
    <mu2 value="1.0"/>
    <kp  value="10000000.0" />
    <kd  value="1.0" />
    <fdir1 value="1 0 0"/>
    <material>Gazebo/White</material>
  </gazebo>
```

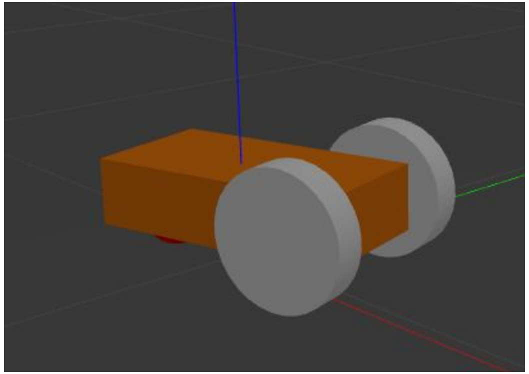
macros.xacro continued ......

```
    <joint name="${lr}_wheel_hinge" type="continuous">
      <parent link="chassis"/>
      <child link="${lr}_wheel"/>
      <origin xyz="${-wheelPos+chassisLength}
${tY*wheelWidth/2+tY*chassisWidth/2} ${wheelRadius}" rpy="0 0 0" />
      <axis xyz="0 1 0" rpy="0 0 0" />
      <limit effort="100" velocity="100"/>
      <joint_properties damping="0.0" friction="0.0"/>
    </joint>

    <transmission name="${lr}_trans">
      <type>transmission_interface/SimpleTransmission</type>
      <joint name="${lr}_wheel_hinge">
        <hardwareInterface>EffortJointInterface</hardwareInterface>
      </joint>
      <actuator name="${lr}Motor">
        <hardwareInterface>EffortJointInterface</hardwareInterface>
        <mechanicalReduction>10</mechanicalReduction>
      </actuator>
    </transmission>
  </macro>

</robot>
```

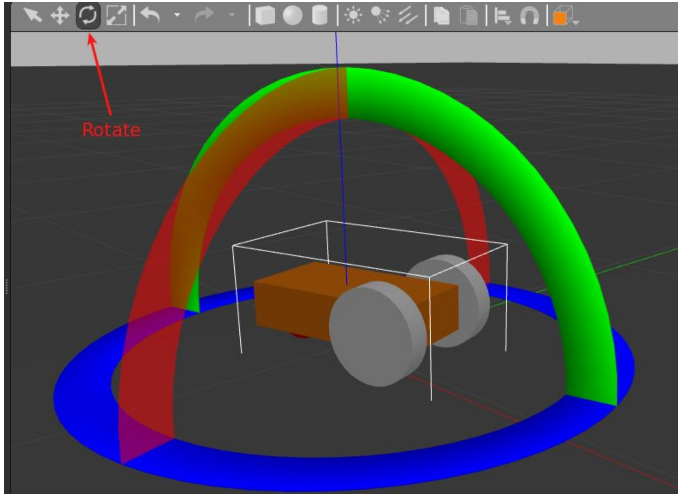
Transmission element is used by ros_control, required for controlling the robot.

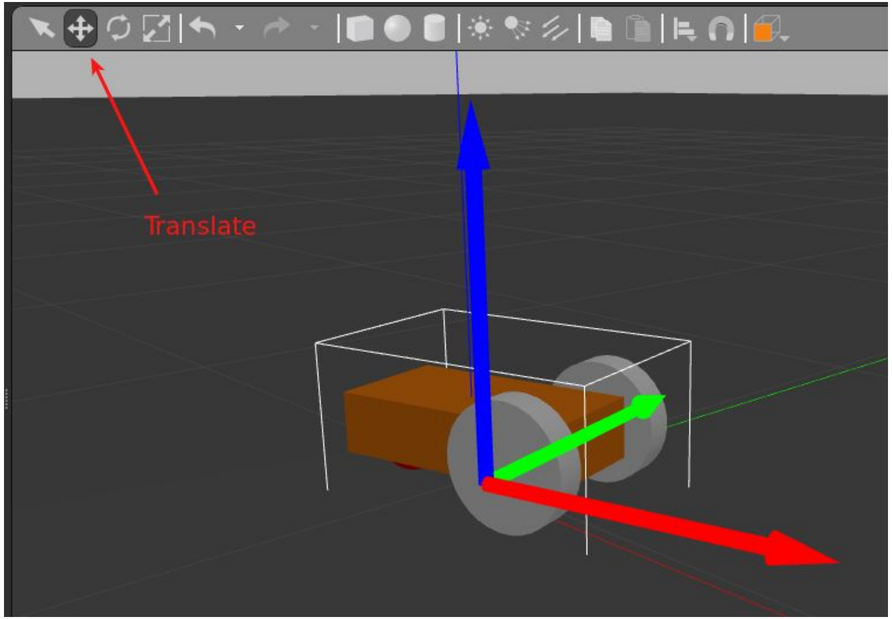
Addition to File: skbot.gazebo

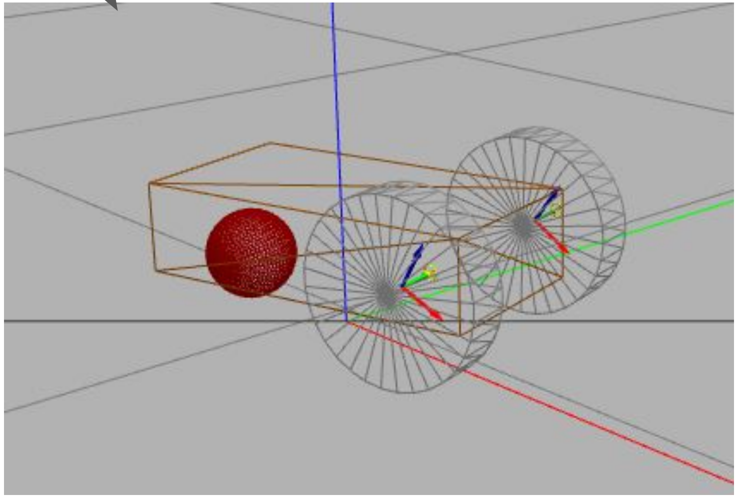
```
 <gazebo
reference="caster_wheel">
    <mu1>0.0</mu1>
    <mu2>0.0</mu2>

<material>Gazebo/Red</material>
  </gazebo>

</robot>
```



view->wireframes







- Moving the robot
  - For this, we need to connect Gazebo to ROS using gazebo plugins.
  - There are different kinds of plugins:
    - **World:** Dynamic changes to the world like illumination, gravity, inserting models.
    - **Model:** Manipulation of models (robots) - moving the robot
    - **Sensor:** Feedback from virtual sensor like camera, laser scanner etc.
    - **System:** plugins that are loaded by GUI, like saving images
  - To activate plugin, add the following to the file: `skbot.gazebo`

```
<gazebo>
  <plugin name="gazebo_ros_control" filename="libgazebo_ros_control.so">
    <robotNamespace>/skbot</robotNamespace>
  </plugin>
</gazebo>
```

  - In order to use this plugin, some additional configurations are required. This is defined in the package “`skbot_control`” as described next.

```
$ roscd skbot_control
$ mkdir config
$ cd config
$ gedit skbot_control.yaml
```

We define three controllers: one for each Wheel and one for publishing joint states.

Now create a launch file:

```
$ roscd skbot_control
$ mkdir launch
$ gedit skbot_control.launch
```

Add the content as shown in the next slide.

Launch the controller by adding the following Line to the ‘`skbot_world.launch`’ file within The <launch> </launch> tags

File: skbot_control.yaml

```yaml
skbot:
  # Publish all joint states -------------------
  joint_state_controller:
    type: joint_state_controller/JointStateController
    publish_rate: 50

  # Effort Controllers ---------------
  leftWheel_effort_controller:
    type: effort_controllers/JointEffortController
    joint: left_wheel_hinge
    pid: {p: 100.0, i: 0.1, d: 10.0}
  rightWheel_effort_controller:
    type: effort_controllers/JointEffortController
    joint: right_wheel_hinge
    pid: {p: 100.0, i: 0.1, d: 10.0}
```

```xml
<!-- ros_control skbot launch file -->
<include file="$(find skbot_control)/launch/skbot_control.launch" />
```

File: skbot_control.launch

```
<launch>
  <!-- Load joint controller configurations from YAML file to parameter server -->
  <rosparam file="$(find skbot_control)/config/ skbot_control.yaml " command="load"/>

  <!-- load the controllers -->
  <node name="controller_spawner"
    pkg="controller_manager"
    type="spawner" respawn="false"
    output="screen" ns="/skbot"
    args="joint_state_controller
      rightWheel_effort_controller
      leftWheel_effort_controller "
  />

  <!-- convert joint states to TF transforms for rviz, etc -->
  <node name="robot_state_publisher" pkg=" robot_state_publisher "
type="robot_state_publisher" respawn="false" output="screen">
    <param name="robot_description" command="$(find xacro)/xacro.py '$(find
skbot_description)/urdf/skbot.xacro'" />
    <remap from="/joint_states" to="/skbot/joint_states" />
  </node>

</launch>
```

This file performs two functions:

- Loads necessary controllers and its parameters as defined in the yaml file.
- Another node to provide 3D transformations (/tf) for the robot

In one terminal, launch the gazebo environment

```
$ roslaunch skbot_gazebo skbot_world.launch
```

In other terminal, type the following command to move the robot

```
$ rostopic list
```

```
$ rostopic pub -1
/skbot/leftWheel_effort_controller/command
std_msgs/Float64 "data: 1.0"
```

```
$ rostopic pub -1
/skbot/rightWheel_effort_controller/command
std_msgs/Float64 "data: 1.5"
```

You can also see the robot joint states by using the following command:

```
$ rostopic echo /skbot/joint_states
```

```
$ rostopic list
/clock
/gazebo/link_states
/gazebo/model_states
/gazebo/parameter_descriptions
/gazebo/parameter_updates
/gazebo/set_link_state
/gazebo/set_model_state
/rosout
/rosout_agg
/skbot/joint_states
/skbot/leftWheel_effort_controller/command
/skbot/rightWheel_effort_controller/command
/tf
/tf_static
```

Teleoperation of the Robot

- It is not convenient to control each wheel separately. So, we will make use of another plugin called **“differential drive”** to make it easier to control the robot. Add the following into the skbot.gazebo file inside the <robot> </robot> tags:

```
<gazebo>
  <plugin name="differential_drive_controller" filename="libgazebo_ros_diff_drive.so">
    <alwaysOn>true</alwaysOn>
    <updateRate>100</updateRate>
    <leftJoint>left_wheel_hinge</leftJoint>
    <rightJoint>right_wheel_hinge</rightJoint>
    <wheelSeparation>${chassisWidth+wheelWidth}</wheelSeparation>
    <wheelDiameter>${2*wheelRadius}</wheelDiameter>
    <torque>20</torque>
    <commandTopic>skbot/cmd_vel</commandTopic>
    <odometryTopic>skbot/odom</odometryTopic>
    <odometryFrame>skbot/odom</odometryFrame>
    <robotBaseFrame>chassis</robotBaseFrame>
  </plugin>
</gazebo>
```

- Now relaunch the skbot_world.launch file and run the following command a separate terminal:

```
$ rosrun turtlesim turtle_teleop_key /turtle1/cmd_vel:=/ skbot/cmd_vel
```

- Now you should be able to control the robot motion using the arrow keys.

Visualization with Rviz

- Create a new launch file for RViz

```
$ roscd skbot description
$ mkdir launch
$ cd launch
$ gedit skbot_rviz.launch
```

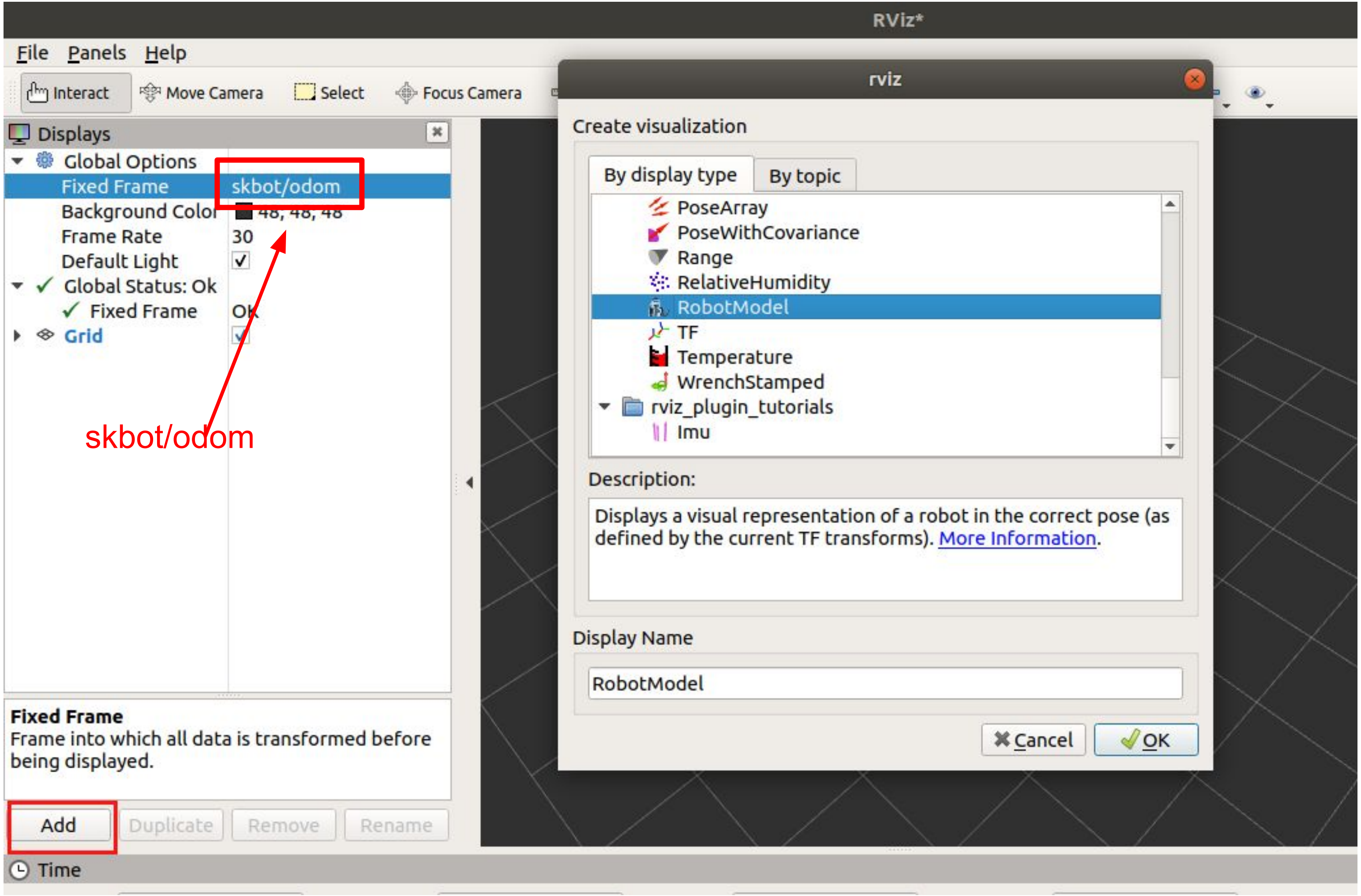
- Now insert the content shown on right hand side. It essentially creates new node to publish joint states to be used by Rviz.

- Launch this file on a separate terminal while gazebo environment is running

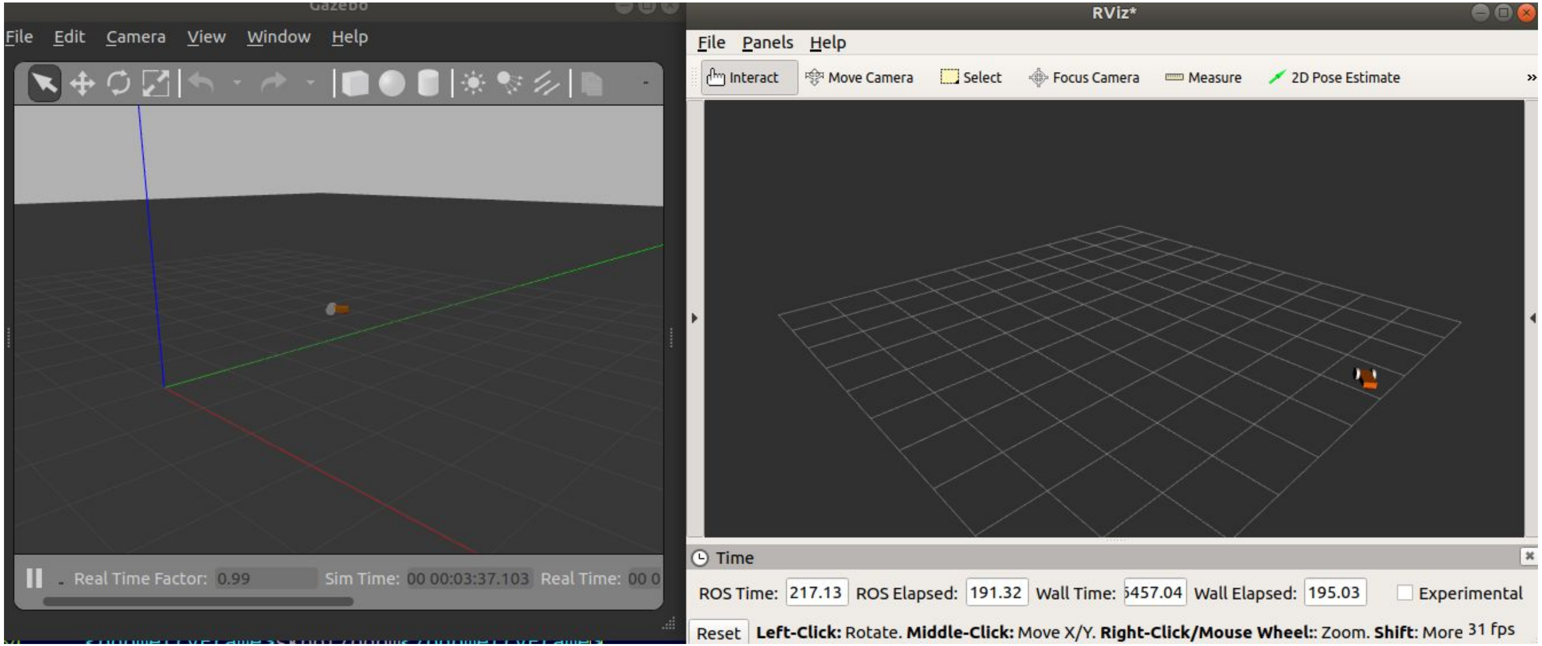
```
$ roslaunch skbot_description
skbot_rviz.launch
```

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

  <param name="robot_description" command="$(find
xacro)/xacro.py '$(find
skbot_description)/urdf/skbot.xacro'"/>

  <!-- send fake joint values -->
  <node name="joint_state_publisher"
pkg="joint_state_publisher"
type="joint_state_publisher">
    <param name="use_gui" value="False"/>
  </node>

  <!-- Combine joint values -->
  <node name="robot_state_publisher"
pkg="robot_state_publisher"
type="state_publisher"/>

  <!-- Show in Rviz   -->
  <node name="rviz" pkg="rviz" type="rviz"/>

</launch>
```

File: skbot_rviz.launch



Add Robot Model and select skbot/odom as the fixed frame.

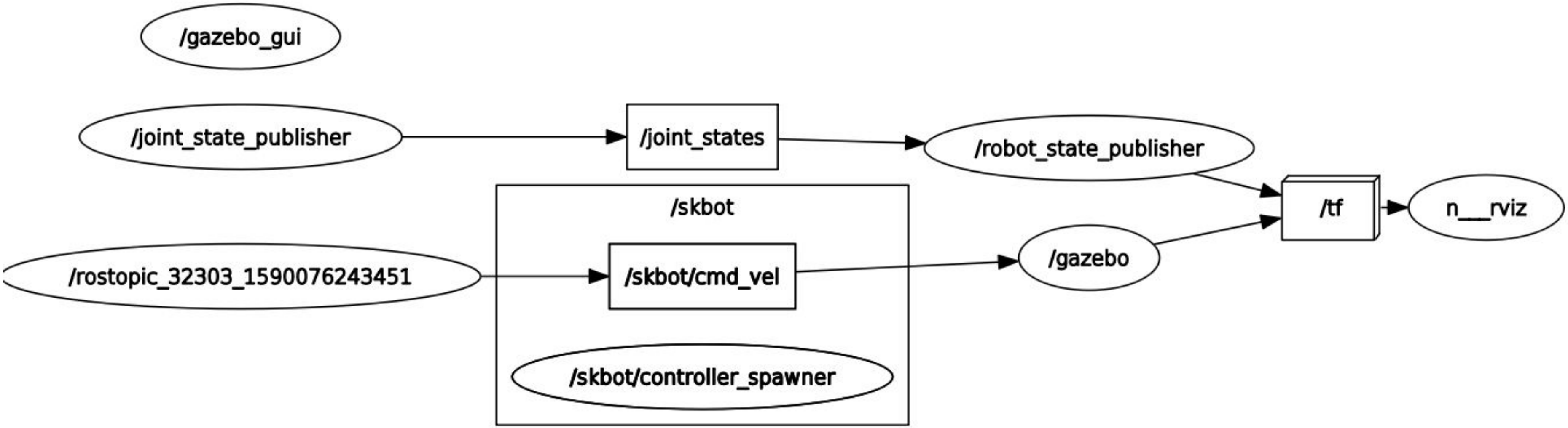


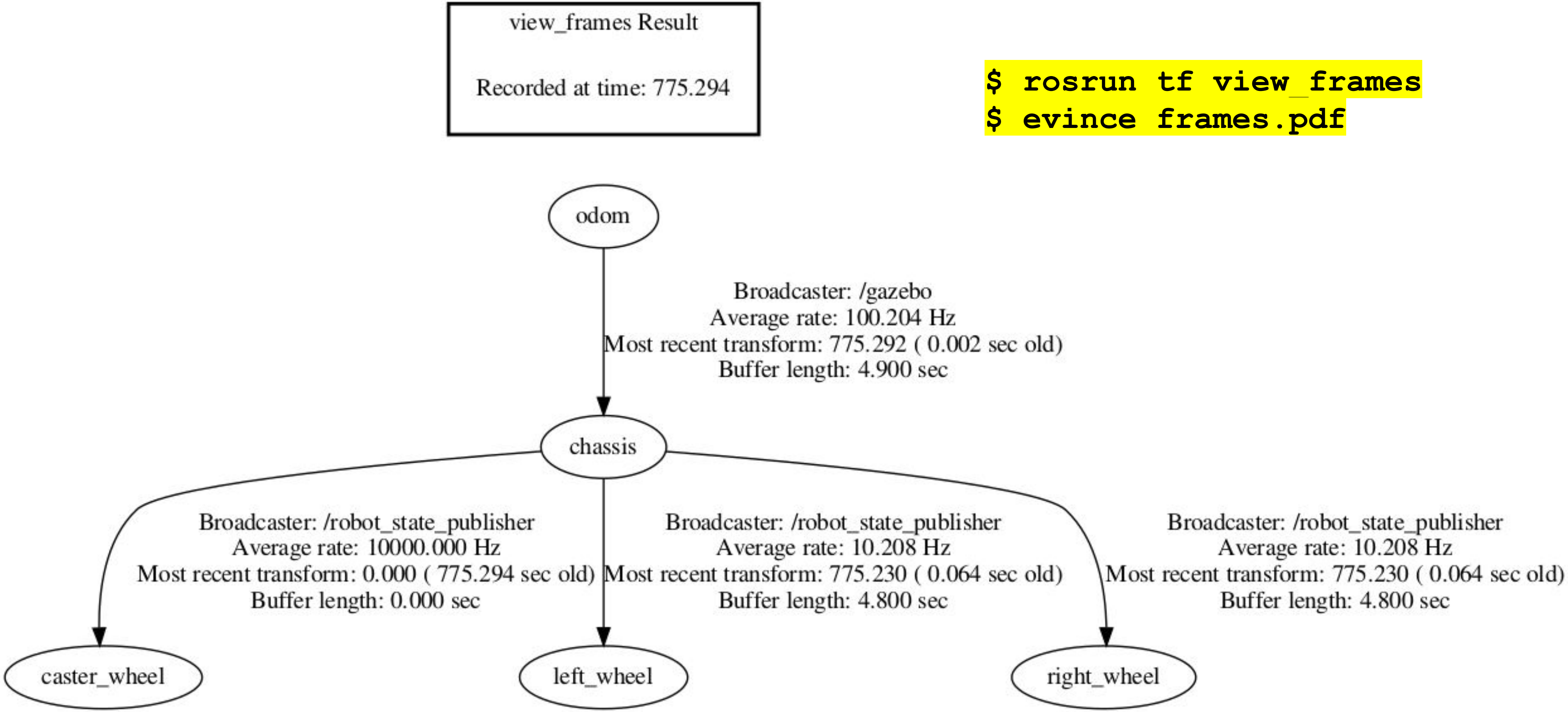

```
$ rostopic pub /skbot/cmd_vel geometry_ms/Twist "linear:
  x: 0.2
  y: 0.0
  z: 0.0
angular:
  x: 0.0
  y: 0.0
  z: 0.1"
```

Robot should start moving in a circular trajectory both in Gazebo and Rviz.

- Using rqt_graph we can visualize various nodes, topics and publishers.
- Note that joint_state_publisher (defined in rviz launch file) publishes joint_states which are used by Rviz to update robot states.
- Gazebo receives the command velocity from a rostopic publisher started by the user.
- Rviz uses data obtained from robot state publisher and gazebo to update robot states.

```
$ rqt_graph
```






```
$ rosrun tf view_frames
$ evince frames.pdf
```

Summary

We learn the following in this module:

- How to create a two-wheeled differential-drive mobile robot in Gazebo?
- Make the robot move by using gazebo-ros plugins
- The source code for this module can be downloaded using the following command:

  $ git clone -b master https://github.com/swagatk/gazebo_expts.git

- Put the folder inside your `~/catkin_ws/src/` folder and run '`catkin_make`' command.

Adding Sensors to the Robot

Source codes

- For this part of the tutorial, you can download the source code from github using the following command:

```
$ cd ~/catkin_ws/src
$ git clone -b sensor_base https://github.com/swagatk/gazebo_expts.git
$ cd ../
$ catkin_make

$ source devel/setup.bash
```

Adding Camera Sensor to the Robot

- Add a camera related description, link and joint information in the main urdf file: `“skbot.xacro”`
- Add Gazebo related information and suitable camera plugin into the file: `“skbot.gazebo”`
- Add some objects to see through camera using <include> tags in the file: `“skbot.world”`
- Now reload the launch file `“skbot_world.launch”`

```
$ roslaunch skbot_gazebo skbot_world.launch
```

- Use the default image_view tool of ROS to view the scene as seen by the robot.
- Use the rotate tool of Gazebo GUI to rotate the robot towards object to view

```
$ rosrun image_view image_view image:=/skbot/camera1/image_raw
```

File: skbot.xacro

```xml
<!-- Adding a Camera -->
<joint name="camera_base" type="fixed">
  <parent link="chassis"/>
  <child link="camera" />
  <origin xyz="${chassisLength/2-cameraSize/2} 0 ${chassisHeight+wheelRadius}" rpy="0 0 0" />
</joint>

<link name="camera">
  <collision>
    <origin xyz="0 0 0" rpy="0 0 0"/>
    <geometry>
      <box size="${cameraSize} ${cameraSize} ${cameraSize}"/>
    </geometry>
  </collision>
  <visual>
    <origin xyz="0 0 0" rpy="0 0 0"/>
    <geometry>
      <box size="${cameraSize} ${cameraSize} ${cameraSize}"/>
    </geometry>
    <material name="blue"/>
  </visual>
  <inertial>
    <mass value="${cameraMass}" />
    <origin xyz="0 0 0" rpy="0 0 0"/>
    <box_inertia m="${cameraMass}" x="${cameraSize}" y="${cameraSize}" z="${cameraSize}" />
  </inertial>
</link>
</robot>
```

File: skbot.gazebo

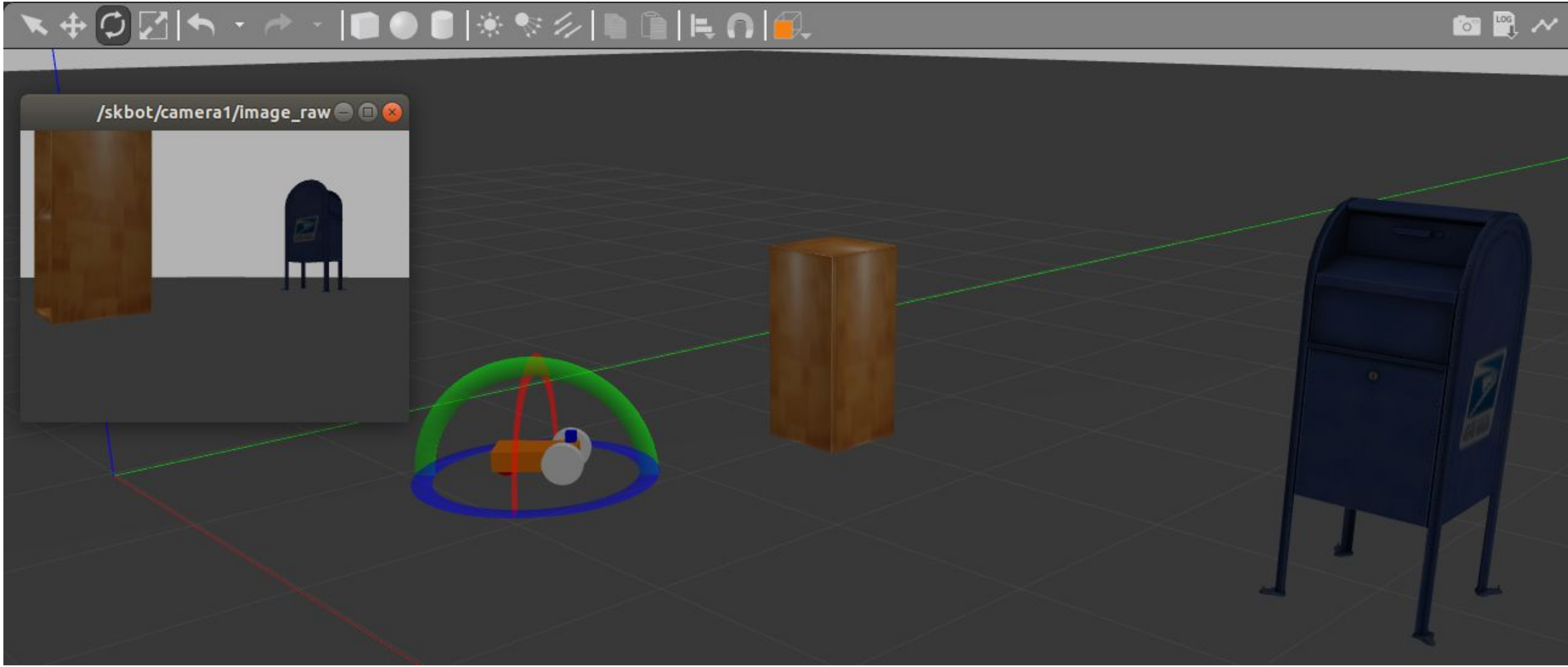
```
<gazebo reference="camera">
  <material>Gazebo/Blue</material>
  <sensor type="camera" name="camera1">
    <update_rate>30.0</update_rate>
    <camera name="head">
      <horizontal_fov>1.3962634</horizontal_fov>
      <image>
        <width>320</width>
        <height>240</height>
        <format>R8G8B8</format>
      </image>
      <clip>
        <near>0.02</near>
        <far>300</far>
      </clip>
    </camera>
    <plugin name="camera_controller" filename="libgazebo_ros_camera.so">
      <alwaysOn>true</alwaysOn>
      <updateRate>0.0</updateRate>
      <cameraName>skbot/camera1</cameraName>
      <imageTopicName>image_raw</imageTopicName>
      <cameraInfoTopicName>camera_info</cameraInfoTopicName>
      <frameName>camera_link</frameName>
      <hackBaseline>0.07</hackBaseline>
      <distortionK1>0.0</distortionK1>
      <distortionK2>0.0</distortionK2>
      <distortionK3>0.0</distortionK3>
      <distortionT1>0.0</distortionT1>
      <distortionT2>0.0</distortionT2>
    </plugin>
  </sensor>
</gazebo> </robot>
```

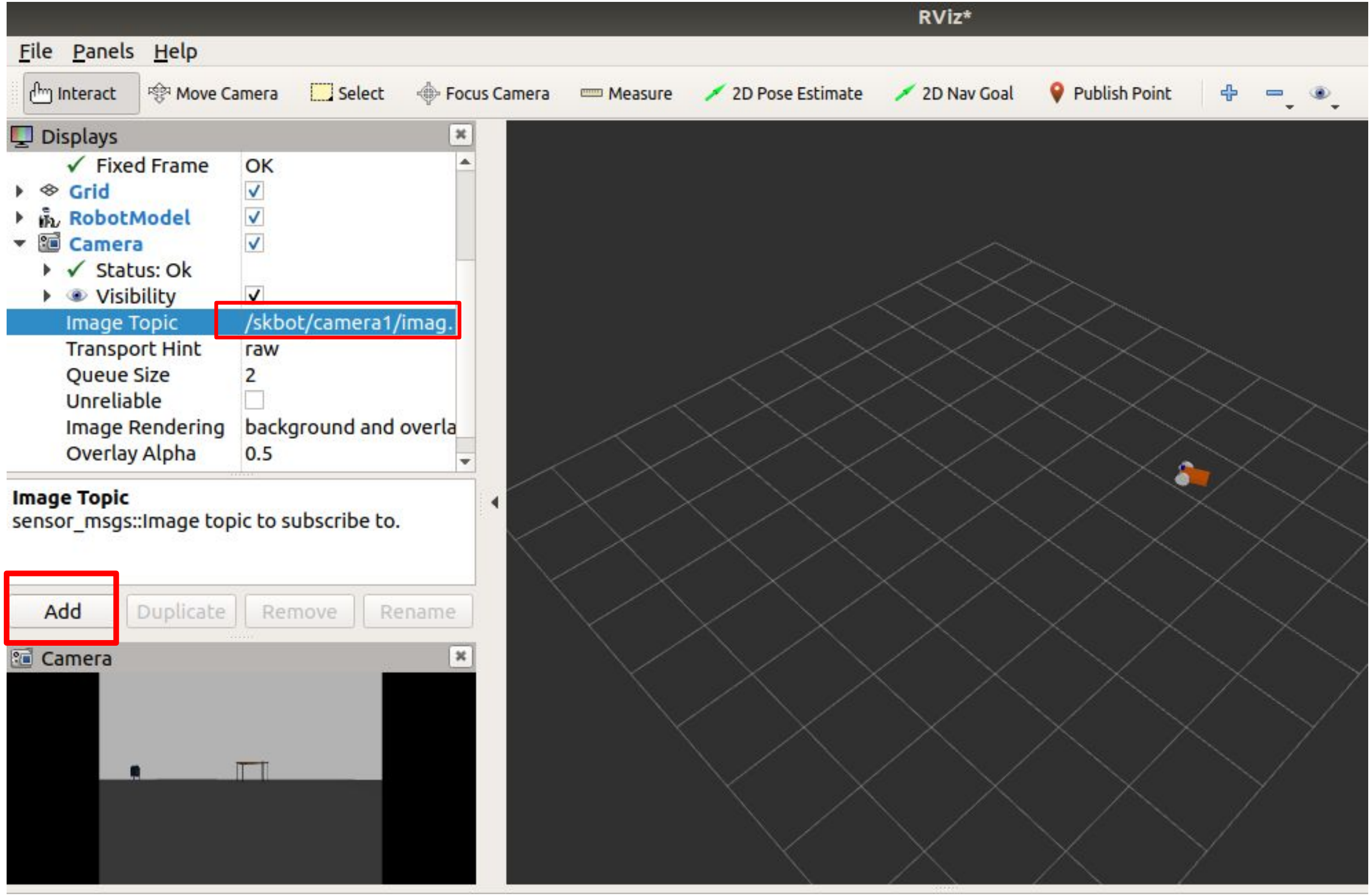
File: skbot.world

```
    <include>
      <uri> model://cabinet </uri>
      <pose>2 3 0 0 0 0</pose>
      <static>true</static>
    </include>

    <include>
      <uri> model://postbox </uri>
      <pose>5 3 0 0 0 0 </pose>
      <static>true</static>
    </include>
  </world>
```

Many built-in objects are already available with Gazebo which can be loaded as shown above. An exhaustive list is available at this link.

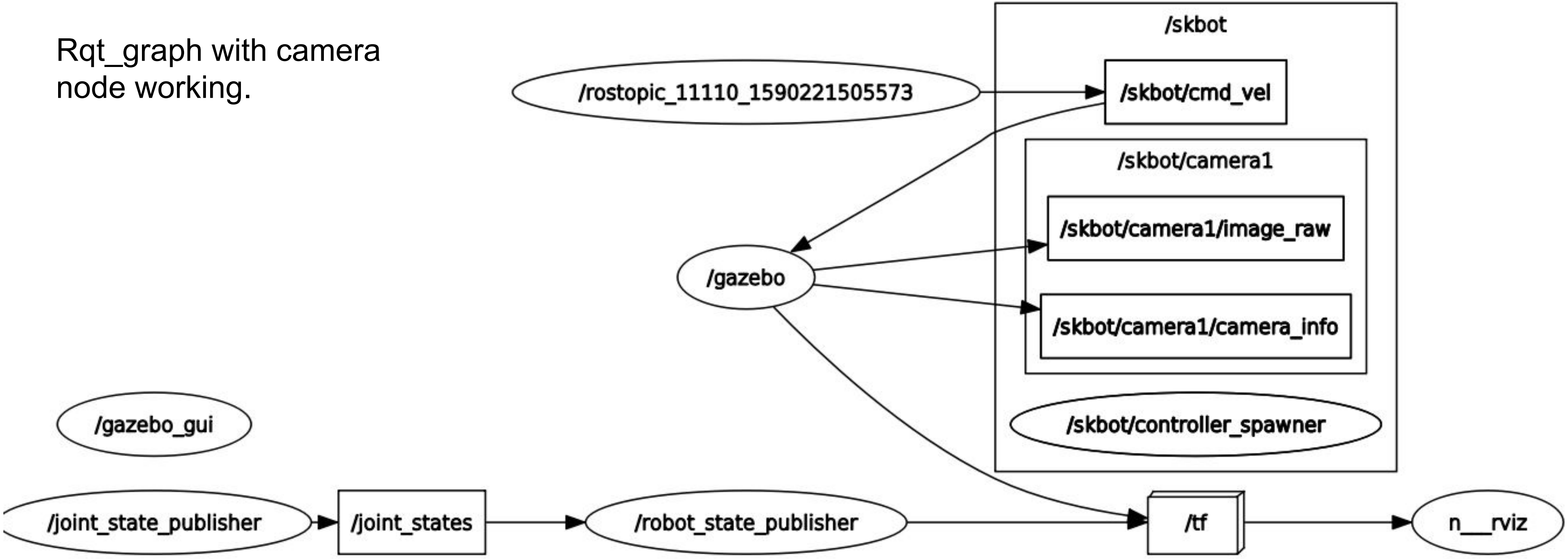
Seeing the world through Robot's Camera.



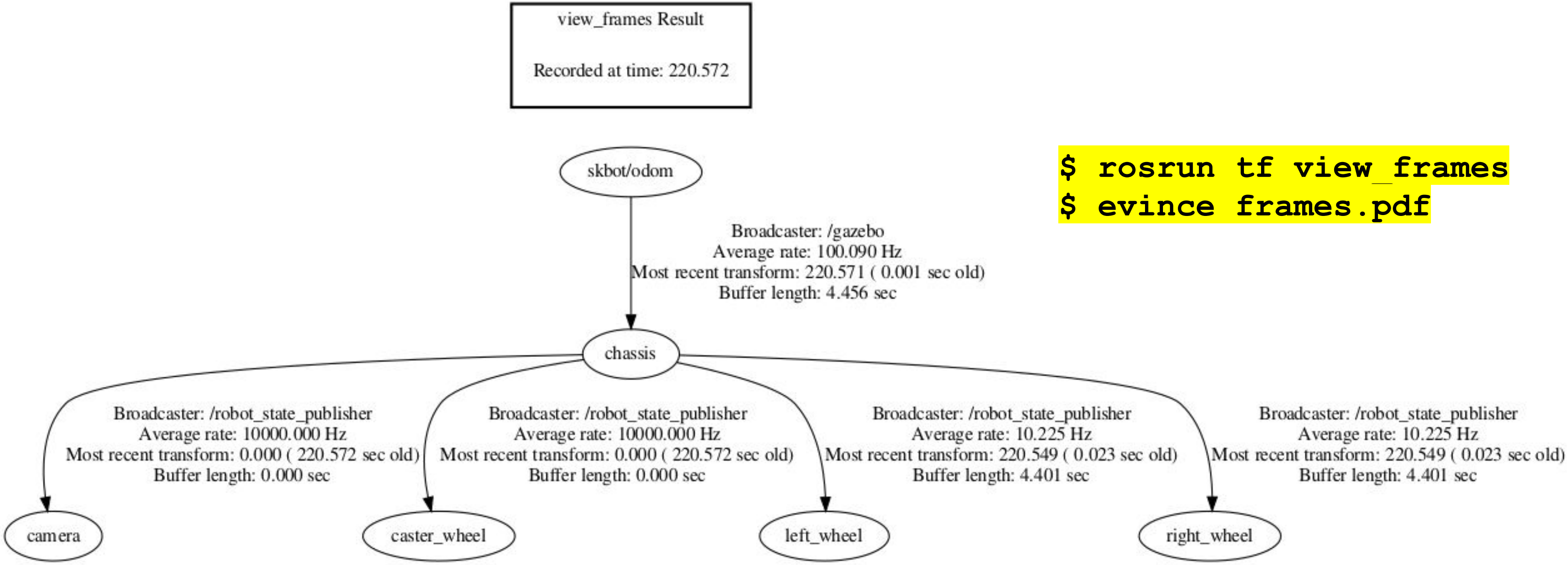


A camera can be similarly added. Change the image Topic to /skbot/camera1/image_raw to access the video feed of on-board camera.

Rqt_graph with camera node working.



- Transform tree shows the geometric and physical relationship between various parts of the robot.
- skbot/odom provides the position of the chassis which is connected to all other parts like camera, caster_wheel, left and right wheels.




```
$ rosrun tf view_frames
$ evince frames.pdf
```

Adding a Laser Scan Sensor

- Modify `“skbot.xacro”` file to include the following descriptions:
  - Add a link named “hokuyo” corresponding to laser scanner to the robot.
  - Add a corresponding joint with “chassis” as the parent link and “hokuyo” as the child link.

- Modify `“skbot.gazebo”` file to include a gazebo reference tag and a gazebo plugin for this laser.

- You will need `“hokuyo.dae”` file provided by the manufacturers to be included in the package (`/skbot_description/meshes/`)

- If you have a GPU, use gpu version of laser plugin library.

- More details on how to use various sensors is available at this link.

```xml
  <!-- Adding a Laser Scanner -->
  <joint name="hokuyo_joint" type="fixed">
    <axis xyz="0 1 0" />
    <origin xyz="${chassisLength/2-0.005} 0 
${chassisHeight+wheelRadius}" rpy="0 0 0" />
    <!--origin xyz=".15 0 .1" rpy="0 0 0"/-->
    <parent link="chassis"/>
    <child link="hokuyo"/>
  </joint>

  <!-- Hokuyo Laser -->
  <link name="hokuyo">
    <collision>
      <origin xyz="0 0 0" rpy="0 0 0"/>
      <geometry>
        <box size="0.1 0.1 0.1"/>
      </geometry>
    </collision>

    <visual>
      <origin xyz="0 0 0" rpy="0 0 0"/>
      <geometry>
        <mesh 
filename="package://skbot_description/meshes/hokuyo.dae"/>
      </geometry>
    </visual>

    <inertial>
        <mass value="1e-5" />
        <origin xyz="0 0 0" rpy="0 0 0"/>
        <inertia ixx="1e-6" ixy="0" ixz="0" iyy="1e-6" iyz="0" 
izz="1e-6" />
      </inertial>
    </link>

</robot>
```

File: skbot.xacro

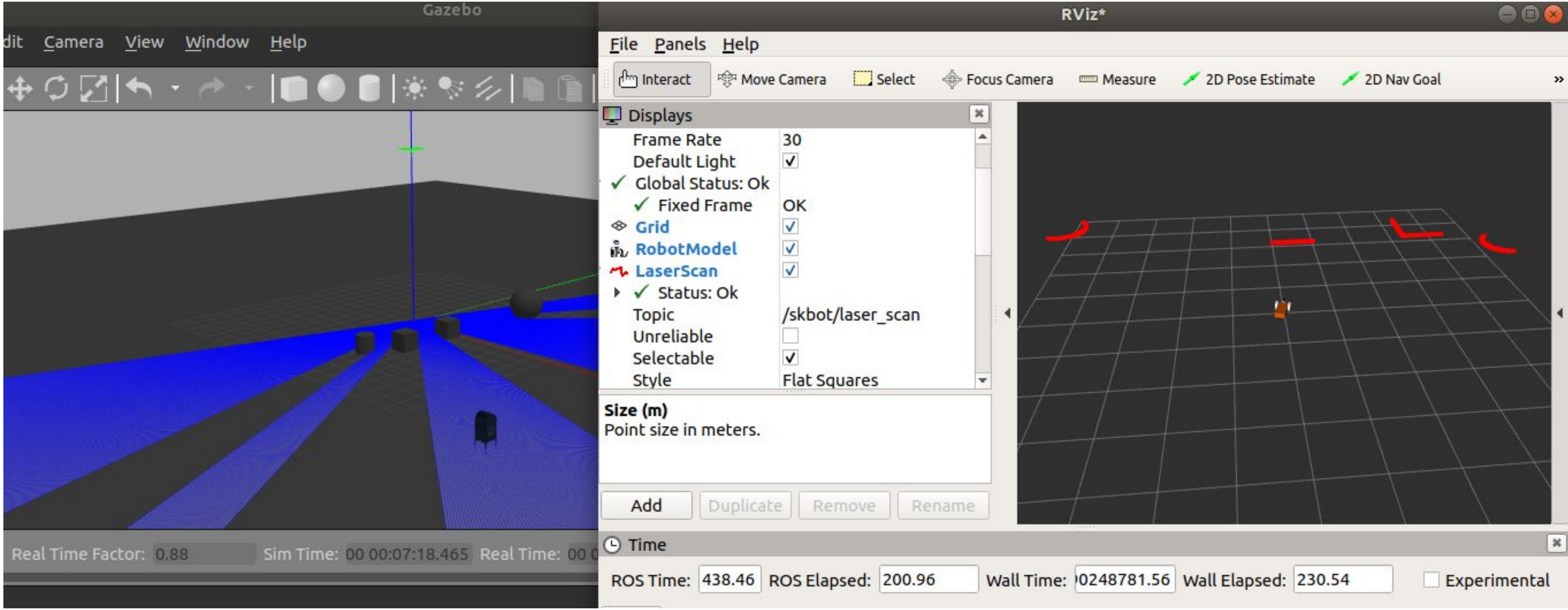
```xml
<!-- Adding a hokuyo Laser Scanner -->
<gazebo reference="hokuyo">
  <sensor type="ray" name="head_hokuyo_sensor">
    <pose>0 0 0 0 0 0</pose>
    <visualize>true</visualize>
    <update_rate>40</update_rate>
    <ray>
      <scan>
        <horizontal>
          <samples>720</samples>
          <resolution>1</resolution>
          <min_angle>-1.570796</min_angle>
          <max_angle>1.570796</max_angle>
        </horizontal>
      </scan>
      <range>
        <min>0.10</min>
        <max>30.0</max>
        <resolution>0.01</resolution>
      </range>
      <noise>
        <type>gaussian</type>
        <mean>0.0</mean>
        <stddev>0.01</stddev>
      </noise>
    </ray>
    <plugin name="gazebo_ros_head_hokuyo_controller" filename="libgazebo_ros_laser.so">
      <topicName>/skbot/laser_scan</topicName>
      <frameName>hokuyo</frameName>
    </plugin>
  </sensor>
</gazebo>
```

File: skbot.gazebo

- If you have gpu, use “gpu_ray” and “libgazebo_ros_gpu_laser.so” instead.
- The laser data is published at topic /skbot/laser_scan.
- Add a LaserScanner model in Rviz and subscribe to above topic to visualize laser scans

```
$ roslaunch skbot_gazebo skbot_world.launch (terminal 1)
```

```
$ roslaunch skbot_description skbot_rviz.launch (terminal 2)
```



Autonomous Navigation

ROS navigation Stack with Turtlebot

- Github Turtlebot repository
  https://github.com/turtlebot/turtlebot

- On ROS-Melodic, you need to build it from source. The instructions are available here.

- You must activate the environment after installation
  `$ source ~/catkin_ws/devel/setup.bash`
  Or
  `$ source ~/catkin_ws/devel_isolated/setup.bash`

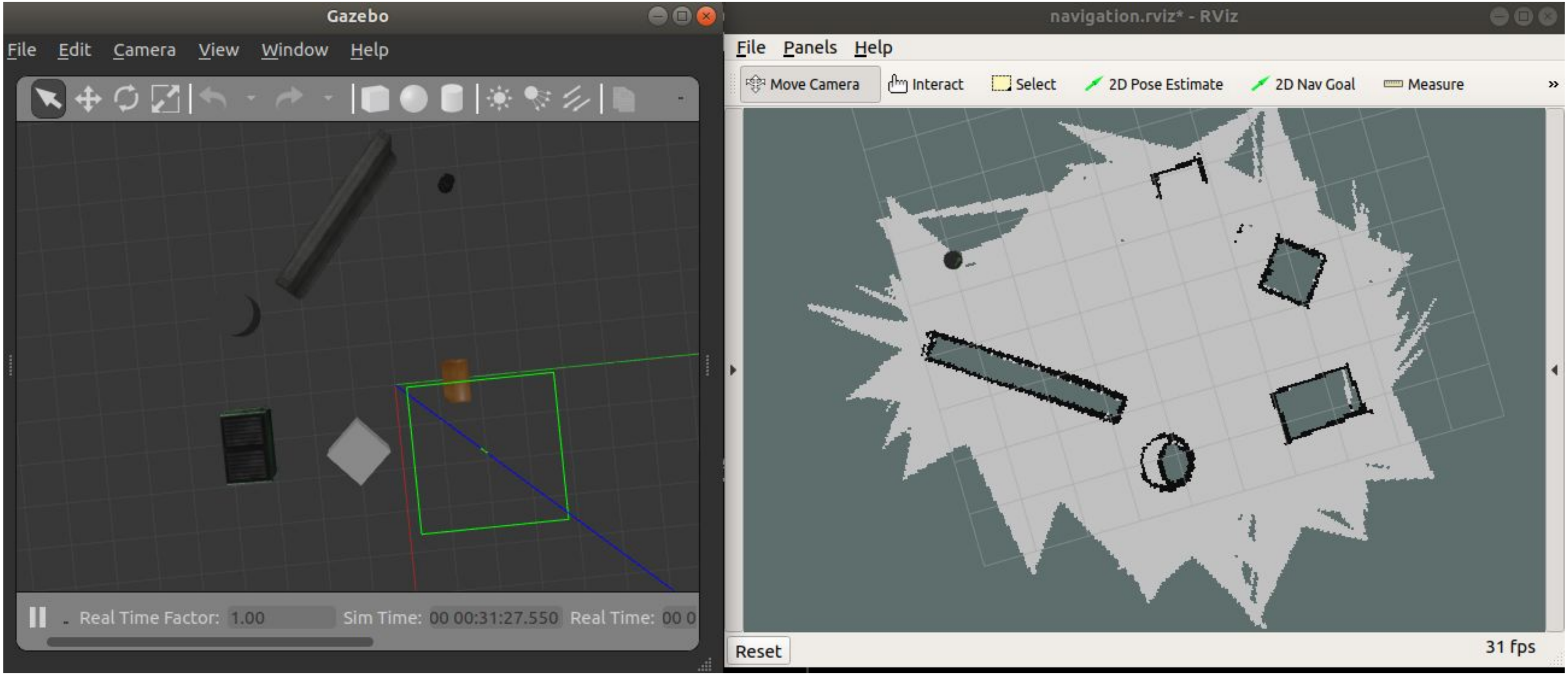
- Step 1: Build the map using Gmapping

  On Terminal 1:
  ```
  $ roslaunch turtlebot_gazebo turtlebot_world.launch
  ```
  On Terminal 2:
  ```
  $ roslaunch turtlebot_gazebo gmapping_demo.launch
  ```
  On Terminal 3:
  ```
  $ roslaunch turtlebot_rviz_launchers view_navigation.launch
  ```
  On Terminal 4:
  ```
  $ roslaunch turtlebot_teleop keyboard_teleop.launch
  ```

  Now make the robot explore its environment by using keyboard and you can see the map developing on Rviz.

- Step 2: Save the map
  ```
  $ rosrun map_server map_saver -f ~/catkin_ws/maps/test_map
  ```

  It creates two files test_map.png and test_map.yaml within the above folder.


Gazebo
File Edit Camera View Window Help
Real Time Factor: 1.00
Sim Time: 00 00:31:27.550
Real Time: 00 0
navigation.rviz* - RViz
File Panels Help
Move Camera
Interact
Select
2D Pose Estimate
2D Nav Goal
Measure
Reset
31 fps

Step 3: Use the saved map to navigate autonomously

On terminal 1:

```
$ roslaunch turtlebot_gazebo turtlebot_world.launch
```

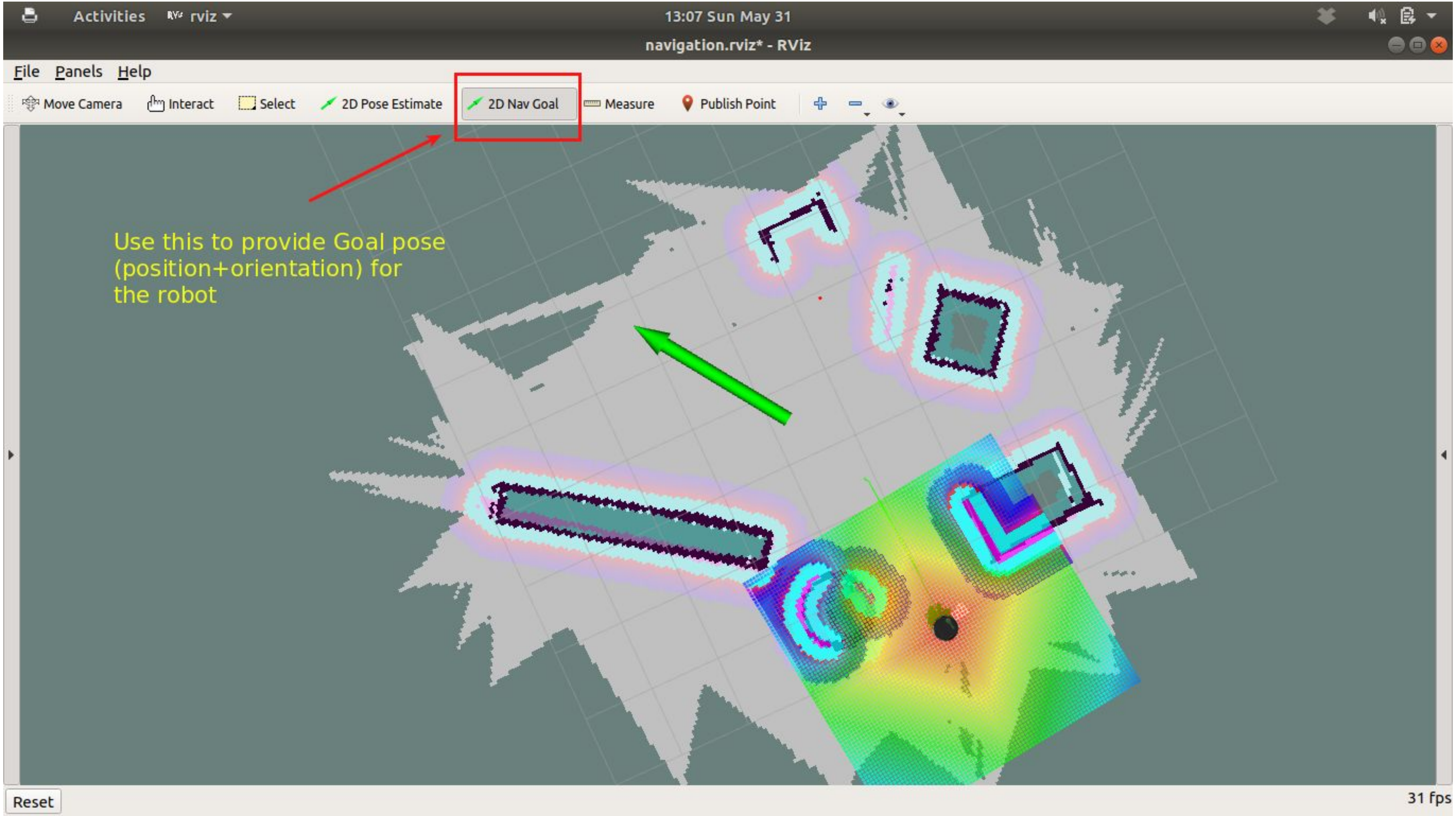
On Terminal 2:

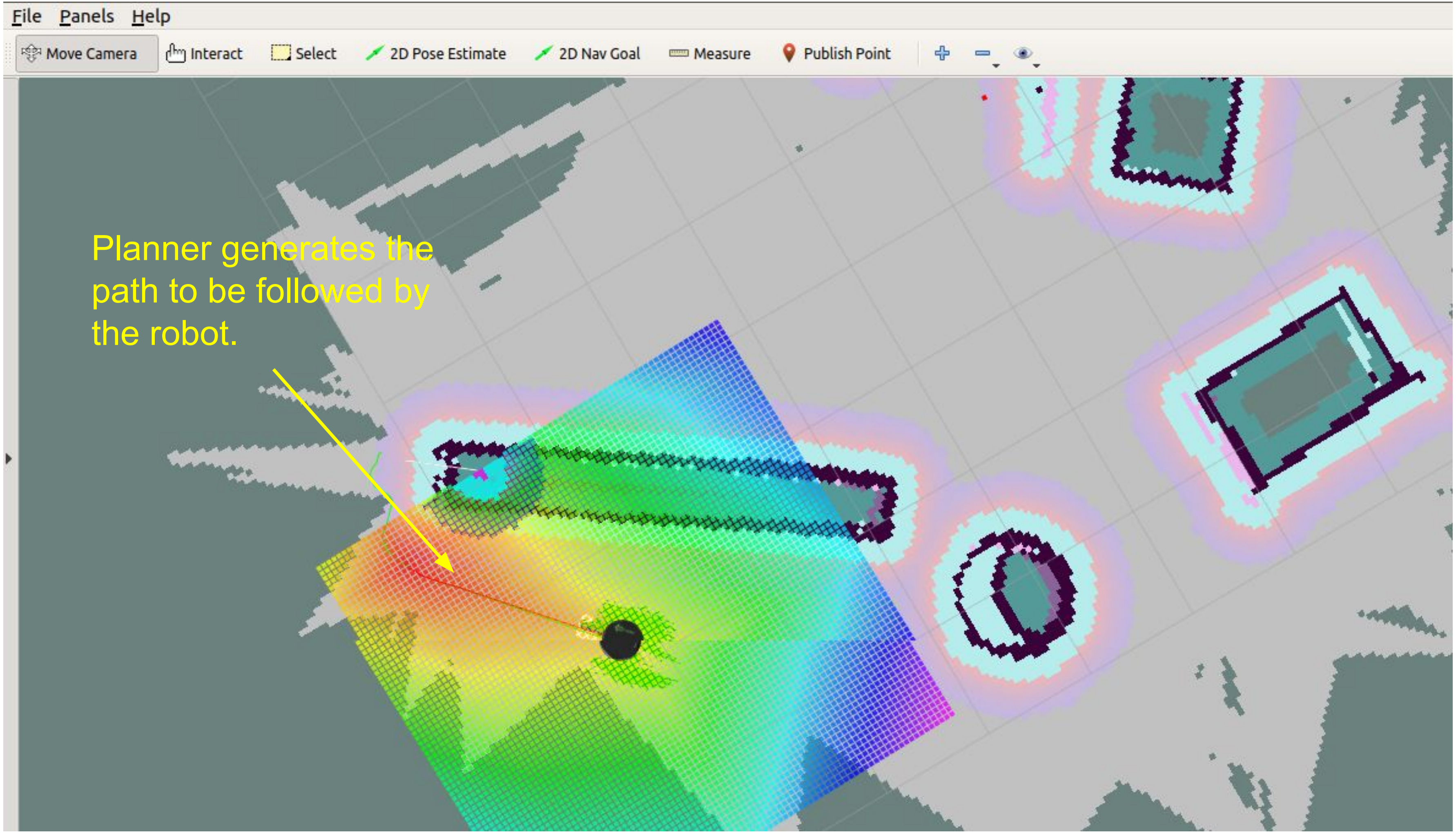
```
$ roslaunch turtelbot_gazebo amcl_demo.launch
map_file:=~/catkin_ws/maps/test_map.yaml
```

On Terminal 3:

```
$ roslaunch rviz_launchers view_navigation.launch
```

Use 2D Nav Goal tool to provide goal pose (position and orientation) for the robot. The AMCL planner generates a path (shown in red) for the robot to follow. Robot then follows this path autonomously by using a scan matching algorithm.


Activities
rviz
13:07 Sun May 31
navigation.rviz* - RViz
File
Panels
Help
Move Camera
Interact
Select
2D Pose Estimate
2D Nav Goal
Measure
Publish Point
Use this to provide Goal pose
(position+orientation) for
the robot
Reset
31 fps


File
Panels
Help
Move Camera
Interact
Select
2D Pose Estimate
2D Nav Goal
Measure
Publish Point
Planner generates the path to be followed by the robot.

Autonomous Navigation with your own Robot

- Copy the ‘playground.world’ file from ‘turtlebot_gazebo’ package to `/skbot_gazebo/worlds/` folder and rename it as ‘turtlebot_playground.world’.

- Modify the `‘/skbot_gazebo/launch/skbot_world.launch’` to load this new world:

```
<include file="$(find gazebo_ros)/launch/empty_world.launch">
<!--arg name="world_name" value="$(find skbot_gazebo)/worlds/skbot.world"/-->
<arg name="world_name" value="$(find skbot_gazebo)/worlds/turtlebot_playground.world"/>
….
</include>
```

- Create a new catkin package named ‘skbot_navigation’:

```
$ catkin_create_pkg skbot_navigation
```

- Copy `‘/skbot_navigation/config/’` folder containing various parameters files needed for tuning mapping functions (available with repo).

- Create a `‘/skbot_navigation/launch/’` folder with the following files:
    - `gmapping_demo.launch`
    - `amcl_demo.launch`
    - `skbot_teleop.launch`

- First two files could be copied from `‘turtlebot_navigation/launch’` folder while the last file could be copied from `‘turtlebot_teleop/launch’` folder.

- We will also create the following custom rviz launch file in the folder `‘skbot_description/launch/’`
    - `skbot_rviz_gmapping.launch`

/skbot_navigation/launch/gmapping_demo.launch

```
<?xml version="1.0"?>
<launch>
  <master auto="start"/>
  <param name="/use_sim_time" value="true"/>
  <!--- Run gmapping -->
  <node pkg="gmapping" name="slam_gmapping" type="slam_gmapping" output="screen">
    <param name="base_frame" value="chassis"/>
    <param name="odom_frame" value="/skbot/odom"/>
    <param name="delta" value="0.01"/>
    <param name="xmin" value="-20"/>
    <param name="xmax" value="20"/>
    <param name="ymin" value="-20"/>
    <param name="ymax" value="20"/>
    <remap from="scan" to="/skbot/laser/scan"/>
    <param name="base_frame" value="chassis" />
    <param name="linearUpdate" value="0.5"/>
    <param name="angularUpdate" value="0.436"/>
    <param name="temporalUpdate" value="-1.0"/>
    <param name="resampleThreshold" value="0.5"/>
    <param name="particles" value="80"/>
    <remap from="scan" to="/skbot/laser/scan"/>
  </node>
</launch>
```

Make sure, these variables point to right values.

/skbot_navigation/launch/skbot_teleop.launch

```
<?xml version="1.0"?>
<launch>
  <!-- turtlebot_teleop_key already has its own built in velocity smoother
-->
  <node pkg="turtlebot_teleop" type="turtlebot_teleop_key"
name="turtlebot_teleop_keyboard"  output="screen">
    <param name="scale_linear" value="0.5" type="double"/>
    <param name="scale_angular" value="0.5" type="double"/>
    <remap from="turtlebot_teleop_keyboard/cmd_vel" to="/skbot/cmd_vel"/>
  </node>
</launch>
```

Requires turtlebot_teleop package

/skbot_description/launch/skbot_rviz_gmapping.launch

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

  <param name="robot_description" command="$(find xacro)/xacro.py '$(find
skbot_description)/urdf/skbot.xacro'"/>

  <!-- send fake joint values -->
  <node name="joint_state_publisher" pkg="joint_state_publisher"
type="joint_state_publisher">
    <param name="use_gui" value="False"/>
  </node>

  <!-- Combine joint values -->
  <node name="robot_state_publisher" pkg="robot_state_publisher" type="state_publisher"/>

  <!-- Show in Rviz   -->
  <node name="rviz" pkg="rviz" type="rviz" />
  <!--node name="rviz" pkg="rviz" type="rviz" args="-d $(find
skbot_description)/rviz/mapping.rviz"/-->
</launch>
```

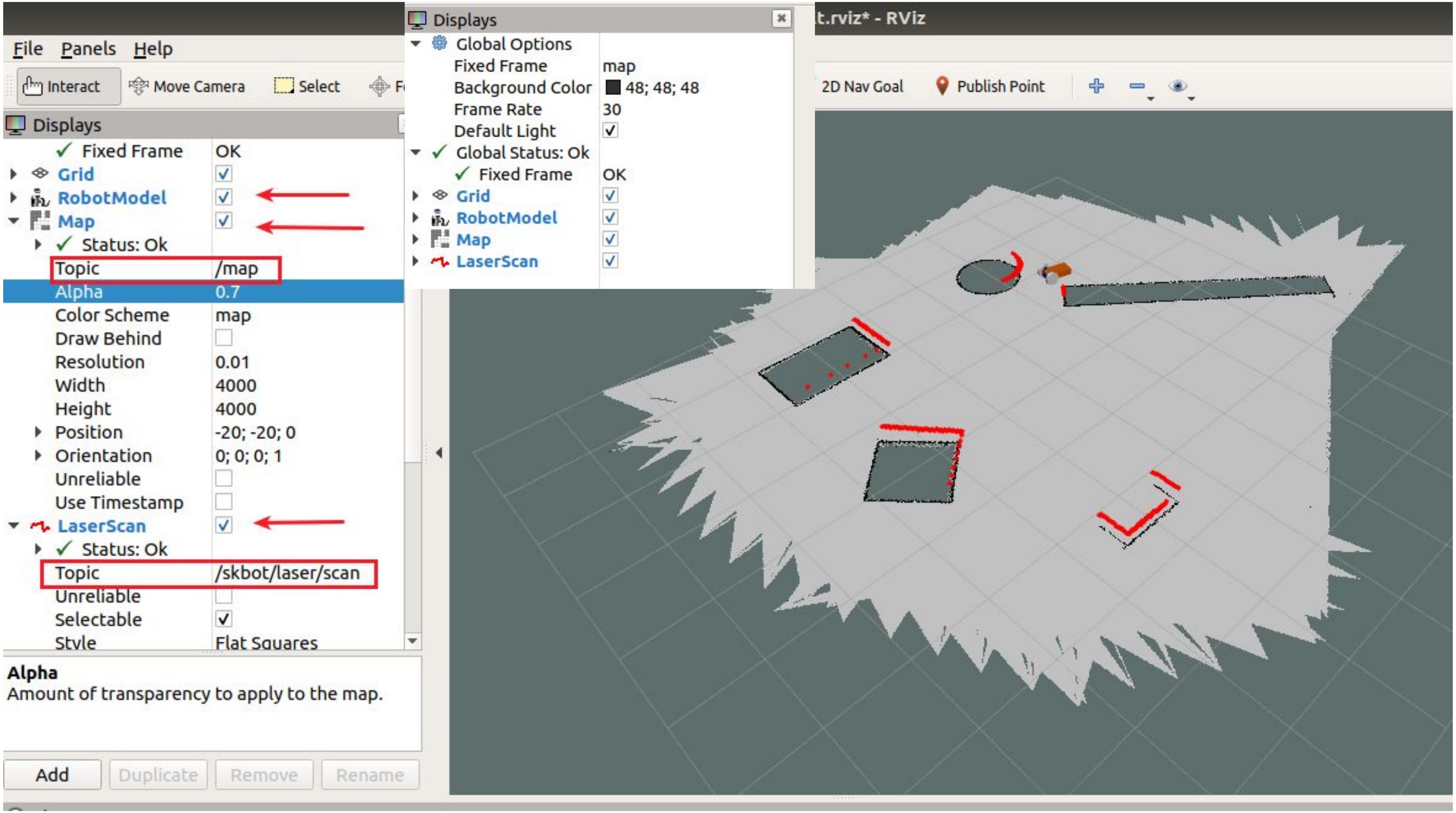
It is possible to load a previously saved rviz file.

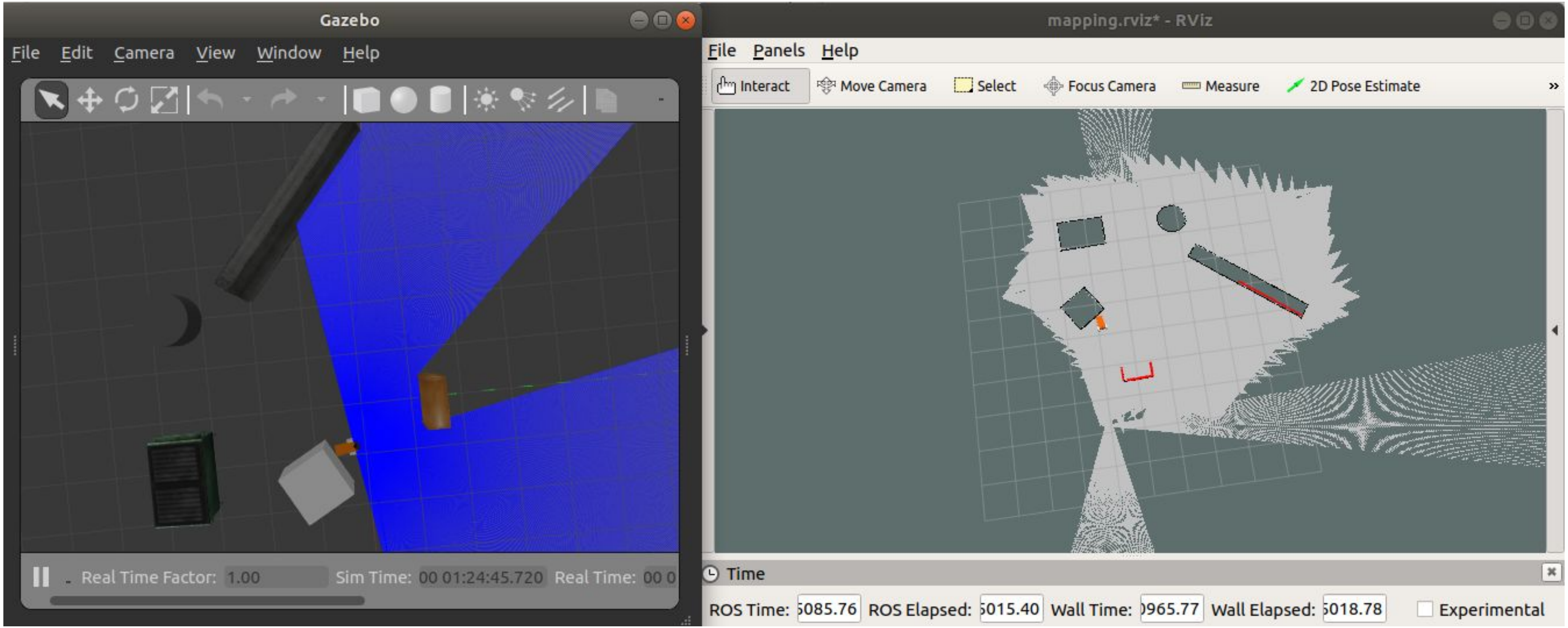
- Step 1: Build the map

  On terminal 1:
  ```
  $ roslaunch skbot_gazebo skbot_world.launch
  ```
  On terminal 2:
  ```
  $ roslaunch skbot_navigation gmapping_demo.launch
  ```
  On terminal 3:
  ```
  $ roslaunch skbot_navigation skbot_teleop.launch
  ```
  On terminal 4:
  ```
  $ roslaunch skbot_description skbot_rviz_gmapping.launch
  ```

  Now use keyboard to make the robot explore its environment. The corresponding map develops on Rviz. Make sure to add components - RobotModel, Maps, LaserScan to Rviz.

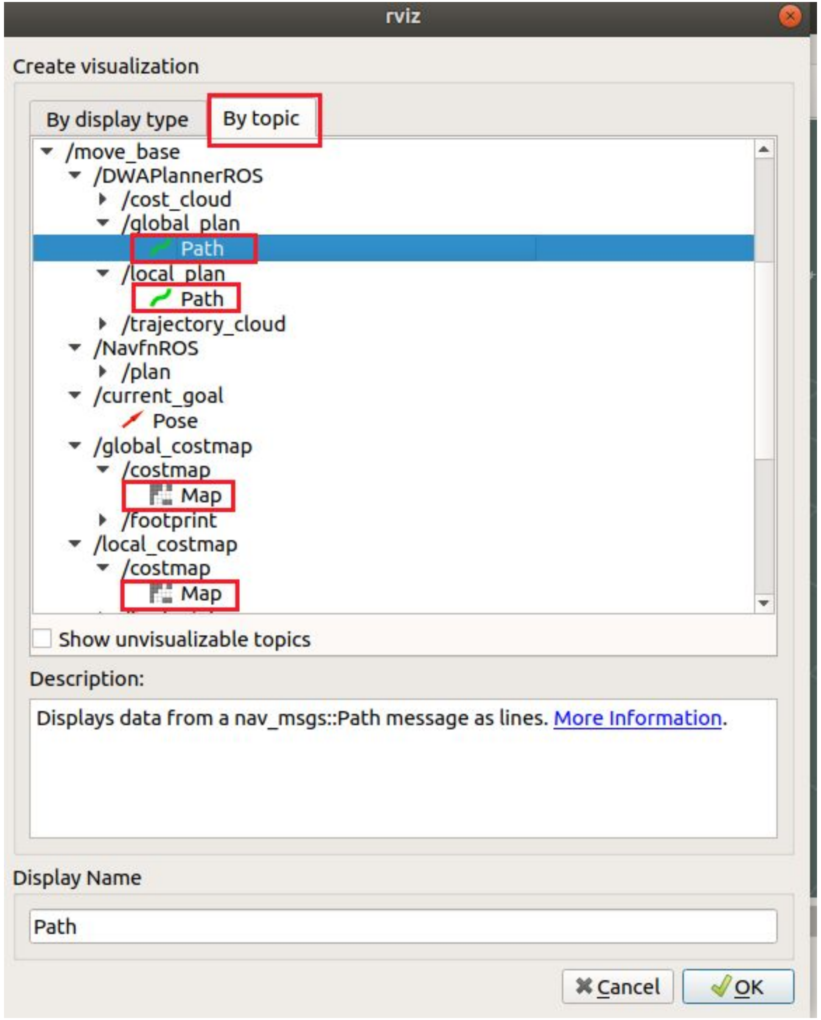
- Step 2: Save the map
  ```
  $ rosrun map_server map_saver -f ~/catkin_ws/maps/test_map
  ```


t.rviz* - RViz
File
Panels
Help
Interact
Move Camera
Select
2D Nav Goal
Publish Point
Displays
Fixed Frame OK
Grid
RobotModel
Map
Status: Ok
Topic /map
Alpha 0.7
Color Scheme map
Draw Behind
Resolution 0.01
Width 4000
Height 4000
Position -20; -20; 0
Orientation 0; 0; 0; 1
Unreliable
Use Timestamp
LaserScan
Status: Ok
Topic /skbot/laser/scan
Unreliable
Selectable
Style Flat Squares
Alpha
Amount of transparency to apply to the map.
Add
Duplicate
Remove
Rename
Displays
Global Options
Fixed Frame map
Background Color 48; 48; 48
Frame Rate 30
Default Light
Global Status: Ok
Fixed Frame OK
Grid
RobotModel
Map
LaserScan



Add ‘RobotModel’, ‘Map’ and ‘LaserScan’ to Rviz. Point them to use suitable robot topics ‘/map’ and ‘/skbot/laser/scan’. Use keyboard to move the robot around in the environment.

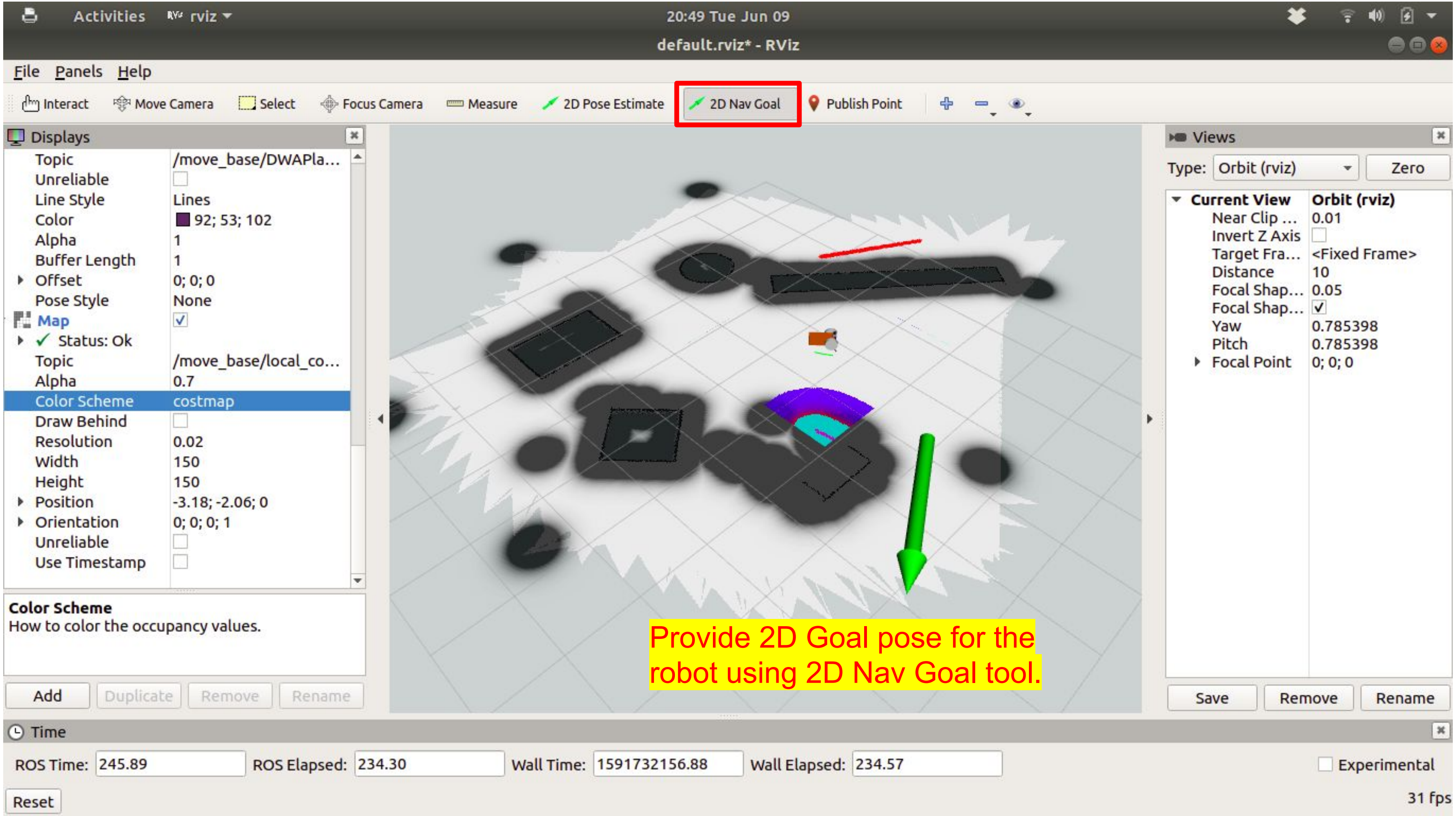
- Step 3: Use the saved map to navigate autonomously
  After terminating all previous commands (Ctrl+C), rerun the following commands on separate terminals.
  On terminal 1:
  ```
  $ roslaunch skbot_gazebo skbot_world.launch
  ```
  On terminal 2:
  ```
  $ roslaunch skbot_navigation amcl_demo.launch
  map_file:=~/catkin_ws/maps/test_map.yaml
  ```
  On terminal 3:
  ```
  $ roslaunch skbot_description skbot_rviz_amcl.launch
  ```
- Use 2D Nav Goal to specify a goal pose for the robot. AMCL planner then finds a path for the robot.
- It would be necessary to tune in some config parameters files in folder /skbot_navigation/config/ to get a correct behaviour from the robot. See the links [here] and [here]

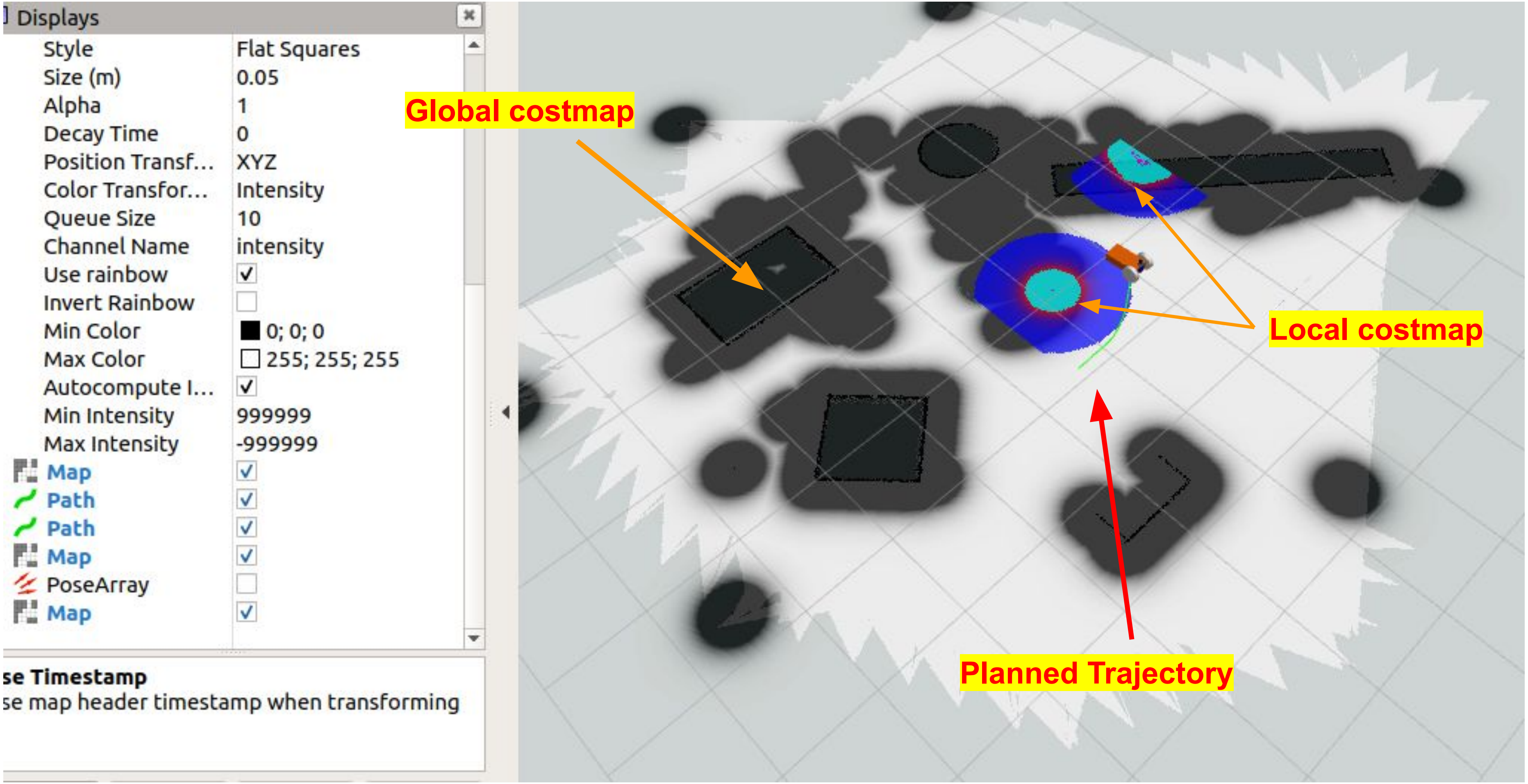


Add following components into your display window:

- Map
- RobotModel
- LaserScan -> /skbot/laser/scan
- Global Path
- Local Path
- Global Costmap
- Local Costmap
- Cost Point cloud

It is easier to add by topic for some of the items. It is also possible to change the color for local / global costmaps, local and global trajectories generated by planner etc. Play around these variables.


Activities
rviz
20:49 Tue Jun 09
default.rviz* - RViz
File
Panels
Help
Interact
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
2D Nav Goal
Publish Point
Displays
Topic
/move_base/DWAPla...
Unreliable
Line Style
Lines
Color
92; 53; 102
Alpha
1
Buffer Length
1
Offset
0; 0; 0
Pose Style
None
Map
Status: Ok
Topic
/move_base/local_co...
Alpha
0.7
Color Scheme
costmap
Draw Behind
Resolution
0.02
Width
150
Height
150
Position
-3.18; -2.06; 0
Orientation
0; 0; 0; 1
Unreliable
Use Timestamp
Color Scheme
How to color the occupancy values.
Add
Duplicate
Remove
Rename
Views
Type:
Orbit (rviz)
Zero
Current View
Orbit (rviz)
Near Clip ...
0.01
Invert Z Axis
Target Fra...
<Fixed Frame>
Distance
10
Focal Shap...
0.05
Focal Shap...
Yaw
0.785398
Pitch
0.785398
Focal Point
0; 0; 0
Save
Remove
Rename
Provide 2D Goal pose for the robot using 2D Nav Goal tool.
Time
ROS Time:
245.89
ROS Elapsed:
234.30
Wall Time:
1591732156.88
Wall Elapsed:
234.57
Experimental
Reset
31 fps



Displays
Style
Flat Squares
Size (m)
0.05
Alpha
1
Decay Time
0
Position Transf...
XYZ
Color Transfor...
Intensity
Queue Size
10
Channel Name
intensity
Use rainbow
Invert Rainbow
Min Color
0; 0; 0
Max Color
255; 255; 255
Autocompute I...
Min Intensity
999999
Max Intensity
-999999
Map
Path
Path
Map
PoseArray
Map
se Timestamp
se map header timestamp when transforming
Global costmap
Local costmap
Planned Trajectory

File: /skbot_navigation/launch/amcl_demo.launch

```
<?xml version="1.0"?>
<launch>
  <master auto="start"/>
  <!-- Map server -->
  <arg name="map_file" default="$(find
skbot_navigation)/maps/test_map.yaml" />
  <node name="map_server" pkg="map_server" type="map_server" args="$(arg
map_file)" />
  <!-- Place map frame at odometry frame -->
  <node pkg="tf" type="static_transform_publisher"
name="map_odom_broadcaster"
      args="0 0 0 0 0 0 map odom 100"/>
  <!-- Localization -->
  <node pkg="amcl" type="amcl" name="amcl" output="screen">
    <remap from="scan" to="/skbot/laser/scan" />
    <param name="odom_frame_id" value= "/skbot/odom"/>
    <param name="odom_model_type" value="diff-corrected"/>
    <param name="base_frame_id" value=" chassis"/>
    <param name="update_min_d" value="0.5"/>
    <param name="update_min_a" value="1.0"/>
  </node>
```

…. contd.

```
 <!-- Move base -->
  <node pkg="move_base" type="move_base" respawn="false" name="move_base" output="screen">
    <param name="base_local_planner" value="dwa_local_planner/DWAPlannerROS"/>
    <rosparam file="$(find skbot_navigation) /config/costmap_common_params.yaml " command="load"
ns="global_costmap" />
    <rosparam file="$(find skbot_navigation) /config/costmap_common_params.yaml"  command="load"
ns="local_costmap" />
    <rosparam file="$(find skbot_navigation)/config/local_costmap_params.yaml" command="load" />
    <rosparam file="$(find skbot_navigation)/config/global_costmap_params.yaml" command="load" />
    <rosparam file="$(find skbot_navigation)/config/base_local_planner_params.yaml"
command="load" />
    <rosparam file="$(find skbot_navigation)/config/move_base_params.yaml" command="load" />
    <rosparam file="$(find skbot_navigation)/config/dwa_local_planner_params.yaml" command="load"
/>
    <remap from="cmd_vel" to= "/skbot/cmd_vel"/>
    <remap from="odom" to= "/skbot/odom"/>
    <remap from="scan" to= "/skbot/laser/scan"/>
    <param name="move_base/DWAPlannerROS/yaw_goal_tolerance" value="1.0"/>
    <param name="move_base/DWAPlannerROS/xy_goal_tolerance" value="1.0"/>
  </node>
</launch>
```

AMCL performance depends on these parameter files. These parameters should be tuned properly to get best performance.

File:/skbot_description/launch/skbot_rviz_amcl.launch

```
<?xml version="1.0"?>
<launch>
  <param name="robot_description" command="$(find xacro)/xacro.py '$(find
skbot_description)/urdf/skbot.xacro'"/>

  <!-- send fake joint values -->
  <node name="joint_state_publisher" pkg="joint_state_publisher"
type="joint_state_publisher">
    <param name="use_gui" value="False"/>
  </node>

  <!-- Combine joint values -->
  <node name="robot_state_publisher" pkg="robot_state_publisher" type="state_publisher"/>

  <!-- Show in Rviz   -->
  <!--node name="rviz" pkg="rviz" type="rviz" args="-d $(find
skbot_description)/rviz/amcl.rviz"/-->

  <node name="rviz" pkg="rviz" type="rviz" />
</launch>
```

Custom Rviz file could be loaded here.

Following files are included in the `/skbot_navigation/config` folder:

```
base_local_planner_params.yaml
global_costmap_params.yaml
costmap_common_params.yaml
local_costmap_params.yaml
dwa_local_planner_params.yaml
move_base_params.yaml
```

More discussion on how to tune these parameters are available at the following links:

- Link1
- Link2

Other Resources

- Richard Wang's Youtube Channel
- Devansh's Github page
- Source code for this project is available at this github link:

  $ git clone -b master https://github.com/swagatk/gazebo_expts.git
  $ git clone -b sensor_base https://github.com/swagatk/gazebo_expts.git
  $ git clone -b navigation https://github.com/swagatk/gazebo_expts.git

Summary

We learned the following in this section:

- How to build map with Gmapping for Turtlebot and use it for autonomous navigation?
- To do the same with our own simulated robot.
- To do list
  - Get a proper understanding of AMCL and tuning cost map parameters.

Writing Your Own Motion Planner

Creating your own Publisher and Subscriber Node

- Prerequisite:
    - Complete ROS Beginner tutorials on how to create Publisher / Subscriber Nodes using Python. [Link]
    - You can choose to build the contents on your own as described in the following slides or may download the codes using the following command:

      ```
      $ git clone -b motion https://github.com/swagatk/gazebo_expts.git
      ```

    - Download the above folder inside your `~/catkin_ws/src/` folder and then build it using `'catkin_make'` command.
    - Next steps assumes that you are going to build the files on your own and you have followed the previous sections until this point.

- Create Catkin Package inside the `~/catkin_ws/src/skbot/` folder:

```
$ catkin_create_pkg skbot_motion rospy std_msgs geometry_msgs
sensor_msgs
$ cd skbot_motion
$ mkdir scripts
$ cd scripts
$ touch reading_laser.py
```

- Use an editor add contents to the file ‘reading_laser.py’ (shown in the next slide)
- Make the script executable:

```
$ chmod a+x ./reading_laser.py
```

- Now we can build the entire catkin workspace

```
$ cd ~/catkin_ws
$ catkin_make
$ source devel/setup.bash
```

file:/skbot/skbot_motion/scripts/reading_laser.py

```
#!/usr/bin/env python
import rospy
from sensor_msgs.msg import LaserScan
def clbk_laser(msg): # callback function
    # 720/5 = 144
    regions = [
      min(min(msg.ranges[0:143]), 10),
      min(min(msg.ranges[144:287]), 10),
      min(min(msg.ranges[288:431]), 10),
      min(min(msg.ranges[432:575]), 10),
      min(min(msg.ranges[576:713]), 10),
     ]
    rospy.loginfo(regions)
def main():
    rospy.init_node('reading_laser')
    sub = rospy.Subscriber("/skbot/laser/scan", LaserScan, clbk_laser)
    rospy.spin()

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

Divides scanner reading into five regions and prints the minimum value of each region between 0 and 10.

Creates a subscriber node to read data from robot laser sensor

- We create a custom world environment for this part. Copy the file 'skbot_custom.world' (from the git repository) into `/skbot_gazebo/worlds/` folder.

- Modify the `'skbot_world.launch'` file present in `/skbot_gazebo/launch` folder to load this custom world file.

```
.........
  <include file="$(find gazebo_ros)/launch/empty_world.launch">
    <!--arg name="world_name" value="$(find skbot_gazebo)/worlds/skbot.world"/-->
    <!--arg name="world_name" value="$(find
skbot_gazebo)/worlds/turtlebot_playground.world"/-->
    <arg name="world_name" value="$(find skbot_gazebo)/worlds/skbot_custom.world"/>
    <arg name="paused" value="$(arg paused)"/>
    ......
    ...........

  </include>
.........
```

Make the change as highlighted into the file keeping other contents unchanged

- Run these two commands in two different terminals:

  On Terminal 1:

  ```
  $ roslaunch skbot_gazebo skbot_world.launch
  ```

  On Terminal 2:

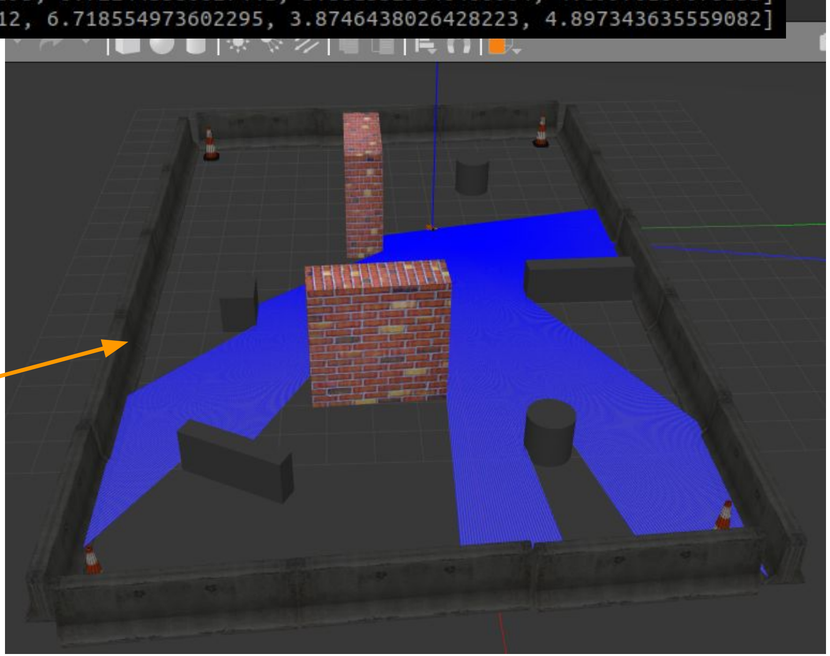
  ```
  $ rosrun skbot_motion reading_laser.py
  ```

- You should be able to see a continuous stream of laser data printed on the terminal 2. Last five readings correspond to the minimum laser reading between 0 and 10 for the five regions (shown on the next slide).

```
[INFO] [1592225700.865641, 2806.976000]: [1.4900996685028076, 6.832234859466553, 6.724250316619873, 3.8751471042633057, 4.88306999206543]
[INFO] [1592225700.867198, 2806.978000]: [1.4972383975982666, 6.832253932952881, 6.727447986602783, 3.8843417167663574, 4.89356565474639]
[INFO] [1592225700.910905, 2807.012000]: [1.491371512413025, 6.834882259368896 5, 6.7267279624938965, 3.8777196407318115, 4.89317131042 4805]
[INFO] [1592225700.926923, 2807.023000]: [1.494140386581421, 6.82312536239624, 6.7144999504089355, 3.87878155708313, 4.901833057403564 5]
[INFO] [1592225700.974653, 2807.060000]: [1.4972929954528809, 6.828401565551758, 6.7256574630737305, 3.8795011043548584, 4.891433238983154]
[INFO] [1592225701.017820, 2807.095000]: [1.4914062023162842, 6.827219486236572, 6.715297222137451, 3.89103627204895, 4.897118091583252]
[INFO] [1592225701.061522, 2807.124000]: [1.4928946495056152, 6.840241432189941, 6.726038455963135, 3.8857359886169434, 4.894305229187012]
[INFO] [1592225701.063159, 2807.126000]: [1.4944872856140137, 6.810795307159424, 6.721227169036865, 3.8574347496032715, 4.88702392578125]
[INFO] [1592225701.105481, 2807.159000]: [1.4902827739715576, 6.837770462036133, 6.713583469390869, 3.885507822036743, 4.896132469177246]
[INFO] [1592225701.122672, 2807.173000]: [1.4870343208312988, 6.840242862701416, 6.719925403594971, 3.8667709827423096, 4.897160053253174]
[INFO] [1592225701.166731, 2807.207000]: [1.4792242050170898, 6.822596073150635, 6.725748538970947, 3.8882980346679688, 4.889766216278076]
[INFO] [1592225701.209406, 2807.244000]: [1.4918454885482788, 6.810230731964111, 6.695789813995361, 3.873197317123413, 4.896898746490479 5]
[INFO] [1592225701.254149, 2807.277000]: [1.4895764589309692, 6.824028491973877, 6.715404987335205, 3.8714802265167236, 4.898824214935303]
[INFO] [1592225701.259325, 2807.282000]: [1.4965587854385376, 6.8290534019470215, 6.71699333190918, 3.87522554397583, 4.893421173095703]
[INFO] [1592225701.302218, 2807.302000]: [1.4895827770233154, 6.8205647468566895, 6.722443580627441, 3.8815529346466064, 4.89976167678833]
[INFO] [1592225701.339506, 2807.325000]: [1.4956141710281372, 6.818865776062012, 6.718554973602295, 3.8746438026428223, 4.897343635559082]
```

Minimum laser readings for five regions

Custom World Environment present in ‘skbot_custom.world’ file.



- Now create another script file called `‘obstacle_avoidance.py’` inside `/skbot_motion/scripts/` folder:

- Provide executable permission to the file:
  `$ chmod a+x obstacle_avoidance.py`

- Now run the following two commands on two different terminals:

  On Terminal 1:
  `$ roslaunch skbot_gazebo skbot_world.launch`

  On Terminal 2:
  `$ rosrun skbot_motion obstacle_avoidance.py`

- You should be able to see the robot moving in the environment while avoiding the obstacles.

File: /skbot/skbot_motion/scripts/obstacle_avoidance.py

```
#! /usr/bin/env python

import rospy
from sensor_msgs.msg import LaserScan
from geometry_msgs.msg import Twist

pub = None

def clbk_laser(msg):
    regions = {
        'right':  min(min(msg.ranges[0:143]), 10),
        'fright': min(min(msg.ranges[144:287]), 10),
        'front':  min(min(msg.ranges[288:431]), 10),
        'fleft':  min(min(msg.ranges[432:575]), 10),
        'left':   min(min(msg.ranges[576:719]), 10),
    }
    take_action(regions)
```

This callback functions reads the laser scans and decides the actions to be taken by the robot.

…. continued

Take different actions (different velocities depending on laser readings)

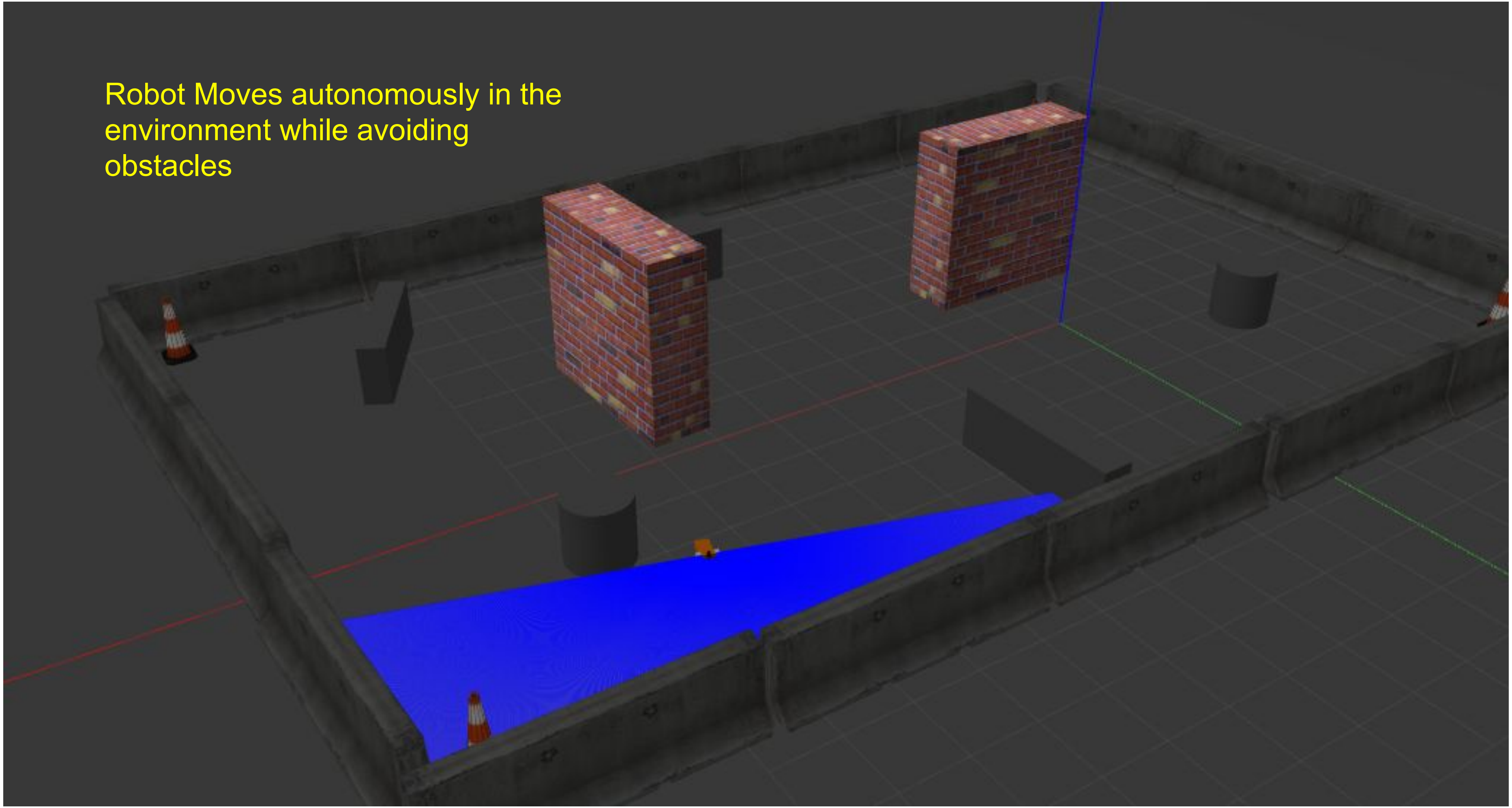
```
def take_action(regions):
    msg = Twist()
    linear_x = 0
    angular_z = 0

    state_description = ''

    if regions['front'] > 1 and regions['fleft'] > 1 and regions['fright'] > 1:
        state_description = 'case 1 - nothing'
        linear_x = 0.6
        angular_z = 0
    elif regions['front'] < 1 and regions['fleft'] > 1 and regions['fright'] > 1:
        state_description = 'case 2 - front'
        linear_x = 0
        angular_z = 0.3
     ### Code Omitted here .. check the actual file from repo ###
      else:
        state_description = 'unknown case'
        rospy.loginfo(regions)

    rospy.loginfo(state_description)
    msg.linear.x = linear_x
    msg.angular.z = angular_z
    pub.publish(msg)
```

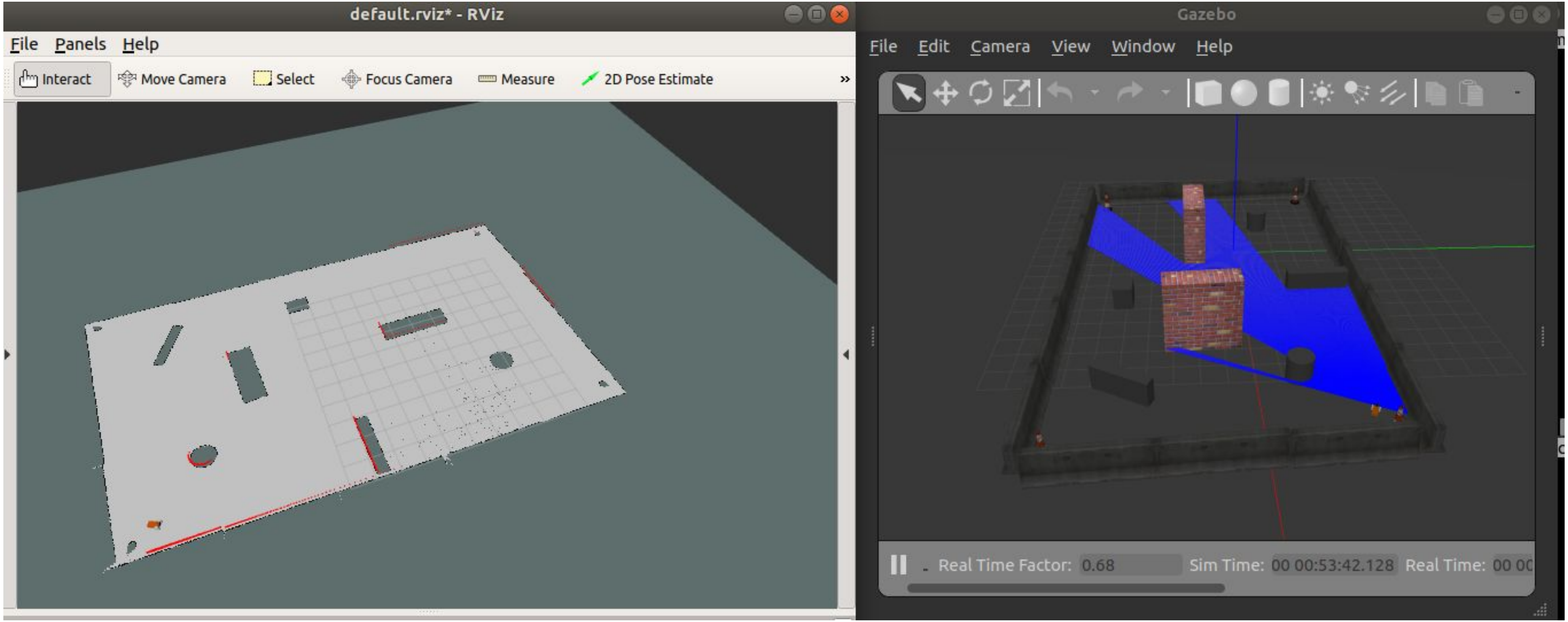
These velocities are published to /skbot/cmd_vel topic.

…. continued

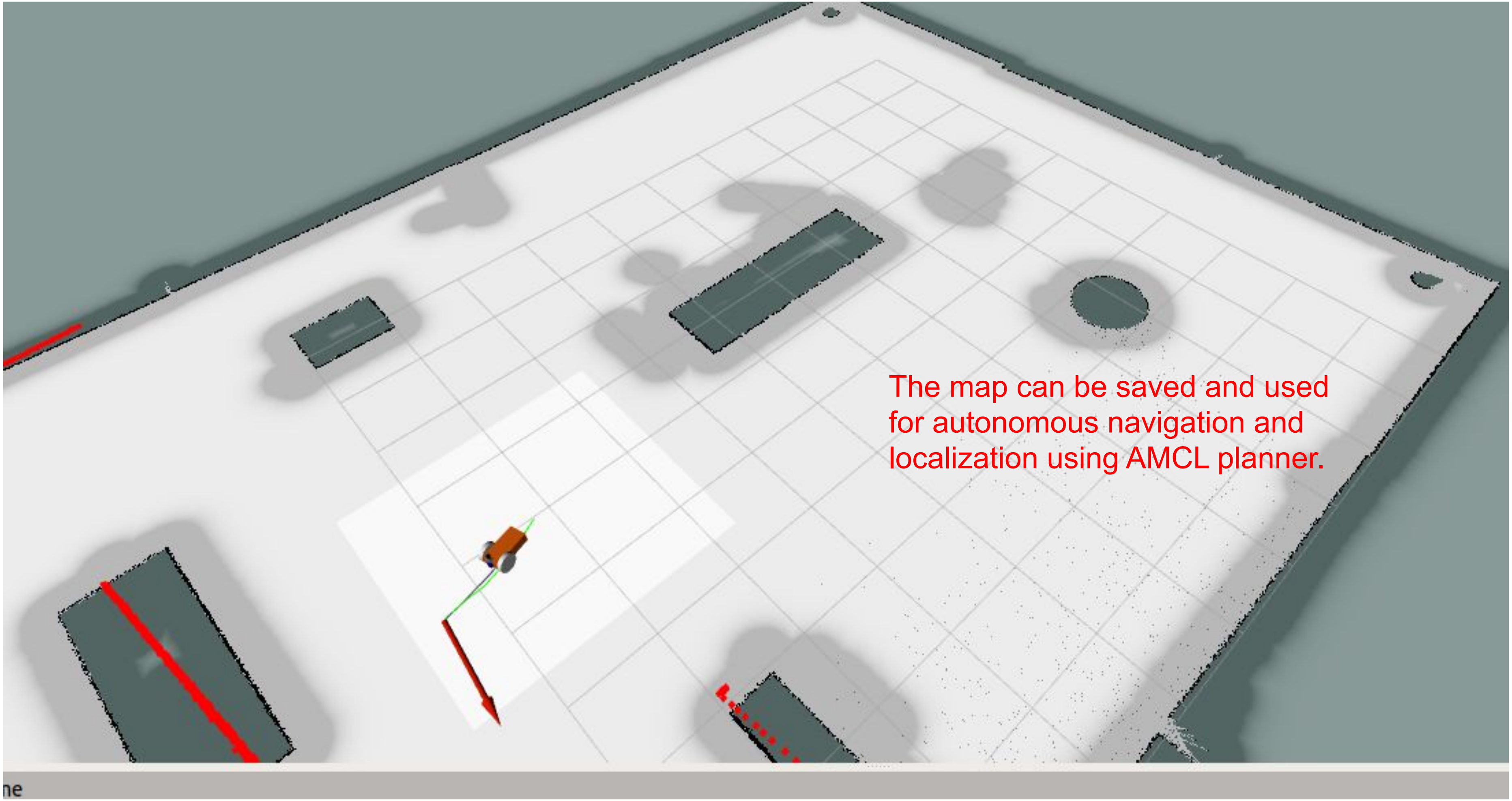
```
def main():
    global pub

    rospy.init_node('reading_laser')

    pub = rospy.Publisher('/skbot/cmd_vel', Twist, queue_size=1)

    sub = rospy.Subscriber('/skbot/laser/scan', LaserScan, clbk_laser)

    rospy.spin()

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

The callback function ‘clbk_laser’ reads the scan value and then publishes the velocities into the publisher node ‘pub’.


Robot Moves autonomously in the
environment while avoiding
obstacles



$ roslaunch skbot_gazebo skbot_world.launch (terminal 1)
$ roslaunch skbot_navigation gmapping_demo.launch (terminal 2)
$ roslaunch skbot_description skbot_rviz_gmapping.launch (add RobotModel, Laser Scanner and Map to Display window) (terminal 3)
$ rosrun skbot_motion obstacle_avoidance.py (terminal 4)


The map can be saved and used for autonomous navigation and localization using AMCL planner.
ne

Summary

- We learned to write our programs (nodes) to control robot motion or process sensor data. This can be used for developing implementing new algorithms on the robot.
- We demonstrate this by implementing obstacle avoidance algorithm.
- To do
  - Wall Following Robot.

- Resources:
  - More information is available at this link