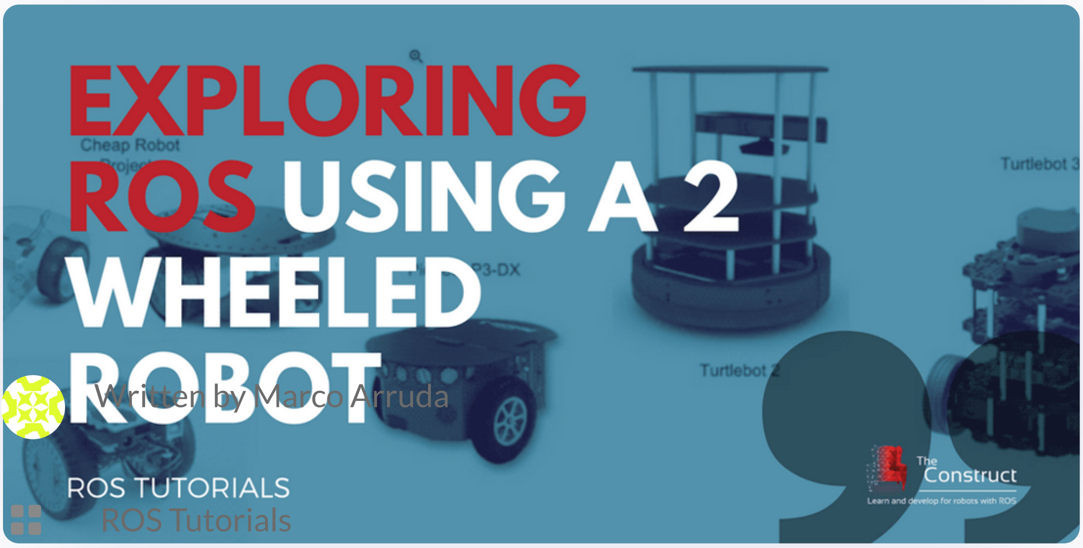
[ROS Projects] – Exploring ROS using a 2 Wheeled Robot



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ROS Tutorials

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This project is about using a Two Wheeled Mobile Robot to explore features and tools provided by ROS (Robot Operating System). We start building the robot from the scratch, using URDF (Unified Robot Description Format) and RViz to visualize it. Further, we describe the inertia and show how to simplify the URDF using XACROS. Later, motion planning algorithms, such as Obstacle Avoidance and Bugs 0, 1 and 2 are developed to be used in the built robot. Some ROS packages, like robot_localization, are used to built a map and localize on it.

Exploring ROS with a 2 Wheeled Robot #Part 1

Format (URDF). At the end of this video, we will have a model ready and running in Gazebo simulator.

Steps to create the project as shown in the video

Step 1.1

- Head to **ROS Development Studio** and create a new project.
- Provide a suitable **project name** and some useful **description**.
- Open the project (this will take few seconds)
- Once the project is loaded run the ***IDE*** from the tools menu. Also verify that the inital **directory structure** should look like following:

```
.
├────── ai_ws
├────── catkin_ws
│      ├─── build
│      ├─── devel
│      └───
├────── notebook_ws
│      ├─── default.ipynb
```

```
├── devel
└── src
```

The directory `simulation_ws` is also called **simulation workspace**, it is supposed to contain the code and scripts relevant for simulation. For all other files we have the `catkin_ws` (or catkin workspace). A few more terminologies to familiarize are `xacro` and `macro`, basically `xacro` is a file format encoded in `xml`. `xacro` files come with extra features called `macros` (akin `functions`) that helps in reducing the amount of written text in writing robot description. Robot model description for Gazebo simulation is described in `URDF` model format and `xacro` files simplify the process of writing elaborate robot description.

Step 1.2

Now we will create a `catkin package` with name **m2wr_description**. We will add rospy as dependency.

Start a **SHELL** from tools menu and navigate to **~simulation_ws/src** directory as follows

> **$ cd simulation_ws/src**

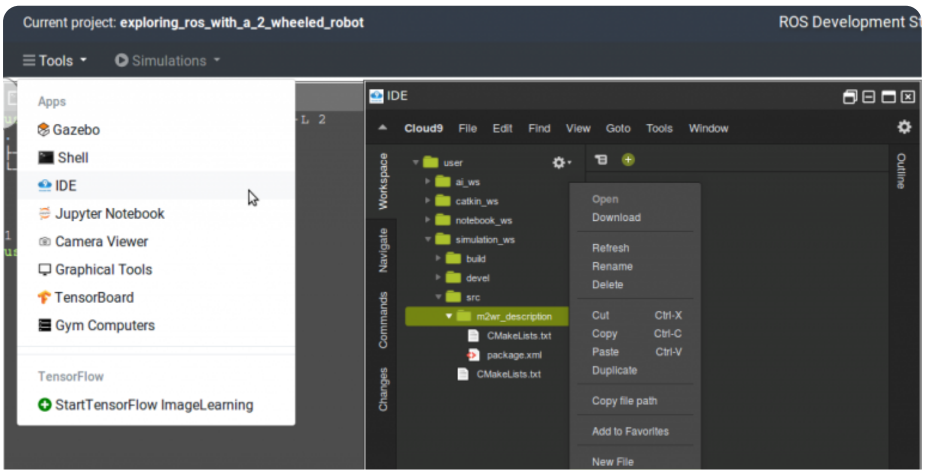
To create `catkin package` use teh following command

> **$ catkin_create_pkg m2wr_description rospy**

At this point we should have the following **directory structure**

```
│       ├── build
│       ├── devel
│       └──
├────── notebook_ws
│       ├── default.ipynb
│       └── images
└────── simulation_ws
        ├── build
        ├── devel
        └── src
            ├──── CMakeLists.txt
            └──── m2wr_description
                  ├─── CMakeLists.txt
                  └─── package.xml
```

Create a directory named **urdf** inside **m2wr_description** directory. Create a file named **m2wr.xacro** inside the newly created **urdf** directory. Creating files and directories is easier (right mouse click and select appropriate option) using the **IDE** from the **Tools** menu option.



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

<robot name="m2wr" xmlns:xacro="https://www.ros

  <material name="black">
    <color rgba="0.0 0.0 0.0 1.0"/>
  </material>
  <material name="blue">
    <color rgba="0.203125 0.23828125 0.28515625
  </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="1.0 0.423529411765 0.039215686
  </material>
  <material name="brown">
    <color rgba="0.870588235294 0.811764705882
  </material>
  <material name="red">
    <color rgba="0.80078125 0.12890625 0.132812
  </material>
  <material name="white">
    <color rgba="1.0 1.0 1.0 1.0"/>
  </material>
```

```
<gazebo reference="link_left_wheel">
  <material>Gazebo/Blue</material>
</gazebo>
<gazebo reference="link_right_wheel">
  <material>Gazebo/Blue</material>
</gazebo>

<link name="link_chassis">
  <!-- pose and inertial -->
  <pose>0 0 0.1 0 0 0</pose>

  <inertial>
    <mass value="5"/>
    <origin rpy="0 0 0" xyz="0 0 0.1"/>
    <inertia ixx="0.0395416666667" ixy="0" ix
  </inertial>

  <collision name="collision_chassis">
    <geometry>
      <box size="0.5 0.3 0.07"/>
    </geometry>
  </collision>

  <visual>
    <origin rpy="0 0 0" xyz="0 0 0"/>
    <geometry>
      <box size="0.5 0.3 0.07"/>
    </geometry>
    <material name="blue"/>
```

```
    <collision name="caster_front_collision">
      <origin rpy=" 0 0 0" xyz="0.35 0 -0.05"/>
      <geometry>
        <sphere radius="0.05"/>
      </geometry>
      <surface>
        <friction>
          <ode>
            <mu>0</mu>
            <mu2>0</mu2>
            <slip1>1.0</slip1>
            <slip2>1.0</slip2>
          </ode>
        </friction>
      </surface>
    </collision>
    <visual name="caster_front_visual">
      <origin rpy=" 0 0 0" xyz="0.2 0 -0.05"/>
      <geometry>
        <sphere radius="0.05"/>
      </geometry>
    </visual>
    </link>

  <!-- Create wheel right -->

  <link name="link_right_wheel">
    <inertial>
      <mass value="0.2"/>
      <origin rpy="0 1.5707 1.5707" xyz="0 0 0"
```

```
    <collision name="link_right_wheel_collision
      <origin rpy="0 1.5707 1.5707" xyz="0 0 0"
      <geometry>
        <cylinder length="0.04" radius="0.1"/>
      </geometry>
    </collision>

    <visual name="link_right_wheel_visual">
      <origin rpy="0 1.5707 1.5707" xyz="0 0 0"
      <geometry>
        <cylinder length="0.04" radius="0.1"/>
      </geometry>
    </visual>

  </link>

  <!--   Joint for right wheel  -->
  <joint name="joint_right_wheel" type="continu
    <origin rpy="0 0 0" xyz="-0.05 0.15 0"/>
    <child link="link_right_wheel" />
    <parent link="link_chassis"/>
    <axis rpy="0 0 0" xyz="0 1 0"/>
    <limit effort="10000" velocity="1000"/>
    <joint_properties damping="1.0" friction="1
  </joint>

  <!-- Left Wheel link -->

  <link name="link_left_wheel">
```

```
      <origin rpy="0 1.5707 1.5707" xyz="0 0 0"
      <inertia ixx="0.00052666666" ixy="0" ixz=
    </inertial>

    <collision name="link_left_wheel_collision"
      <origin rpy="0 1.5707 1.5707" xyz="0 0 0"
      <geometry>
        <cylinder length="0.04" radius="0.1"/>
      </geometry>
    </collision>

    <visual name="link_left_wheel_visual">
      <origin rpy="0 1.5707 1.5707" xyz="0 0 0"
      <geometry>
        <cylinder length="0.04" radius="0.1"/>
      </geometry>
    </visual>

  </link>

  <!--   Joint for right wheel  -->
  <joint name="joint_left_wheel" type="continuo
    <origin rpy="0 0 0" xyz="-0.05 -0.15 0"/>
    <child link="link_left_wheel" />
    <parent link="link_chassis"/>
    <axis rpy="0 0 0" xyz="0 1 0"/>
    <limit effort="10000" velocity="1000"/>
    <joint_properties damping="1.0" friction="1
  </joint>
```

In this `xacro` file we have defined the following:

- **chasis + caster wheel** : `link` type element
- **wheels** : `link` type elements (left + right)
- **joints** : `joint` type elements (left + right)

All of these elements have some common properties like `inertial`, `collision` and `visual`. The `inertial` and `collision` properties enable physics simulation and the `visual` property controls the appearance of the robot.

The `joints` help in defining the relative motion between links such as the motion of wheel with respect to the chassis. The **wheels** are links of cylindrical geometry, they are oriented (using `rpy` property) such that rolling is possible. The placement is controlled via the `xyz` property. For joints, we have specified the values for damping and friction as well. Now we can visualize the robot with rviz.

Step 1.3

To visualize the robot we just defined, we will create a lunch file named **rviz.launch** inside **launch** folder. We will populate it with following content:

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

  <param name="robot_description" command="cat

  <!-- send fake joint values -->
```

```
    <!-- Combine joint values -->
    <node name="robot_state_publisher" pkg="robot

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

</launch>
```

To launch the project use the following command

> **$ roslaunch m2wr_description rviz.launch**

Once the node is launched we need to open **Graphical Tools** from the **Tools** menu, it will help us to see the rviz window.

- Change the frame to `link_chasis` in **Fixed Frame** option
- Add a Robot Description display

Step 1.4

We are now ready to simulate the robot in gazebo. We will load a **empty world** from the **Simulations** menu option

To load our robot into the **empty world** we will need another launch file. We will create another launch file with name **spawn.launch** inside the launch directory with the following contents:

```
<?xml version="1.0" encoding="UTF-8"?>
<launch>
    <param name="robot_description" command="ca

    <arg name="x" default="0"/>
    <arg name="y" default="0"/>
    <arg name="z" default="0.5"/>

    <node name="mybot_spawn" pkg="gazebo_ros" t
          args="-urdf -param robot_description

</launch>
```

Next we will spawn our robot with the launch file in the empty gazebo world. Use the following command

> **$ roslaunch m2wr_description spawn.launch**

The robot should load in the gazebo window

At this point our directory structure should look like following

```
.
├────── ai_ws
├────── catkin_ws
│      ├─── build
│      ├─── devel
│      └───
```

```
└────── simulation_ws
      ├─── build
      ├─── devel
      └─── src
         ├── CMakeLists.txt
         └── m2wr_description
            ├── CMakeLists.txt
            ├── launch
            │   ├── rviz.launch
            │   └── spawn.launch
            ├── package.xml
            └── urdf
                └── m2wr.xacro
```

Step 1.5

Now we are ready to add control to our robot. We will add a new element called **plugin** to our `xacro` file. We will add a `differential drive` **plugin** to our robot. The new tag looks like follows:

```
<gazebo>
    <plugin filename="libgazebo_ros_diff_drive.
      <alwaysOn>true</alwaysOn>
      <updateRate>20</updateRate>
      <leftJoint>joint_left_wheel</leftJoint>
      <rightJoint>joint_right_wheel</rightJoint
      <wheelSeparation>0.4</wheelSeparation>
      <wheelDiameter>0.2</wheelDiameter>
      <torque>0.1</torque>
      <commandTopic>cmd_vel</commandTopic>
```

```
      <robotBaseFrame>link_chassis</robotBaseFr
    </plugin>
  </gazebo>
```

Add this element inside the `<robot> </robot>` tag and relaunch the project. Now we will be able to control the robot, we can check this by listing the available topics using following command

> **$ rostopic list**

To control the motion of the robot we can use the **keyboard_teleop** to publish motion commands using the keyboard. Use the following command in **Shell**

Now we can make the robot navigate with **keyboard** keys. This finishes the part-1.

References

RDS: **https://rds.theconstructsim.com/**

Source Code Repository:

https://bitbucket.org/theconstructcore/two-wheeled-robot/

Inertia Matrix reference:

https://en.wikipedia.org/wiki/List_of_moments_of_inertia

[irp posts="7150″ name="ROS Q&A | Showing my own URDF model in Gazebo"]

Exploring ROS with a 2 Wheeled Robot #Part 2 – URDF Macros

In this video, we are going to explore the macros for URDF files, using XACRO files. At the end of this video, we will have the same model organized in different files, in a organized way.

Steps continued from last part

Step 2.1

In the last 5 steps we acheived the following:

- Created a `xacro` file that contains the urdf description of our robot
- Created a `launch` files to spawn the robot in gazebo environment
- Controlled the simulated robot using **keyboard teleoperation**

In this part we will organize the existing project to make it more readable and modular. Even though our robot description had only few components, we had written a lengthy `xacro` file. Also in robot spawn `launch` file we have used the following line

```
<param name="robot_description" command="cat '$
```

Here we are using the `cat` command to **read** the contents of **m2wr.xacro** file into **robot_description** parameter. However, to use the features of the xacro file we need to parse and execute the `xacro` file and to achieve that we will modify the above line to

```
<param name="robot_description" command="$(find
```

The above command, uses the `xacro.py` file to exucute the instructions of **m2wr.xacro** file. A similar edit is needed for the **rviz.launch** file as well. So change the following line in **rviz.launch** file

```
<param name="robot_description" command="cat '$
```

```
<param name="robot_description" command="$(find
```

Step 2.2

At the moment, our `xacro` file does not contain any `instructions`. We will now split up the large **m2wr.xacro** file into smaller files and using the features of `xacro` we will assimilate the smaller files.

First we will extract the **material** properties from our `xacro` file and place them in a new file called **materials.xacro**. We will create a new file named **materials.xacro** inside the urdf folder and write the following contents into it

```
<?xml version="1.0" ?>
<robot name="m2wr" xmlns:xacro="https://www.ros
  <material name="black">
    <color rgba="0.0 0.0 0.0 1.0"/>
  </material>
  <material name="blue">
    <color rgba="0.203125 0.23828125 0.28515625
  </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="1.0 0.423529411765 0.039215686
```

```
  </material>
  <material name="red">
    <color rgba="0.80078125 0.12890625 0.132812
  </material>
  <material name="white">
    <color rgba="1.0 1.0 1.0 1.0"/>
  </material>
</robot>
```

We need to replace all `material` elements in the original **m2wr.xacro** file with following `include` directive

```
<xacro:include filename="$(find m2wr_descriptio
```

To test the changes we can start the rviz visualization with command

> **$ roslaunch m2wr_description rviz.launch**

Use **Graphical Tool** to see the rviz output

Going further we will now remove more code from the **m2wr.xacro** file and place it in a new file. Create a new file with name **m2wr.gazebo** inside the urdf directory. We will move all the `gazebo` tags from the **m2wr.xacro** file to this new file. We will need to add the enclosing

```
<?xml version="1.0" ?>
<robot name="m2wr" xmlns:xacro="https://www.ros
<gazebo reference="link_chassis">
    <material>Gazebo/Orange</material>
  </gazebo>
  <gazebo reference="link_left_wheel">
    <material>Gazebo/Blue</material>
  </gazebo>
  <gazebo reference="link_right_wheel">
```

```
  <gazebo>
    <plugin filename="libgazebo_ros_diff_drive.
      <alwaysOn>true</alwaysOn>
      <updateRate>20</updateRate>
      <leftJoint>joint_left_wheel</leftJoint>
      <rightJoint>joint_right_wheel</rightJoint
      <wheelSeparation>0.4</wheelSeparation>
      <wheelDiameter>0.2</wheelDiameter>
      <torque>0.1</torque>
      <commandTopic>cmd_vel</commandTopic>
      <odometryTopic>odom</odometryTopic>
      <odometryFrame>odom</odometryFrame>
      <robotBaseFrame>link_chassis</robotBaseFr
    </plugin>
  </gazebo>
```

We will add another `include` directive to the **m2wr.xacro** file (as shown)

```
<xacro:include filename="$(find m2wr_descriptio
```

To see whether everything works, we can launch the `gazebo simulation` of and **empty world** and **spawn** the robot. First we will start the gazebo simulation from the **Simulations** menu option and then spawn a robot with the following command

> **$ roslaunch m2wr_description spawn.launch**

Step 2.3

Next we will use `macros`, which are like functions, to reduce the remaining code in **m2wr.xacro** file.

Create a new file **macro.xacro** inside the urdf directory with following contents

```
<?xml version="1.0"?>
<robot xmlns:xacro="http://www.ros.org/wiki/xac
    <xacro:macro name="link_wheel" params="name
        <link name="${name}">
            <inertial>
              <mass value="0.2"/>
              <origin rpy="0 1.5707 1.5707" xyz
              <inertia ixx="0.000526666666667"
```

```
          <geometry>
            <cylinder length="0.04" radius=
          </geometry>
        </collision>
        <visual name="${name}_visual">
          <origin rpy="0 1.5707 1.5707" xyz
          <geometry>
            <cylinder length="0.04" radius=
          </geometry>
        </visual>
      </link>
    </xacro:macro>

    <xacro:macro name="joint_wheel" params="nam
      <joint name="${name}" type="continuous">
        <origin rpy="0 0 0" xyz="${origin_xyz}"
        <child link="${child}"/>
        <parent link="link_chassis"/>
        <axis rpy="0 0 0" xyz="0 1 0"/>
        <limit effort="10000" velocity="1000"/>
        <joint_properties damping="1.0" frictio
      </joint>
    </xacro:macro>

</robot>
```

In the above code we have defined three `macros`, their purpose is to take parameters and create the required element (`link` element). The first `macro` is named **link_wheel** and it accepts three parameters **name**, **child** and **origin_xyz** and it creates a **joint** link.

We will use these `macro` in our robot description file (**m2wr.xacro**). To use macros we will replace the `link` element by the `macros` as follows

```
<link name="link_right_wheel">
    <inertial>
      <mass value="0.2"/>
      <origin rpy="0 1.5707 1.5707" xyz="0 0 0"
      <inertia ixx="0.00052666666" ixy="0" ixz=
    </inertial>

    <collision name="link_right_wheel_collision
      <origin rpy="0 1.5707 1.5707" xyz="0 0 0"
      <geometry>
        <cylinder length="0.04" radius="0.1"/>
      </geometry>
    </collision>

    <visual name="link_right_wheel_visual">
      <origin rpy="0 1.5707 1.5707" xyz="0 0 0"
      <geometry>
        <cylinder length="0.04" radius="0.1"/>
      </geometry>
    </visual>
  </link>

  <link name="link_left_wheel">
```

```
      <inertia ixx="0.00052666666" ixy="0" ixz=
    </inertial>

    <collision name="link_left_wheel_collision"
      <origin rpy="0 1.5707 1.5707" xyz="0 0 0"
      <geometry>
        <cylinder length="0.04" radius="0.1"/>
      </geometry>
    </collision>

    <visual name="link_left_wheel_visual">
      <origin rpy="0 1.5707 1.5707" xyz="0 0 0"
      <geometry>
        <cylinder length="0.04" radius="0.1"/>
      </geometry>
    </visual>
  </link>
```

replaced by

```
 <xacro:link_wheel name="link_right_wheel" />
 <xacro:link_wheel name="link_left_wheel" />
```

Similar addition for the **link_left_wheel**. We will also replace the two wheel `joint` elements with following

```
 <xacro:joint_wheel name="joint_right_wheel"  ch
 <xacro:joint_wheel name="joint_left_wheel"   ch
```

```
<xacro:include filename="$(find m2wr_descriptio
```

The final contents of the **m2wr.xacro** shoud be following

```
<?xml version="1.0" ?>
<robot name="m2wr" xmlns:xacro="https://www.ros

  <!-- include the xacro files-->
  <xacro:include filename="$(find m2wr_descript
  <xacro:include filename="$(find m2wr_descript
  <xacro:include filename="$(find m2wr_descript

  <!-- Chasis defined here -->
  <link name="link_chassis">
    <pose>0 0 0.1 0 0 0</pose>
    <inertial>
      <mass value="5"/>
      <origin rpy="0 0 0" xyz="0 0 0.1"/>
      <inertia ixx="0.0395416666667" ixy="0" ix
    </inertial>

    <collision name="collision_chassis">
      <geometry>
        <box size="0.5 0.3 0.07"/>
      </geometry>
    </collision>

    <visual>
      <origin rpy="0 0 0" xyz="0 0 0"/>
```

```
      <material name="blue"/>
    </visual>

    <!-- caster front -->
    <collision name="caster_front_collision">
      <origin rpy=" 0 0 0" xyz="0.35 0 -0.05"/>
      <geometry>
        <sphere radius="0.05"/>
      </geometry>
      <surface>
        <friction>
          <ode>
            <mu>0</mu>
            <mu2>0</mu2>
            <slip1>1.0</slip1>
            <slip2>1.0</slip2>
          </ode>
        </friction>
      </surface>
    </collision>
    <visual name="caster_front_visual">
      <origin rpy=" 0 0 0" xyz="0.2 0 -0.05"/>
      <geometry>
        <sphere radius="0.05"/>
      </geometry>
    </visual>
    </link>


  <!-- Create wheel right -->
```

```
  <xacro:joint_wheel name="joint_right_wheel"


  <!-- Left Wheel link -->

  <xacro:link_wheel name="link_left_wheel" />
  <xacro:joint_wheel name="joint_left_wheel"

</robot>
```

The above code is much shorter than what we started with. We have only used a few of the features available in `xacro` description.

Finally, we can test everything together by launching the `gazebo` simulator and spawing our robot. Start a new `gazebo` simulator with **empty world** and spawn our robot

> **$ roslaunch m2wr_description spawn.launch**

That is it, we have optimized our code by splitting the large `xacro` file into other files and using `macros`.

References

RDS: **https://rds.theconstructsim.com/**

Source Code Repository:

https://bitbucket.org/theconstructcore/two-wheeled-robot

[irp posts="9004″ name="My Robotic Manipulator – Part #1 –

Exploring ROS with a 2 Wheeled Robot #Part 3 – URDF Laser Scan Sensor

In this video, we are going to insert a laser scan sensor to a 2 wheeled robot the robot.

Steps continued from last part

Step 3.1

Now we will add a **laser scan sensor** to our robots urdf model.

We will modify the urdf file (**m2wr.xacro**) as follows

- Add a `link` element to our robot. This `link` will be ***cylindrical*** in shape and will represent the sensor.
- Add a `joint` element to our robot. This will connect the sensor to robot body rigidly.
- Define a new `macro` to calculate the inertial property of a cylinder using its dimensions (`length` and `radius`)
- Finally a **laser scan sensor** `plugin` element will add sensing ability to the `link` that we created (the cylinder representing the sensor).

Open the **m2wr.xacro** file and add a new `link` element and a new `joint` element

```
      <mass value="1" />
      <!-- RANDOM INERTIA BELOW -->
      <inertia ixx="0.02" ixy="0" ixz="0" iyy="
    </inertial>

    <visual>
      <origin xyz="0 0 0" rpy="0 0 0" />
      <geometry>
        <cylinder radius="0.05" length="0.1"/>
      </geometry>
      <material name="white" />
    </visual>

    <collision>
      <origin xyz="0 0 0" rpy="0 0 0"/>
      <geometry>
        <cylinder radius="0.05" length="0.1"/>
      </geometry>
    </collision>
  </link>

  <joint name="joint_sensor_laser" type="fixed"
    <origin xyz="0.15 0 0.05" rpy="0 0 0"/>
    <parent link="link_chassis"/>
    <child link="sensor_laser"/>
  </joint>
```

The above code block will result in the following visualization

---

Step 3.2

The `link` element we just added (for acting as sensor) has random inertia property (see line 5 of the above code). We can write some **sane** values using a `macro` that will calculate the **inertia** values using ***cylinder dimensions***. For this we add a new `macro` to our **macro.xacro** script. Add the following `macro` to the file

```
<xacro:macro name="cylinder_inertia" params="ma
    <inertia ixx="${mass*(3*r*r+l*l)/12}" ixy =
                iyy="${mass*(3*r*r+l*l)/12}" iy
</xacro:macro>
```

Lets use this `macro` in the sensor description `link` by modifying

Now we can simulate the robot and see if everything works well. Load an **empty world** in **gazebo simulator** window. Also open a **Shell** window and run the following command

> **$ roslaunch m2wr_description spawn.launch**

Next we need to add the sensor beharior to the `link`. To do so we will use the `laser` gazebo plugin. Information about this plugin is available **here**. Open the **m2wr.gazebo** file and add the following **plugin element**

```
<gazebo reference="sensor_laser">
    <sensor type="ray" name="head_hokuyo_sensor
      <pose>0 0 0 0 0 0</pose>
      <visualize>false</visualize>
```

```
        <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>10.0</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_cont
        <topicName>/m2wr/laser/scan</topicName>
        <frameName>sensor_laser</frameName>
      </plugin>
    </sensor>
  </gazebo>
```

This code specifies many important parameters

Update rate : Controls how often (how fast) the laser data is captured readings captured in a laser scan

range : Defines the minimum sense distance and maximum sense distance. If a point is below minimum sense its reading becomes zero(`0`) and if a point is further than the maximum sense distance its reading becomes `inf`. The **range resolution** defines the minimum distance between 2 points such that two points can be resolved as two separate points.

noise : This parameter lets us add gaussian noise to the range data captured by the sensor

topicName : Defines the name which is used for publishing the laser data

frameName : Defines the link to which the plugin has to be applied

With this plugin incorporated in the urdf file we are now ready to simulate and visualize the laser scan in action. Start the **empty world** and spawn the robot by launching the **spawn.launch** file in a **Shell**. To verify the working of the scan sensor check the list of topics in **Shell** window with following command

> **$ rostopic list**

You should get **/m2wr/laser/scan** in the list of topics

Step 3.3

We will visualize the laser scan data with rviz. First we will populate the robot environment with a few obstacles to better see the laser scan result. Use the box icon on top right of **gazebo** window to create a few box type obstacles (simply click and drop)

To start `rviz` visualization launch the **rviz.launch** file in a new **Shell** and use **Graphical Tool** window to load the visualization. Use the following command to launch rviz

> **$ roslaunch m2wr_description rviz.launch**

After starting `rviz` open the **Graphical Tools** window. Once `rviz` window loads you need to do the following settings

- Select **odom** in the **Fixed Frame** field (see the image below)
- Add two new displays using the **Add** button on the left bottom of rviz screen. The first display should be RobotModel and the other should be **LaserScan**
- Expand the **LaserScan** display by double clicking on its name and choose **Topic** as **/m2wr/laser/scan** (as shown in image below)

Now when we move the robot we can see the laser scan changing.

References

RDS: **https://rds.theconstructsim.com/**

Source Code Repository: **https://bitbucket.org/theconstructcore/two-wheeled-robot**

Gazebo plugins: **http://gazebosim.org/tutorials?tut=ros_gzplugins#Laser**

ROS URDF Links: **http://wiki.ros.org/urdf/XML/link**

ROS URDF Joints: **http://wiki.ros.org/urdf/XML/joint**

In this video, we are going to read the values of the laser scanner and filter a small part to work with

Steps to recreate the project as shown in the video

Step 4.1

- Head to ROS Development Studio and create a new project. Provide a suitable project name and some useful description. (We have named the project **video_no_4**)
- Open the project (this will take few seconds).
- We will clone the github repository to start. Open a **Shell** from the **Tools** menu and run the following commands in the **Shell**

> **$ cd simulation_ws/src**
>
> **$ git clone https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-simulation.git**

- We should have the following directory structure at this point

```
.
├────── ai_ws
├────── catkin_ws
|       ├─── build
```

```
├────── notebook_ws
│     ├─── default.ipynb
│     └─── images
└────── simulation_ws
      ├─── build
      ├─── devel
      └─── src
          ├── m2wr_description
          │   ├── CMakeLists.txt
          │   ├── launch
          │   ├── package.xml
          │   └── urdf
          └── my_worlds
              ├── CMakeLists.txt
              ├── launch
              ├── package.xml
              └── worlds
```

The package **m2wr_description** contains the project files developed so far (i.e. robot + laser scan sensor). The other package **my_worlds** contains two directories

- **launch** : Contains a launch file (we will use it shortly)
- **worlds** : Contains multiple world description files

From **Simulations** menu, choose the option **Select launch file…** and select the **world1.launch** option

We will create a new `catkin` package named **motion_plan** with dependencies **rospy**, **std_msgs**, **geometry_msgs** and **sensor_msgs**. Open a **Shell** from the **Tools** menu and write the following commands

> **$ cd ~/catkin_ws/src $ catkin_create_pgk motion_plan rospy std_msgs geometry_msgs sensor_msgs $ cd motion_plan $ mkdir scripts $ touch scripts/reading_laser.py**

These commands will create a directory (named **scripts**) inside the **motion_plan** package. This directory will contains a python scripts (**reading_laser.py**) that we will use to read the laser scan data coming on the **/m2wr/laser/scan** topic (we created this topic in last part). Add the following code to the **reading_laser.py** file

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

import rospy
from sensor_msgs.msg import LaserScan

def clbk_laser(msg):
    # 720/5 = 144
    regions = [
      min(msg.ranges[0:143]),
      min(msg.ranges[144:287]),
      min(msg.ranges[288:431]),
      min(msg.ranges[432:575]),
      min(msg.ranges[576:713]),
    ]
```

```
def main():
    rospy.init_node('reading_laser')
    sub= rospy.Subscriber("/m2wr/laser/scan", L

    rospy.spin()

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

We will make this script executable with following commands

> **$ cd ~/catkin_ws/src/motion_plan/scripts/ $ chmod +x reading_laser.py**

Before we run this file, we need to spawn our robot into the gazebo simulation. Use the following commands

> **$ roslaunch m2wr_description spawn.launch $ rosrun motion_plan reading_laser.py**

```
def clbk_laser(msg):
    # 720/5 = 144
    regions = [
      min(msg.ranges[0:143]),
      min(msg.ranges[144:287]),
      min(msg.ranges[288:431]),
      min(msg.ranges[432:575]),
      min(msg.ranges[576:713]),
     ]
     rospy.loginfo(regions)
```

The above code converts the 720 readings contained inside the `LaserScan` msg into five distinct readings. Each reading is the minimum distance measured on a sector of 60 degrees (total 5 sectors = 180 degrees).

Lets run this code again and see the data

Step 4.3

We can see the changes in range measurements as we move the robot near to the boundaries. One noticable thing is the `inf` value that is measured when the wall is away.

We can modify the code to change this value to read maximum range. The changed code is

```
def clbk_laser(msg):
    # 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),
```

With this modification we will only receive a value of range between 0 and 10.

This finishes the part 4.

References

RDS: **https://rds.theconstructsim.com/**

Source Code Repository:

https://bitbucket.org/theconstructcore/two-wheeled-robot

Gazebo plugins: **http://gazebosim.org/tutorials?tut=ros_gzplugins#Laser**

Exploring ROS with a 2 Wheeled Robot – Part 5

Steps to recreate the project as shown in the video

Step 5.1

- Head to ROS Development Studio and create a new project.
- Provide a suitable project name and some useful description. (We have named the project **part 5-obstacle avoidance**)
- Load/Start the project (this will take few seconds).
- Clone the github repository **two-wheeled-robot – Simulation**.
- Checkout to the **right** branch (**here** is more information about branch and branching in git)
- Open a **Shell** from the **Tools** menu and run the following commands in the **Shell**

> **$ cd simulation_ws/src**
>
> **$ git clone https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-simulation.git**
>
> **$ cd two-wheeled-robot-simulation**
>
> **$ git checkout 16e45ce**

- Compile the project to make it ready to use

> **cd ~/simulation_ws/src**

- Clone another github repository **two-wheeled-robot – Motion Planning**. Execute the following commands in the **Shell**

> **$ cd catkin_ws/src**
>
> **$ git clone https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning.git**

- Compile the project to make it ready to use

> **cd ~/catkin_ws/src**
>
> **catkin_make**

- At this point we should have the following directory structure

```
.
├────── ai_ws
├────── catkin_ws
│      ├─── build/
│      ├─── devel/
│      └─── src
│          ├── CMakeLists.txt
│          └── two-wheeled-robot-motion-planni
│              ├── CMakeLists.txt
│              ├── examples/
│              ├── launch/
│              ├── package.xml
│              └── scripts/
├────── notebook_ws
│      ├─── default.ipynb
│      └─── images/
└────── simulation_ws
    ├─── build/
    ├─── devel/
```

```
│   ├── package.xml
│   └── urdf/
└── my_worlds
    ├── CMakeLists.txt
    ├── launch/
    │   └── world.launch
    ├── package.xml
    └── worlds/
        ├── world01.world
        └── world02.world
```

Step 5.2

Start a simulation using the **Simulations** menu option. Select the **world.launch** option and launch the simulation.

Now we will take a look at the obstacle avoidance algorithm.

planning/scripts/obstacle_avoidance.py. There are 3 functions defined in this file:

- `main`
  This is the entry point of the file. This function sets up a **Subscriber** to the laser scan topic **/m2wr/laser/scan** and a **Publisher** to **/cmd_vel** topic.

```
def main():
    global pub

    rospy.init_node('reading_laser')
    pub = rospy.Publisher('/cmd_vel', Twist
    sub = rospy.Subscriber('/m2wr/laser/sca
    rospy.spin()
```

- `clbk_laser`
  We need to provide a callback function to the **Subscriber** defined in main, for this purpose we have this function. It receives laser scan data comprising of 720 readings and converts it into 5 readings (details in part 4 video).

```
def clbk_laser(msg):
    regions = {
        'right':  min(min(msg.ranges[0:143]
        'fright': min(min(msg.ranges[144:28
        'front':  min(min(msg.ranges[288:43
        'fleft':  min(min(msg.ranges[432:57
        'left':   min(min(msg.ranges[576:71
    }

    take_action(regions)
```

on the distances sensed in the five region (left, center-left, center, center-right, right). We consider possible combinations for obstacles, once we identify the obstacle configuration we steer the robot away from obstacle.

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

    state_description = ''

    if regions['front'] > 1 and regions['fleft'
        state_description = 'case 1 - nothing'
        linear_x = 0.6
        angular_z = 0
    elif regions['front'] < 1 and regions['flef
        state_description = 'case 2 - front'
        linear_x = 0
        angular_z = 0.3
    elif regions['front'] > 1 and regions['flef
        state_description = 'case 3 - fright'
        linear_x = 0
        angular_z = 0.3
    elif regions['front'] > 1 and regions['flef
        state_description = 'case 4 - fleft'
        linear_x = 0
        angular_z = -0.3
    elif regions['front'] < 1 and regions['flef
        state_description = 'case 5 - front and
```

```
        state_description = 'case 6 - front and
        linear_x = 0
        angular_z = -0.3
    elif regions['front'] < 1 and regions['flef
        state_description = 'case 7 - front and
        linear_x = 0
        angular_z = 0.3
    elif regions['front'] > 1 and regions['flef
        state_description = 'case 8 - fleft and
        linear_x = 0.3
        angular_z = 0
    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)
```

To test the logic lets run the simulation. We have the world loaded, now we will spawn the differential drive robot with following command

> **$ roslaunch m2wr_description spawn.launch**

Finally we launch the **obstacle avoidance** script to move the robot around and avoid obstacles

> **$ rosrun motion_plan obstacle_avoidance.py**

That finishes the instructions. You can change various settings like speed of robot, sensing distance etc and see how it works.

References

Simulation:

https://bitbucket.org/theconstructcore/two-wheeled-robot-simulation

Motion Planning:

https://bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning

Exploring ROS with a 2 Wheeled Robot – Part 6

In this video, we are going create an algorithm to go from a point to another using the odometry data to localize the robot.

Steps to recreate the project as shown in the video (continued from part 5)

Step 6.1

In this part we are going to implement a simple navigation algorithm to move our robot from **any point** to a desired point. We will use the concept of state machines to implement the navigation logic. In a **state machine** there are finite number of states that represent the current situation (or behavior) of the

- **Fix Heading** : Denotes the state when `robot heading` differs from the `desired heading` by more than a threshold (represented by `yaw_precision_` in code)
- **Go Straight** : Denotes the state when robot has **correct** heading but is away from the desired point by a distance greater than some threshold (represented by `dist_precision_` in code)
- **Done** : Denotes the state when robot has correct heading and has reached the destination.

The robot can be in any one state at a time and can switch to other states as different conditions arise. This is depicted by the following state transition diagram

To implement this state logic lets create a new python script inside the **~/catkin_ws/src/two-wheeled-robot-motion-planning/scripts/** directory named **go_to_point.py** with

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

# import ros stuff
import rospy
from sensor_msgs.msg import LaserScan
from geometry_msgs.msg import Twist, Point
from nav_msgs.msg import Odometry
from tf import transformations

import math

# robot state variables
position_ = Point()
yaw_ = 0
# machine state
state_ = 0
# goal
desired_position_ = Point()
desired_position_.x = -3
desired_position_.y = 7
desired_position_.z = 0
# parameters
yaw_precision_ = math.pi / 90 # +/- 2 degree al
dist_precision_ = 0.3

# publishers
pub = None

# callbacks
```

```
    # position
    position_ = msg.pose.pose.position

    # yaw
    quaternion = (
        msg.pose.pose.orientation.x,
        msg.pose.pose.orientation.y,
        msg.pose.pose.orientation.z,
        msg.pose.pose.orientation.w)
    euler = transformations.euler_from_quaterni
    yaw_ = euler[2]

def change_state(state):
    global state_
    state_ = state
    print 'State changed to [%s]' % state_

def fix_yaw(des_pos):
    global yaw_, pub, yaw_precision_, state_
    desired_yaw = math.atan2(des_pos.y - positi
    err_yaw = desired_yaw - yaw_

    twist_msg = Twist()
    if math.fabs(err_yaw) > yaw_precision_:
        twist_msg.angular.z = 0.7 if err_yaw >

    pub.publish(twist_msg)
```

```
        change_state(1)

def go_straight_ahead(des_pos):
    global yaw_, pub, yaw_precision_, state_
    desired_yaw = math.atan2(des_pos.y - positi
    err_yaw = desired_yaw - yaw_
    err_pos = math.sqrt(pow(des_pos.y - positio

    if err_pos > dist_precision_:
        twist_msg = Twist()
        twist_msg.linear.x = 0.6
        pub.publish(twist_msg)
    else:
        print 'Position error: [%s]' % err_pos
        change_state(2)

    # state change conditions
    if math.fabs(err_yaw) > yaw_precision_:
        print 'Yaw error: [%s]' % err_yaw
        change_state(0)

def done():
    twist_msg = Twist()
    twist_msg.linear.x = 0
    twist_msg.angular.z = 0
    pub.publish(twist_msg)

def main():
    global pub
```

```
    pub = rospy.Publisher('/cmd_vel', Twist, qu

    sub_odom = rospy.Subscriber('/odom', Odomet

    rate = rospy.Rate(20)
    while not rospy.is_shutdown():
        if state_ == 0:
            fix_yaw(desired_position_)
        elif state_ == 1:
            go_straight_ahead(desired_position_
        elif state_ == 2:
            done()
            pass
        else:
            rospy.logerr('Unknown state!')
            pass
        rate.sleep()

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

Lets analyze the contents of this script. We have defined the following function

- `main`
  This is the entry point of the file. This function sets up a **Subscriber** to the odometry topic **/odom** and a **Publisher** to **/cmd_vel** topic to command velocity of the robot. Further this function processes the state machine depending on the value of `state` variable.
- `clbk_odom`
  This is a callback function for the Subscriber defined in main

orientation information in **quaternions**. To obtains **yaw** the **quaternion** is converted into **euler angles** (line 43)

- `change_state`
  This function changes the value of the global `state` variable that stores the robot **state** information.
- `fix_yaw`
  This function is executed when robot is in state 0 (**Fix heading**). First the **current heading** of the robot is checked with **desired heading**. If the differene in **heading** is more than a threshold the robot is commanded to turn in its place.
- `go_straight_ahead`
  This function is executed when robot is in state 1 (**Go Straight**). This state occurs after robot has fixed the error in **yaw**. In this state, the distance between the robots **current position** and **desired position** is compared with a threshold. If robot is further away from **desired position** it is commanded to move forward. If the **current position** lies closer to the **desired position** then the `yaw` is again checked for error, if `yaw` is significantly different from the desired `yaw` value the robot goes to `state` 0.
- `done`
  Eventually robot achieves **correct heading** and **correct position**. Once in this state the robot stops.

Step 6.2

Start a simulation using the **Simulations** menu option. Select the **world.launch** option and launch the simulation.

To test the logic lets run the simulation. We have the world loaded, now we will spawn the differential drive robot with following command

> **$ roslaunch m2wr_description spawn.launch**

> **$ rosrun motion_plan obstacle_avoidance.py**

Now you should see the robot navigate to the point given in the **go_to_point.py** script (line 19-21) from its current location. With the navigation implemented we have finished the part 6 of the series.

References
RDS: **https://rds.theconstructsim.com/**
Simulation:
https://bitbucket.org/theconstructcore/two-wheeled-robot
Motion package:
https://bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning

Wall Following Robot Algorithm – Two Wheeled Robot #Part 7

In this video, we are going work with wall following robot algorithm. We'll start watching the demo, then let's go straight to the code and understand line by line how to perform the task.

Steps to recreate the project as shown in the video

Step 7.1

In this part we will write an algorithm to make the robot follow a wall. We can continue from the last part or start with a new project. These instructions are for starting with a new project.

- Go to **ROS Development Studio** and create a new project.
- Provide a suitable project name and some useful description. (We have named the project **exploring_ros_video_7**)
- Load/Start the project.

Now We will fetch the project files we have developed in previous part:

- Clone the bitbucket repository **two-wheeled-robot – Simulation**.
- Checkout to the **right** branch (**here** is more information about branch and branching in git)
- Open **Tools > Shell** and run the following commands

> **$ cd simulation_ws/src**
>
> **$ git clone https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-simulation.git**
>
> **$ cd two-wheeled-robot-simulation**
>
> **$ git checkout 16e45ce**

- Compile the project to make it ready to use

> **cd ~/simulation_ws/src**
>
> **catkin_make**

- Clone another github repository **two-wheeled-robot – Motion**

> **$ cd catkin_ws/src**
>
> **$ git clone**
>
> **https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning.git**
>
> **$ cd two-wheeled-robot-motion-planning**
>
> **$ git checkout f62dda2**

- Compile the project to make it ready to use

> **cd ~/catkin_ws/src**
>
> **catkin_make**

- At this point we should have the following directory structure

```
.
├── ai_ws
├── catkin_ws
│   ├── build
│   ├── devel
│   └── src
│       ├── CMakeLists.txt
│       └── two-wheeled-robot-motion-planning
│           ├── CMakeLists.txt
│           ├── package.xml
│           └── scripts
│               ├── follow_wall.py
│               ├── go_to_point.py
│               ├── obstacle_avoidance.py
│               └── reading_laser.py
├── explore_ros_video_7.zip
```

```
└── simulation_ws
    ├── build
    ├── devel
    └── src
        ├── CMakeLists.txt
        └── two-wheeled-robot-simulation
            ├── m2wr_description
            │   ├── CMakeLists.txt
            │   ├── launch
            │   ├── package.xml
            │   └── urdf
            └── my_worlds
                ├── CMakeLists.txt
                ├── launch
                ├── package.xml
                └── worlds
```

Step 7.2

- Launch the simulation with **Simulations > Select launch file > my_worlds > world.launch**
- Spawn the robot with following command

> **$ roslaunch m2wr_description spawn.launch**

- The wall following algorithm is written inside the **follow_wall.py** script located within the **~catkin_ws/src/two-wheeled-robot-motion-planning/scripts/** directory. Open **Tools>IDE** and browse to this script. It contains following code

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

import rospy
```

```
from nav_msgs.msg import Odometry
from tf import transformations

import math

pub_ = None
regions_ = {
        'right': 0,
        'fright': 0,
        'front': 0,
        'fleft': 0,
        'left': 0,
}
state_ = 0
state_dict_ = {
    0: 'find the wall',
    1: 'turn left',
    2: 'follow the wall',
}

def clbk_laser(msg):
    global regions_
    regions_ = {
        'right':  min(min(msg.ranges[0:143]), 1
        'fright': min(min(msg.ranges[144:287]),
        'front':  min(min(msg.ranges[288:431]),
        'fleft':  min(min(msg.ranges[432:575]),
        'left':   min(min(msg.ranges[576:713]),
    }
```

```
def change_state(state):
    global state_, state_dict_
    if state is not state_:
        print 'Wall follower - [%s] - %s' % (st
        state_ = state

def take_action():
    global regions_
    regions = regions_
    msg = Twist()
    linear_x = 0
    angular_z = 0
        state_description = ''

    d = 1.5

    if regions['front'] > d and regions['fleft'
        state_description = 'case 1 - nothing'
        change_state(0)
    elif regions['front'] < d and regions['flef
        state_description = 'case 2 - front'
        change_state(1)
    elif regions['front'] > d and regions['flef
        state_description = 'case 3 - fright'
        change_state(2)
    elif regions['front'] > d and regions['flef
        state_description = 'case 4 - fleft'
        change_state(0)
    elif regions['front'] < d and regions['flef
```

```
        state_description = 'case 6 - front and
        change_state(1)
    elif regions['front'] < d and regions['flef
        state_description = 'case 7 - front and
        change_state(1)
    elif regions['front'] > d and regions['flef
        state_description = 'case 8 - fleft and
        change_state(0)
    else:
        state_description = 'unknown case'
        rospy.loginfo(regions)

def find_wall():
    msg = Twist()
    msg.linear.x = 0.2
    msg.angular.z = -0.3
    return msg

def turn_left():
    msg = Twist()
    msg.angular.z = 0.3
    return msg

def follow_the_wall():
    global regions_

    msg = Twist()
    msg.linear.x = 0.5
    return msg
```

```
    rospy.init_node('reading_laser')

    pub_ = rospy.Publisher('/cmd_vel', Twist, q

    sub = rospy.Subscriber('/m2wr/laser/scan',

    rate = rospy.Rate(20)
    while not rospy.is_shutdown():
        msg = Twist()
        if state_ == 0:
            msg = find_wall()
        elif state_ == 1:
            msg = turn_left()
        elif state_ == 2:
            msg = follow_the_wall()
            pass
        else:
            rospy.logerr('Unknown state!')

        pub_.publish(msg)

        rate.sleep()

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

Lets analyze the contents of this scripts:

  - regions_ : this is a dictionary variable that holds the distances to five directions
  - state_ : this variable stores the current state of the robot
  - state_dict_ : this variable holds the possible states

- The functions defined are:
  - `main` : This is the entry point for the algorithm, it initializes a node, a publisher and a subscriber. Depending on the value of the `state_` variable, a suitable control action is taken (by calling other functions). This function also configures the frequency of execution of control action using `Rate` function.
  - `clbk_laser` : This function is passed to the `Subscriber` method and it executes when a new laser data is made available. This function writes **distance** values in the global variable `regions_` and calls the function `take_actions`
  - `take_action` : This function manipulates the **state** of the robot. The various distances stored in `regions_` variable help in determining the **state** of the robot.
  - `find_wall` : This function defines the action to be taken by the robot when it is not surrounded by any obstacle. This method essentially makes the robot move in a anti-clockwise circle (until it finds a wall).
  - `turn_left` : When the robot detects an obstacle it executes the turn left action
  - `follow_the_wall` : Once the robot is positioned such that its front and front-left path is clear while its front-right is obstructed the robot goes into the **follow wall** state. In this state this function is executed and this function makes the robot to follow a straight line.

This is the overall logic that governs the **wall following** behavior of the robot.

Step 7.3

spawned into it. Open **Tools>Shell** and enter the following command

> **$ rosrun motion_plan follow_wall**

This finishes the part 7.

References

RDS: **https://rds.theconstructsim.com/**

Simulation:

https://bitbucket.org/theconstructcore/two-wheeled-robot

Motion package:

https://bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning

Bug 0 Algorithm – Two Wheeled Robot #Part 8

algorithm using the previous scripts we have created before: Wall following + Go to point

Steps to recreate the project as shown in the video

Step 8.1

In this part we are going to program **Bug 0** behavior for our mobile robot. Basic requirements of **Bug 0** algorithm are:

- direction to goal should be known
- Wall sensing ability

We will start by creating a new project and cloning the project files in our project.

- Go to **ROS Development Studio** and create a new project.
- Provide a suitable project name and some useful description. (We have named the project **exploring_ros_video_8**)
- Load/Start the project.

Now We will fetch the project files we have developed in previous part:

- Clone the bitbucket repository **two-wheeled-robot – Simulation**.
- Checkout to the **right** branch (**here** is more information about

> **$ cd simulation_ws/src**
>
> **$ git clone**
>
> **https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-simulation.git**
>
> **$ cd two-wheeled-robot-simulation**
>
> **$ git checkout 16e45ce**

- Compile the project to make it ready to use

> **cd ~/simulation_ws/src**
>
> **catkin_make**

- Clone another github repository **two-wheeled-robot – Motion Planning**. Open **Tools > Shell** and run the following commands

> **$ cd catkin_ws/src**
>
> **$ git clone**
>
> **https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning.git**
>
> **$ cd two-wheeled-robot-motion-planning $ git checkout be714ee**

- Compile the project to make it ready to use

> **cd ~/catkin_ws/src**
>
> **catkin_make**

Step 8.2

The script **bug0.py** inside the **catkin_ws/src/two-wheeled-**

points (goal), while doing so if the robot detects an obstacle it goes around it.

The important functions we have defines in the **bug0.py** script are:

- `main` : The entry point of the program. It initializes a node, two subscribers (laser scan and odometry) and two **Service clients** (`go_to_point_switch` and `wall_follower_switch`). A **state** based logic is used to drive robot towards the **goal** position. Initially the robot is put in `Go to point` state, and when an obstacle is detected the state is switched to `Wall following` state. When there is a straight free path towards the goal the robot again switches to state `Go to point`.
- `change_state` : This function accepts a `state` argument and calls the respective service handler.

Other functions are similar to those implemented before in part 7 (eg. `clbk_odom`, `clbk_laser` and `normalize_angle`).

Also we have done changes to previously created scripts **follow_wall.py** and **go_to_point.py**. These scripts now implement an additional **service** server. The server helps in *activating* and *deactivating* the execution of respective algorithm based on the **state** maintained in the **bug0.py** script.

For example, when we are in `Go to point` state we communicate the server (`go_to_point_switch`) to activate `go_to_point` algorithm and we deactivate the other server (`wall_follower_switch`).

Here is the code for **bug0.py** script for reference:

```
# import ros message
from geometry_msgs.msg import Point
from sensor_msgs.msg import LaserScan
from nav_msgs.msg import Odometry
from tf import transformations
# import ros service
from std_srvs.srv import *

import math

srv_client_go_to_point_ = None
srv_client_wall_follower_ = None
yaw_ = 0
yaw_error_allowed_ = 5 * (math.pi / 180) # 5 de
position_ = Point()
desired_position_ = Point()
desired_position_.x = rospy.get_param('des_pos_
desired_position_.y = rospy.get_param('des_pos_
desired_position_.z = 0
regions_ = None
state_desc_ = ['Go to point', 'wall following']
state_ = 0
# 0 - go to point
# 1 - wall following

# callbacks
def clbk_odom(msg):
    global position_, yaw_

    # position
```

```
    # yaw
    quaternion = (
        msg.pose.pose.orientation.x,
        msg.pose.pose.orientation.y,
        msg.pose.pose.orientation.z,
        msg.pose.pose.orientation.w)
    euler = transformations.euler_from_quaterni
    yaw_ = euler[2]

def clbk_laser(msg):
    global regions_
    regions_ = {
        'right':  min(min(msg.ranges[0:143]), 1
        'fright': min(min(msg.ranges[144:287]),
        'front':  min(min(msg.ranges[288:431]),
        'fleft':  min(min(msg.ranges[432:575]),
        'left':   min(min(msg.ranges[576:719]),
    }

def change_state(state):
    global state_, state_desc_
    global srv_client_wall_follower_, srv_clien
    state_ = state
    log = "state changed: %s" % state_desc_[sta
    rospy.loginfo(log)
    if state_ == 0:
        resp = srv_client_go_to_point_(True)
        resp = srv_client_wall_follower_(False)
    if state_ == 1:
```

```
def normalize_angle(angle):
    if(math.fabs(angle) > math.pi):
        angle = angle - (2 * math.pi * angle) /
    return angle

def main():
    global regions_, position_, desired_positio
    global srv_client_go_to_point_, srv_client_

    rospy.init_node('bug0')

    sub_laser = rospy.Subscriber('/m2wr/laser/s
    sub_odom = rospy.Subscriber('/odom', Odomet

    srv_client_go_to_point_ = rospy.ServiceProx
    srv_client_wall_follower_ = rospy.ServicePr

    # initialize going to the point
    change_state(0)

    rate = rospy.Rate(20)
    while not rospy.is_shutdown():
        if regions_ == None:
            continue

        if state_ == 0:
            if regions_['front'] > 0.15 and reg
                change_state(1)
```

```
            err_yaw = normalize_angle(desired_y

            if math.fabs(err_yaw) < (math.pi /
               regions_['front'] > 1.5:
                change_state(0)

            if err_yaw > 0 and \
               math.fabs(err_yaw) > (math.pi /
               math.fabs(err_yaw) < (math.pi /
               regions_['left'] > 1.5:
                change_state(0)

            if err_yaw < 0 and \
               math.fabs(err_yaw) > (math.pi /
               math.fabs(err_yaw) < (math.pi /
               regions_['right'] > 1.5:
                change_state(0)

        rate.sleep()

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

Lastly, we have defined a new launch file (inside directory **~catkin_ws/src/two-wheeled-robot-motion-planning/launch**) that will help us run all these scripts. We can manually run individual scripts too but that is tiresome. The script **behaviors.launch** helps us launch the two behaviors i.e. **wall follower** and **go to point**. Here are the contents this launch file

```
<launch>
    <arg name="des_x" />
    <arg name="des_y" />
    <param name="des_pos_x" value="$(arg des_x)
    <param name="des_pos_y" value="$(arg des_y)
    <node pkg="motion_plan" type="follow_wall.p
    <node pkg="motion_plan" type="go_to_point.p
</launch>
```

Step 8.3

Let us now run the simulation and see the robot in action

- Launch the simulation with **Simulations > Select launch file > my_worlds > world.launch**
- Spawn the robot with following command

> **$ roslaunch m2wr_description spawn.launch**

- Launch the behavior nodes

> **$ roslaunch motion_plan behaviors.launch des_x:=0 des_y:=8**

  Notice the last two arguments are the co-ordinates of the **goal** location
- Run the bug0 algorithm

> **$ rosrun motion_plan bug0.py**

Now the robot should navigate towards the goal location.

References

RDS: **https://rds.theconstructsim.com/**

Simulation:

https://bitbucket.org/theconstructcore/two-wheeled-robot

Motion package:

https://bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning

ROS Basics: **Robot Ignite Academy**

Bug 0 Foil vs. Bug 1 – Two Wheeled Robot #Part 9

In this video, the 9th of the series Exploring ROS with a 2 Wheeled Robot, we are gonna see the Bug 0 Foil, why it happens and how it is improved using the Bug 1

Below are the steps to replicate the project as shown in the video

Step 9.1

We will start by creating a new project and cloning the project files in our project.

- Go to **ROS Development Studio** and create a new project.
- Provide a suitable project name and some useful description. (We have named the project **exploring_ros_video_9**)
- Load/Start the project.

Now We will fetch the project files we have developed in previous part:

- Clone the bitbucket repository **two-wheeled-robot – Simulation**.
- Checkout to the **right** branch (**here** is more information about branch and branching in git)
- Open **Tools > Shell** and run the following commands

> **$ cd simulation_ws/src**
>
> **$ git clone**
>
> **https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-simulation.git**
>
> **$ cd two-wheeled-robot-simulation**
>
> **$ git checkout 0d263ae**

> **cd ~/simulation_ws/src**
>
> **catkin_make**

- Clone another github repository **two-wheeled-robot – Motion Planning**. Open **Tools > Shell** and run the following commands

> **$ cd catkin_ws/src**
>
> **$ git clone https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning.git**
>
> **$ cd two-wheeled-robot-motion-planning $ git checkout 1b69124**

- Compile the project to make it ready to use

> **cd ~/catkin_ws/src**
>
> **catkin_make**

Step 9.2

- Launch the new simulation world with **Simulations > Select launch file > world.launch**This will start the gazebo window with a world (as shown)

- Open **Tools > Shell** and spawn the robot with following commands on shell

> **$ roslaunch m2wr_description spawn.launch y:=8**

- Once the robot is loaded into the world. Lets run our **Bug 0** algorithm to navigate to a point **x = 2** and **y = -3**

> **$ roslaunch motion_plan bug0.launch des_x:=2 des_y:=-3**

Notice that the robot moves in the circumference of the new fencing structure in the world, never reaching the goal position (as shown)

Thus we see the inherent drawback of the **Bug 0** algorithm. We can do better using the **Bug 1** algorithm as depicted in the image below

The **Bug 1** algorithm moves the robot about the obstacle (circumnavigate). When the robot passes near the goal it records this point and keeps on circumnavigating the obstacle. Once the robot reaches the initial point (where the robot first met the obstacle) it then goes to the point stored in memory and then moves towards the goal from there.

We can see that **Bug 1** algorithm, though lengthy, works better in situations where **Bug 0** will fail.

In the next part we will implement the **Bug 1** algorithm. This finishes the part 9.

References
RDS: **ROS Development Studio**
Simulation:
https://bitbucket.org/theconstructcore/two-wheeled-robot
Motion package:
https://bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning
ROS Basics: **Robot Ignite Academy**

Bug 1 – Two Wheeled Robot #Part 10

In this video an algorithm to perform the motion planning task Bug 1 is implemented using a machine state.

Steps to replicate the project as shown in the video

Step 10.1

We will start by creating a new project and cloning the project files in our project.

- Go to **ROS Development Studio** and create a new project.
- Provide a suitable project name and some useful description. (We have named the project **exploring_ros_video_10**)
- Load/Start the project.

Now We will fetch the project files we have developed in previous part:

- Clone the bitbucket repository **two-wheeled-robot – Simulation**.
- Checkout to the **right** branch (**here** is more information about branch and branching in git)
- Open **Tools > Shell** and run the following commands

> **$ cd simulation_ws/src**
>
> **$ git clone https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-simulation.git**
>
> **$ cd two-wheeled-robot-simulation**
>
> **$ git checkout 0d263ae**

- Compile the project to make it ready to use

- Clone another github repository **two-wheeled-robot – Motion Planning**. Open **Tools > Shell** and run the following commands

> **$ cd catkin_ws/src**
>
> **$ git clone**
>
> **https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning.git**
>
> **$ cd two-wheeled-robot-motion-planning**
>
> **$ git checkout 300b107**

- Compile the project to make it ready to use

> **cd ~/catkin_ws/src**
>
> **catkin_make**

Step 10.2

- Load the world file **Simulations > Select launch file > world.launch**

- Lets spawn the robot at **x=0, y=8**. Open **Tools > Shell** and enter the following commands

> **$ roslaunch m2wr_description spawn.launch y:=8**

- Next we set the **goal** (point **x=0, y=-3**) for our robot and launch the **Bug 1** behavior with following command

> **$ roslaunch motion_plan bug1.launch des_x:=0 des_y:=-3**

- While the robot performs the navigation, we can analyze the structure and contents of **Bug 1** algorithm

Here is the code for the **bug1.py** script contained in **~/catkin_ws/src/two-wheeled-robot-motion-planning/scripts/** directory:

```
from sensor_msgs.msg import LaserScan
from nav_msgs.msg import Odometry
from tf import transformations
# import ros service
from std_srvs.srv import *

import math

srv_client_go_to_point_ = None
srv_client_wall_follower_ = None
yaw_ = 0
yaw_error_allowed_ = 5 * (math.pi / 180) # 5 de
position_ = Point()
desired_position_ = Point()
desired_position_.x = rospy.get_param('des_pos_
desired_position_.y = rospy.get_param('des_pos_
desired_position_.z = 0
regions_ = None
state_desc_ = ['Go to point', 'circumnavigate o
state_ = 0
circumnavigate_starting_point_ = Point()
circumnavigate_closest_point_ = Point()
count_state_time_ = 0 # seconds the robot is in
count_loop_ = 0
# 0 - go to point
# 1 - circumnavigate
# 2 - go to closest point

# callbacks
```

```
    # position
    position_ = msg.pose.pose.position

    # yaw
    quaternion = (
        msg.pose.pose.orientation.x,
        msg.pose.pose.orientation.y,
        msg.pose.pose.orientation.z,
        msg.pose.pose.orientation.w)
    euler = transformations.euler_from_quaterni
    yaw_ = euler[2]

def clbk_laser(msg):
    global regions_
    regions_ = {
        'right':  min(min(msg.ranges[0:143]), 1
        'fright': min(min(msg.ranges[144:287]),
        'front':  min(min(msg.ranges[288:431]),
        'fleft':  min(min(msg.ranges[432:575]),
        'left':   min(min(msg.ranges[576:719]),
    }

def change_state(state):
    global state_, state_desc_
    global srv_client_wall_follower_, srv_clien
    global count_state_time_
    count_state_time_ = 0
    state_ = state
    log = "state changed: %s" % state_desc_[sta
```

```
            resp = srv_client_wall_follower_(False)
        if state_ == 1:
            resp = srv_client_go_to_point_(False)
            resp = srv_client_wall_follower_(True)
        if state_ == 2:
            resp = srv_client_go_to_point_(False)
            resp = srv_client_wall_follower_(True)

    def calc_dist_points(point1, point2):
        dist = math.sqrt((point1.y - point2.y)**2 +
        return dist

    def normalize_angle(angle):
        if(math.fabs(angle) > math.pi):
            angle = angle - (2 * math.pi * angle) /
        return angle

    def main():
        global regions_, position_, desired_positio
        global srv_client_go_to_point_, srv_client_
        global circumnavigate_closest_point_, circu
        global count_loop_, count_state_time_

        rospy.init_node('bug1')

        sub_laser = rospy.Subscriber('/m2wr/laser/s
        sub_odom = rospy.Subscriber('/odom', Odomet

        rospy.wait_for_service('/go_to_point_switch
```

```
srv_client_wall_follower_ = rospy.ServicePr

# initialize going to the point
change_state(0)

rate_hz = 20
rate = rospy.Rate(rate_hz)
while not rospy.is_shutdown():
    if regions_ == None:
        continue

    if state_ == 0:
        if regions_['front'] > 0.15 and reg
            circumnavigate_closest_point_ =
            circumnavigate_starting_point_
            change_state(1)

    elif state_ == 1:
        # if current position is closer to
        if calc_dist_points(position_, desi
            circumnavigate_closest_point_ =

        # compare only after 5 seconds - ne
        # if robot reaches (is close to) st
        if count_state_time_ > 5 and \
           calc_dist_points(position_, circ
            change_state(2)

    elif state_ == 2:
```

```
            count_loop_ = count_loop_ + 1
            if count_loop_ == 20:
                count_state_time_ = count_state_tim
                count_loop_ = 0

            rate.sleep()

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

Following are the important changes:

- Addition of new states in the robot states. These states are `circumnavigate obstacle` and `go to closest point`, as discussed in the previous part, the first one makes the robot go around the obstacle perimeter and the second state makes the robot to navigate to the point (on obstacle perimeter) that takes the robot closest to the goal.
- We have new variables to store the `start point` and the `closest point`.
- The `change state` function is similar to that in **Bug 0** with more number of states (3) :
  - State 1 : `Go to point` : Uses the **go_to_point** algorithm
  - State 2 : `circumnavigate obstacle` : Uses the **follow_wall** algorithm
  - State 3 : `go to closest point` : Uses the **follow_wall** algorithm

  In the last two states, we are using the same algorithm but there is a difference of the stop point. For the state 2, the stop point is the `start pont` (circumnavigate) while for the state 3 the stop point is the `closest point`

- Lastly, there is an additional variable that stores the number of seconds elapsed while in a state. This variable helps us in determining if we have completed the circumnavigation otherwise there can be ambiguity when the robot has to change from state 2 to state 3.

This finishes the Bug 1 algorithm.

References

RDS: **ROS Development Studio**

Simulation:

https://bitbucket.org/theconstructcore/two-wheeled-robot

Motion package:

https://bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning

ROS Basics: **Robot Ignite Academy**

From ROS Indigo to Kinetic – Exploring ROS with a 2 wheeled Robot – Part 11

In this video, the 11th of the series, you'll see the necessary changes in the project to make it work with ROS Kinetic, the new version supported by RDS (ROS Development Studio).

Lets start by creating a new project on RDS and cloning the project files from online repository.

- Go to **ROS Development Studio** and create a new project.
- Provide a suitable project name and some useful description. (We have named the project **exploring_ros_video_11**)
- Load/Start the project.

Now We will fetch the project files we have developed in previous part:

- Clone the bitbucket repository **two-wheeled-robot – Simulation**.
- Checkout to the **right** branch (**here** is more information about branch and branching in git)
- Open **Tools > Shell** and run the following commands

> **$ cd simulation_ws/src**
>
> **$ git clone https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-simulation.git**

- Compile the project to make it ready to use

> **cd ~/simulation_ws/src**
>
> **catkin_make**

- Clone another github repository **two-wheeled-robot – Motion Planning**. Open **Tools > Shell** and run the following commands

> **$ cd catkin_ws/src**
>
> **$ git clone**

> **$ cd two-wheeled-robot-motion-planning**
>
> **$ git checkout 3c130c8**

- Compile the project to make it ready to use

> **cd ~/catkin_ws/src**
>
> **catkin_make**

Step 11.2

At the time of creation of these video tutorials, RDS got upgraded from **ROS Indigo** to **ROS Kinetic**. While the code we have written in previous parts works fine, we can improve upon the organization and improve usability of the code. Thus, we have made the following changes to the project since the last part.

- **Removed** `Legacy mode` from the differential drive plugin (otherwise we see warning)
- Some minor modification to the launch file. Earlier we had the following syntax to import a file`<param name="robot_description" command="$(find xacro)xacro.py '$(find mono_bot)/urdf/mono_b.xacro'" />`
  Now we need not write the **.py** extension and also need to add **–inorder** argument
  `<param name="robot_description" command="$(find xacro)xacro --inorder '$(find mono_bot)/urdf/mono_b.xacro'" />`
- Next the macro tags are also fixed in **macro.xacro** file`<xacro name="link_wheel" params="name">`
  changes to
  `<xacro:macro name="link_wheel" params="name">`

```
<robot
xmlns:xacro="https://www.ros.org/wiki/xacro">
```

Next, we will integrate the **robot spawning** code into the **simulation launch** file. This will make the job of starting a simulation easier and faster as now the robot will automatically get spawned in a desired location when simulation starts.

Here is the launch file code (**bug1.launch**) for reference

```
<?xml version="1.0" encoding="UTF-8"?>


<launch>
  <arg name="robot" default="machines"/>
  <arg name="debug" default="false"/>
  <arg name="gui" default="true"/>
  <arg name="headless" default="false"/>
  <arg name="pause" default="false"/>
  <arg name="world" default="world03" />
  <include file="$(find gazebo_ros)/launch/empt
    <arg name="world_name" value="$(find my_wor
    <arg name="debug" value="$(arg debug)" />
    <arg name="gui" value="$(arg gui)" />
    <arg name="paused" value="$(arg pause)"/>
    <arg name="use_sim_time" value="true"/>
    <arg name="headless" value="$(arg headless)
    <env name="GAZEBO_MODEL_PATH" value="$(find
  </include>
  <include file="$(find m2wr_description)/launc
      <arg name="y" value="8" />
  </include>
```

Finally, we will create a script to do a robot position reset because everytime we make some change to our algorithm we need to start the simulation again and again. With the help of script we will not need to restart the simulation. This is possible because **gazebo** provides a **node** called **/gazebo/set_model_state** to set the model state. The following script shows how this is done

```
import rospy
from gazebo_msgs.srv import SetModelState
from gazebo_msgs.msg import ModelState

srv_client_set_model_state = rospy.ServiceProxy
model_state = ModelState()
model_state.model_name = 'm2wr'
model_state.pose.position.x = 0
model_state.pose.position.y = 8
resp = srv_client_set_model_state(model_state)
```

We can incorporate this same code (which is actually done inside **bug1.py**) to move the robot at a desired location before starting our navigation algorithm.

Finally we can test the changes made by launching the project. Start the simulation from **Simulations > Select launch file… > my_worlds > bug1.launch**. Then execute the **bug1** algorithm by opening **Tools > Shell** and enter commands

> **$ roslaunch motion_plan bug1.launch**

defined arguments in this launch file (**bug1.launch**). That finishes this part.

RDS: **ROS Development Studio**

Simulation: https://bitbucket.org/theconstructcore/two-wheeled-robot-simulation
Motion planning: https://bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning

ROS Courses: **Robot Ignite Academy**

[irp posts="8349″ name="How to add a rotating join to Kinect in Turtlebot"]

Bug 2 – Exploring ROS with a 2 wheeled robot #Part 12

Motion planning algorithms – In this video we show the implemented code for Bug 2 behavior and a simulation using it as well. From planning the line between starting and desired points, going straight to the point and following obstacles. Using the same robot and code we have been developing in this series.

Step 12.1

Lets start by creating a new project on RDS and cloning the project files from online repository.

- Go to **ROS Development Studio** and create a new project.
- Provide a suitable project name and some useful description. (We have named the project **exploring_ros_video_12**)
- Load/Start the project.

Now We will fetch the project files we have developed in previous part:

- Clone the bitbucket repository **two-wheeled-robot – Simulation**.
- Checkout to the **right** branch (**here** is more information about branch and branching in git)
- Open **Tools > Shell** and run the following commands

> **$ cd simulation_ws/src**
>
> **$ git clone**
>
> **https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-simulation.git**

- Compile the project to make it ready to use

> **cd ~/simulation_ws/src**
>
> **catkin_make**

- Clone another github repository **two-wheeled-robot – Motion Planning**. Open **Tools > Shell** and run the following commands

> **$ cd catkin_ws/src**

> **$ cd two-wheeled-robot-motion-planning**
>
> **$ git checkout 389faca**

- Compile the project to make it ready to use

> **cd ~/catkin_ws/src**
>
> **catkin_make**

Step 12.2

- Run a simulation. Open **Simulations > Select launch file… > my_worlds > world2.launch**.
- Open the script **bug2.py** located inside **~catkin_ws/src/two-wheeled-robot-motion-planning/scripts** directory

This script (**bug2.py**) contains the code for the new **Bug 2** navigation algorithm. Lets us analyze the contents of this script. Here are the contents of this file for reference

```
import rospy
# import ros message
from geometry_msgs.msg import Point
from sensor_msgs.msg import LaserScan
from nav_msgs.msg import Odometry
from tf import transformations
from gazebo_msgs.msg import ModelState
from gazebo_msgs.srv import SetModelState
# import ros service
from std_srvs.srv import *

import math
```

```
yaw_error_allowed_ = 5 * (math.pi / 180) # 5 de
position_ = Point()
initial_position_ = Point()
initial_position_.x = rospy.get_param('initial_
initial_position_.y = rospy.get_param('initial_
initial_position_.z = 0
desired_position_ = Point()
desired_position_.x = rospy.get_param('des_pos_
desired_position_.y = rospy.get_param('des_pos_
desired_position_.z = 0
regions_ = None
state_desc_ = ['Go to point', 'wall following']
state_ = 0
count_state_time_ = 0 # seconds the robot is in
count_loop_ = 0
# 0 - go to point
# 1 - wall following

# callbacks
def clbk_odom(msg):
    global position_, yaw_

    # position
    position_ = msg.pose.pose.position

    # yaw
    quaternion = (
        msg.pose.pose.orientation.x,
        msg.pose.pose.orientation.y,
```

```
    yaw_ = euler[2]

def clbk_laser(msg):
    global regions_
    regions_ = {
        'right':  min(min(msg.ranges[0:143]), 1
        'fright': min(min(msg.ranges[144:287]),
        'front':  min(min(msg.ranges[288:431]),
        'fleft':  min(min(msg.ranges[432:575]),
        'left':   min(min(msg.ranges[576:719]),
    }

def change_state(state):
    global state_, state_desc_
    global srv_client_wall_follower_, srv_clien
    global count_state_time_
    count_state_time_ = 0
    state_ = state
    log = "state changed: %s" % state_desc_[sta
    rospy.loginfo(log)
    if state_ == 0:
        resp = srv_client_go_to_point_(True)
        resp = srv_client_wall_follower_(False)
    if state_ == 1:
        resp = srv_client_go_to_point_(False)
        resp = srv_client_wall_follower_(True)

def distance_to_line(p0):
    # p0 is the current position
```

```
    p2 = desired_position_
    # here goes the equation
    up_eq = math.fabs((p2.y - p1.y) * p0.x - (p
    lo_eq = math.sqrt(pow(p2.y - p1.y, 2) + pow
    distance = up_eq / lo_eq

    return distance



def normalize_angle(angle):
    if(math.fabs(angle) > math.pi):
        angle = angle - (2 * math.pi * angle) /
    return angle

def main():
    global regions_, position_, desired_positio
    global srv_client_go_to_point_, srv_client_
    global count_state_time_, count_loop_

    rospy.init_node('bug0')

    sub_laser = rospy.Subscriber('/m2wr/laser/s
    sub_odom = rospy.Subscriber('/odom', Odomet

    rospy.wait_for_service('/go_to_point_switch
    rospy.wait_for_service('/wall_follower_swit
    rospy.wait_for_service('/gazebo/set_model_s

    srv_client_go_to_point_ = rospy.ServiceProx
```

```
# set robot position
model_state = ModelState()
model_state.model_name = 'm2wr'
model_state.pose.position.x = initial_posit
model_state.pose.position.y = initial_posit
resp = srv_client_set_model_state(model_sta

# initialize going to the point
change_state(0)

rate = rospy.Rate(20)
while not rospy.is_shutdown():
    if regions_ == None:
        continue

    distance_position_to_line = distance_to

    if state_ == 0:
        if regions_['front'] > 0.15 and reg
            change_state(1)

    elif state_ == 1:
        if count_state_time_ > 5 and \
           distance_position_to_line < 0.1:
            change_state(0)

    count_loop_ = count_loop_ + 1
    if count_loop_ == 20:
        count_state_time_ = count_state_tim
```

```
        rate.sleep()


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

- The number of states is again 2 (as in **Bug 0**) `Go to point` and `wall following`.
- We have one more function **distance_to_line()**. It calculates the distance of the robot from the `imaginary line` that joins **initial position** of the robot with the **desired position** of the robot.
- The idea of **Bug 2** algorithm is to follow this `imaginary line` in absense of obstacle (remember `go to point`). When an obstacle shows up, the robot starts circumnavigating it till it again finds itself close to the imaginary line.
- Rest of the code is similar to those of the previous parts (callbacks and state transition logic)
- Also note that we have made use of the `count_state_time_` variable to track time elapsed since changing state. This helps us to wrongly triggering state transition on the first contact with the `imaginary line` on first encounter. We let some time go by before we seek to find the `imaginary line` after we have started circumnavigating the obstacle.

Now we can go ahead and run the code. Open **Tools > Shell** and enter commands

> **$ roslaunch motion_plan bug2.launch**

The robot in the simulation will start the robot motion. With that we have finished the part 12.

References

ROS Development Studio: **RDS**

Simulation:

https://bitbucket.org/theconstructcore/two-wheeled-robot

Motion package:

https://bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning

GMapping – Exploring ROS with a 2 wheeled robot #Part 13

In this video we are going to use ROS GMapping in our 2 wheeled robot, the one used in the previous videos, to generate a map using SLAM technique. We are using the robot Laser Scan and Odometry data to generate the map.

Steps to recreate the project as shown in the video

Step 13.1

- Go to **ROS Development Studio** and create a new project.
- Provide a suitable project name and some useful description. (We have named the project **exploring_ros_video_13**)
- Load/Start the project.

Now We will fetch the project files we have developed in previous part:

- Clone the bitbucket repository **two-wheeled-robot – Simulation**.
- Checkout to the **right** branch (**here** is more information about branch and branching in git)
- Open **Tools > Shell** and run the following commands

> **$ cd simulation_ws/src**
>
> **$ git clone https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-simulation.git**

- Compile the project to make it ready to use

> **cd ~/simulation_ws/src**
>
> **catkin_make**

- Clone another github repository **two-wheeled-robot – Motion Planning**. Open **Tools > Shell** and run the following commands

> **$ cd catkin_ws/src**
>
> **$ git clone https://marcoarruda@bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning.git**

> **cd ~/catkin_ws/src**
>
> **catkin_make**

Step 13.2

In this part we are going to work with the **gmapping package**.

The **Gmapping** package package helps in creating the map of the robot environment and it requires the following informations to create environment map

- Laser scan
- Odometry information
- Sensor to robot base transform (named **link_chassis** in our robot urdf model)

The project we cloned contains the **launch file** to start the project. Open **Tools > IDE**, browse to **~catkin_ws/src/two-wheeled-robot-motion-planning/launch/** directory and load the **gmapping.launch** file. Here are the contents of this file for reference

The various elements and their utility is discussed next

Topics:

- scan_topic : points to the laser scan topic (**/m2wr/laser/scan**)
- base_frame : points to the robot base element (link_chassis)
- odom_frame : point to the odometry topic (**/odom**)

Transform:

- robot_state_publisher : publishes the transform of laser scanner with respect to robots chassis (**link_chassis**)
- Rviz : To visualize the map data and robot.
- Gmapping node: This node is responsible for doing the mapping. We have specified various important arguments to

Lets launch the simulation and see the robot in action. Load the **Bug 1** scene , open **Simulations > Select launch file… > my_worlds > bug1.launch**. We need to start a **Graphical Tool** from **Tools > Graphical Tools** menu to see the map in **rviz**. Also we will need a **Shell** to launch the **Gmapping** package.

Once the **rviz** window appears in the **Graphical Tools**, use the **Add** button (left bottom) to add a **laser_scan** and **map** display to the pane.

Now we can start another **Shell** and start the **Bug 1** algorithm to make the robot move. While the robot moves and registers the laser scan data we will see the map building.

Robot Ignite Academy: https://goo.gl/DCR2EA

ROS Development Studio: https://goo.gl/aW7x5y

Repositories:
Simulation: https://bitbucket.org/theconstructcore/two-wheeled-robot-simulation
Motion Planning: https://bitbucket.org/theconstructcore/two-wheeled-robot-motion-planning

[irp posts="9045″ name="ROS Mapping Tutorial. How To Provide a Map"]

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