EE405A
Gazebo Simulator

(TA) Gyuree Kang
School of Electrical Engineering
KAIST

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fingb20@kaist.ac.kr

Gazebo

What is Gazebo?

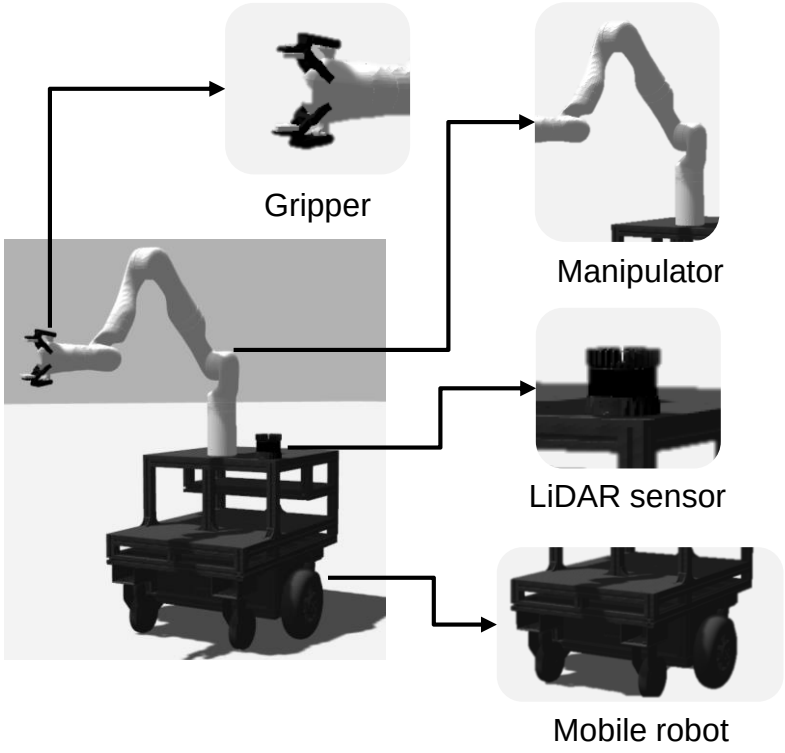
- Gazebo is an open source 3D robotics simulator with high-performance physics engines.

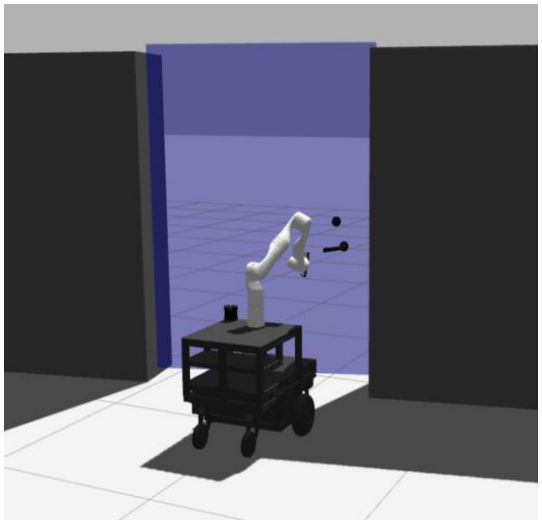
Tutorials: https://classic.gazebosim.org/

Gazebo

What can we do with Gazebo?

- Build and control your own robot model with actuator controllers.
- Obtain sensor data with simple plugins (2D/3D LiDAR, camera, force-torque sensor, contact sensor, IMU, etc.).
- Visualize robot and the environment (world).





Robot and surrounding environment

Gazebo

Goal

- Build a custom robot model.
- Make a simulation world to deploy the robot.
- Obtain sensor data from the simulator.
- Control the robot through external controller.

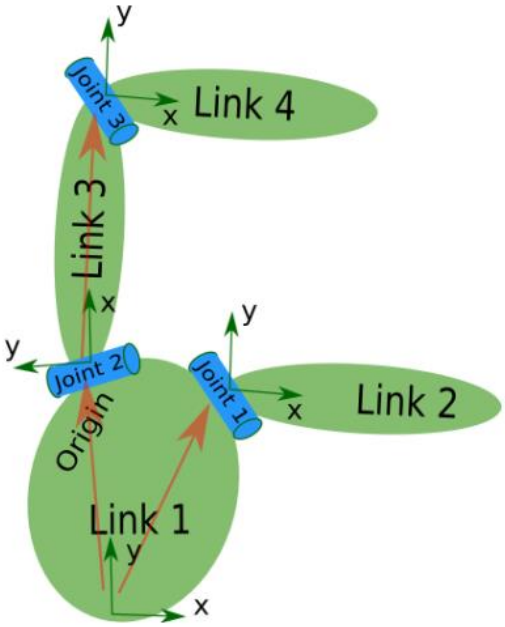
Download code: https://github.com/Guri-cccc/EE405A-2023-F1-simulation.git

URDF

URDF: (Universal Robot Description Format)
XML format for representing a robot model

- Link & joint definitions
  - Visual / collision
- Sensor plugins
- Controllers
- Robot states (joint states, tfs)

.xacro files: A scripting mechanism that allows more modularity and code re-use when defining a URDF model



Link&joints

Tutorials on make your own model: http://wiki.ros.org/urdf/Tutorials

```
<!-- camera object -->
<xacro:unless value="$(optenv DISABLE_GAZEBO_CAMERA false)">
  <xacro:include filename="$(find realsense_gazebo_plugin)/urdf/_d435.urdf.xacro" />
  <sensor_d435 parent="$(arg robot_name)_chassis">
    <origin xyz="0.390 0 0.075" rpy="0 0 0"/>
  </sensor_d435>
</xacro:unless>
```

Xacro file

File path: https://github.com/Guri-cccc/EE405A-2023-F1-simulation/blob/eeb1877c11b9c9cee4a1a0b1c9eaba842cd89b84/f1tenth-sim/urdf/macros_with_realsense.xacro

Car Model Urdf

Links and joints of the model

Car model

Link1

Link2

Joint

```
<link name="$(arg robot_name)_base_link"/>

<link name="$(arg robot_name)_chassis">
  <visual>
    <xacro:chassis_geometry/>
    <material name="red" />
  </visual>
</link>

<joint name="$(arg robot_name)_base_link_joint" type="fixed">
  <origin xyz="0 0 0.05" rpy="0 0 0" />
  <parent link="$(arg robot_name)_base_link" />
  <child link="$(arg robot_name)_chassis" />
</joint>
```

Link definitions and joint relationship

Bring up mesh

```
<xacro:macro name="chassis_geometry">
  <origin xyz="0.46 -0.135 -0.180" rpy="1.57 0 3.14" />
  <geometry>
    <mesh filename="package://f1tenth-sim/urdf/meshes/chassis.stl" scale="0.000990 0.0009375 0.0009375"/>
  </geometry>
</xacro:macro>
```

Link parameters

File path: https://github.com/Guri-cccc/EE405A-2023-F1-simulation/blob/eeb1877c11b9c9cee4a1a0b1c9eaba842cd89b84/f1tenth-sim/urdf/macros_with_realsense.xacro

Car model

Link definitions

Visual mesh: representation of a robot's links in the simulation
Collision mesh: actual area where collisions are detected

Use simple shaped collision mesh to decrease the computation cost

inertia

collision mesh

Visual mesh

```
<link name="$(arg robot_name)_laser_link">
  <inertial>
    <xacro:hokuyo_inertial_params />
  </inertial>
  <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://f1tenth-sim/urdf/meshes/hokuyo.stl"/>
      <material name="grey" />
    </geometry>
  </visual>
</link>
```

Link definition

File path: https://github.com/Guri-cccc/EE405A-2023-F1-simulation/blob/eeb1877c11b9c9cee4a1a0b1c9eaba842cd89b84/f1tenth-sim/urdf/macros_with_realsense.xacro

Car model

Joint definitions

Joint types

- Fixed
- Revolute:
  rotation with limit
- Continuous:
  rotation without limit
- Prismatic
- Floating:
  joint with 6 degrees of freedom
- Planar

```
<joint name="$(arg robot_name)_base_link_joint" type="fixed">
  <origin xyz="0 0 0.05" rpy="0 0 0" />
  <parent link="$(arg robot_name)_base_link" />
  <child link="$(arg robot_name)_chassis" />
</joint>
```

Fixed joint

```
<joint name="$(arg robot_name)_right_front_wheel_joint" type="continuous">
  <origin xyz="0 0 0" rpy="1.5708 0 0" />
  <parent link="$(arg robot_name)_right_steering_hinge" />
  <child link="$(arg robot_name)_right_front_wheel" />
  <axis xyz="0 0 -1" />
  <limit effort="10" velocity="100"/>
</joint>
```

Continuous joint

```
<joint name="$(arg robot_name)_left_steering_hinge_joint" type="revolute">
  <origin xyz="0.325 0.1 0" rpy="0 1.5708 0" />
  <parent link="$(arg robot_name)_chassis" />
  <child link="$(arg robot_name)_left_steering_hinge" />
  <axis xyz="-1 0 0" />
  <limit lower="-1.0" upper="1.0" effort="10" velocity="100" />
</joint>
```

Revolute joint

File path: https://github.com/Guri-cccc/EE405A-2023-F1-simulation/blob/eeb1877c11b9c9cee4a1a0b1c9eaba842cd89b84/f1tenth-sim/urdf/macros_with_realsense.xacro

Car model

```
<xacro:macro name="steering_hinge_transmission" params="name">
  <transmission name="${name}_transmission" type="SimpleTransmission">
    <type>transmission_interface/SimpleTransmission</type>
    <joint name="${name}_joint">
      <hardwareInterface>hardware_interface/EffortJointInterface</hardwareInterface>
    </joint>
    <actuator name="${name}_motor">
      <hardwareInterface>hardware_interface/EffortJointInterface</hardwareInterface>
      <mechanicalReduction>1</mechanicalReduction>
    </actuator>
  </transmission>
</xacro:macro>
```

Revolute joint transmission

```
<xacro:macro name="wheel_transmission" params="name">
  <transmission name="${name}_transmission" type="SimpleTransmission">
    <type>transmission_interface/SimpleTransmission</type>
    <joint name="${name}_joint">
      <hardwareInterface>hardware_interface/EffortJointInterface</hardwareInterface>
    </joint>
    <actuator name="${name}_motor">
      <hardwareInterface>hardware_interface/EffortJointInterface</hardwareInterface>
      <mechanicalReduction>1</mechanicalReduction>
    </actuator>
  </transmission>
</xacro:macro>
```

Continuous joint transmission

Sensor plugins (camera)

Define sensor type and name

Sensor properties

Add noise to sensor data

Define update rate (hz)

```
<sensor name="${camera_name}color" type="camera">
  <camera name="${camera_name}">
    <horizontal_fov>${69.4*deg_to_rad}</horizontal_fov>
    <image>
      <width>1920</width>
      <height>1080</height>
      <format>RGB_INT8</format>
    </image>
    <clip>
      <near>0.1</near>
      <far>100</far>
    </clip>
    <noise>
      <type>gaussian</type>
      <mean>0.0</mean>
      <stddev>0.007</stddev>
    </noise>
  </camera>
  <always_on>1</always_on>
  <update_rate>30</update_rate>
  <visualize>0</visualize>
</sensor>
```

Camera properties

File path: https://github.com/Guri-cccc/EE405A-2023-F1-simulation/blob/eeb1877c11b9c9cee4a1a0b1c9eaba842cd89b84/realsense_gazebo_plugin/urdf/_d435.gazebo.xacro

Sensor plugins (camera)

Intel realsense D435:
https://www.intelrealsense.com/depth-camera-d435/

```
<gazebo>
  <plugin name="${topics_ns}" filename="librealsense_gazebo_plugin.so">
    <prefix>${camera_name}</prefix>
    <depthUpdateRate>60.0</depthUpdateRate>
    <colorUpdateRate>60.0</colorUpdateRate>
    <infraredUpdateRate>60.0</infraredUpdateRate>
    <depthTopicName>depth/image_raw</depthTopicName>
    <depthCameraInfoTopicName>depth/camera_info</depthCameraInfoTopicName>
    <colorTopicName>color/image_raw</colorTopicName>
    <colorCameraInfoTopicName>color/camera_info</colorCameraInfoTopicName>
    <infrared1TopicName>infra1/image_raw</infrared1TopicName>
    <infrared1CameraInfoTopicName>infra1/camera_info</infrared1CameraInfoTopicName>
    <infrared2TopicName>infra2/image_raw</infrared2TopicName>
    <infrared2CameraInfoTopicName>infra2/camera_info</infrared2CameraInfoTopicName>
    <colorOpticalframeName>${color_optical_frame}</colorOpticalframeName>
    <depthOpticalframeName>${depth_optical_frame}</depthOpticalframeName>
    <infrared1OpticalframeName>${infrared1_optical_frame}</infrared1OpticalframeName>
    <infrared2OpticalframeName>${infrared2_optical_frame}</infrared2OpticalframeName>
    <rangeMinDepth>0.2</rangeMinDepth>
    <rangeMaxDepth>10.0</rangeMaxDepth>
    <pointCloud>true</pointCloud>
    <pointCloudTopicName>depth/points</pointCloudTopicName>
    <pointCloudCutoff>0.5</pointCloudCutoff>
  </plugin>
</gazebo>
```

Camera plugin

File path: https://github.com/Guri-cccc/EE405A-2023-F1-simulation/blob/eeb1877c11b9c9cee4a1a0b1c9eaba842cd89b84/realsense_gazebo_plugin/urdf/_d435.gazebo.xacro

Car model

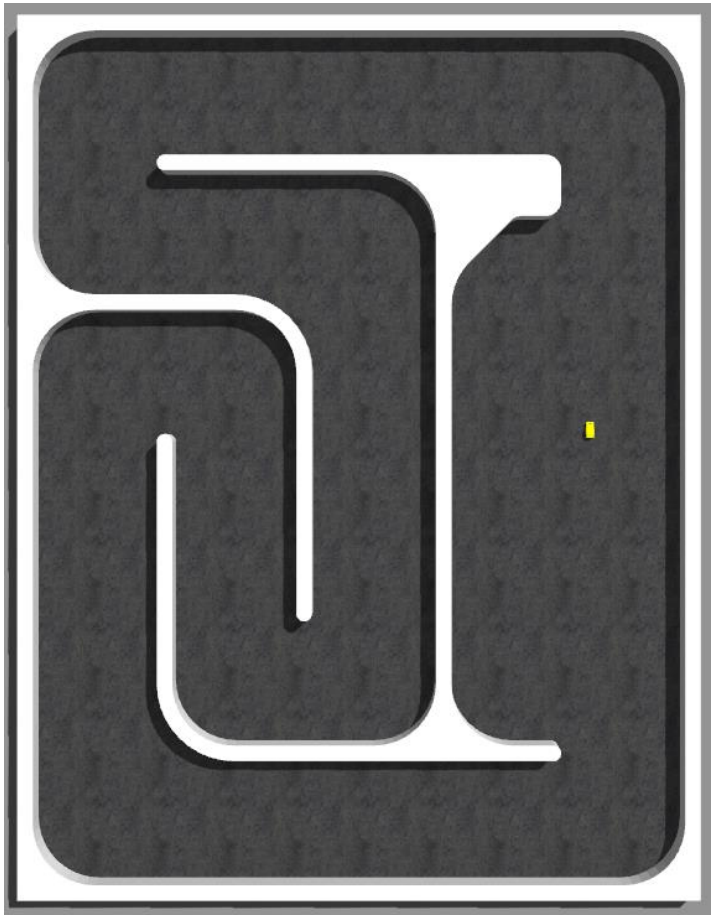
Spawning the car in the simulation

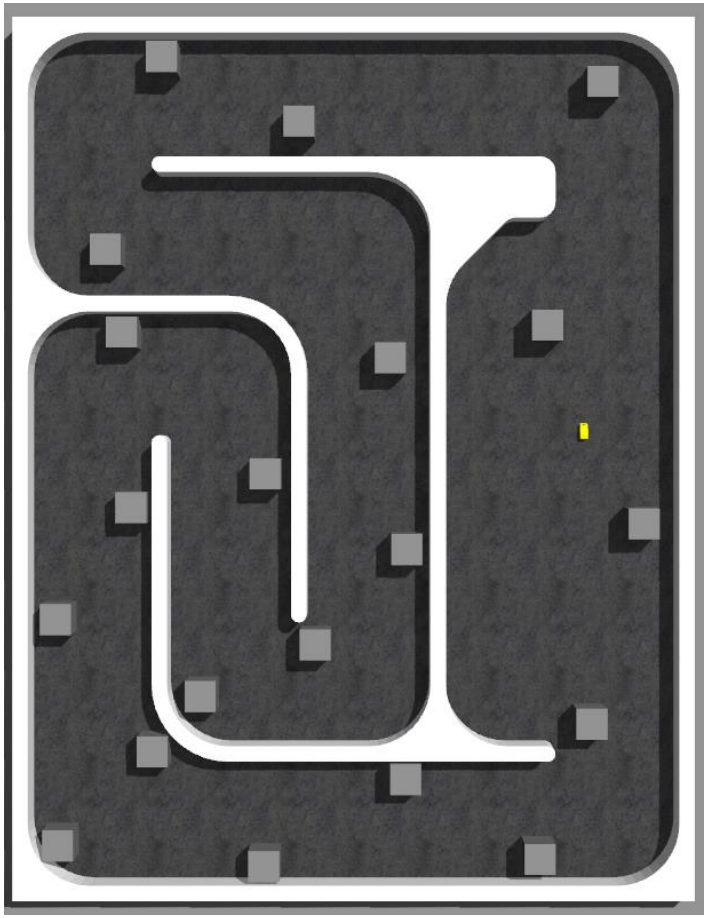
```
<!-- urdf xml robot description loaded on the Parameter Server, converting the xacro into a proper urdf file-->
<param       name            = '$(arg car_name)/robot_description'
             command         = '$(find xacro)/xacro
                               "$(find f1tenth-sim)/urdf/macros_with_realsense.xacro" robot_name:=$(arg car_name) robot_skin:=$(arg paint)'/>

<!-- push robot_description to factory and spawn robot in gazebo -->
<node        name            = '$(arg car_name)_spawn_model'
             pkg             = 'gazebo_ros'
             type            = 'spawn_model'
             output          = 'screen'
             args            = '-urdf -param $(arg car_name)/robot_description
                                      -model $(arg car_name)
                                      -x $(arg x_pos)
                                      -y $(arg y_pos)
                                      -z $(arg z_pos)'/>
```

Path to the car model .xacro

File path: https://github.com/Guri-cccc/EE405A-2023-F1-simulation/blob/eeb1877c11b9c9cee4a1a0b1c9eaba842cd89b84/f1tenth-sim/urdf/macros_with_realsense.xacro

World





File path: https://github.com/Guri-cccc/EE405A-2023-F1-simulation/blob/eeb1877c11b9c9cee4a1a0b1c9eaba842cd89b84/f1tenth-sim/urdf/macros_with_realsense.xacro

World

```
<model name='ground_plane'>
  <static>1</static>
  <link name='link'>
    <collision name='collision'>
      <geometry>
        <plane>
          <normal>0 0 1</normal>
          <size>100 100</size>
        </plane>
      </geometry>
      <surface>
        <friction>
          <ode>
            <mu>100</mu>
            <mu2>50</mu2>
          </ode>
          <torsional>
            <ode/>
          </torsional>
        </friction>
        <contact>
          <ode/>
        </contact>
        <bounce/>
      </surface>
      <max_contacts>10</max_contacts>
    </collision>
```

collision

```
    <visual name='visual'>
      <cast_shadows>0</cast_shadows>
      <geometry>
        <plane>
          <normal>0 0 1</normal>
          <size>100 100</size>
        </plane>
      </geometry>
      <material>
        <script>
          <uri>file://media/materials/scripts/gazebo.material</uri>
          <name>Gazebo/Grey</name>
        </script>
      </material>
    </visual>
    <self_collide>0</self_collide>
    <kinematic>0</kinematic>
    <gravity>1</gravity>
    <enable_wind>0</enable_wind>
  </link>
</model>
```

visual

File path: https://github.com/Guri-cccc/EE405A-2023-F1-simulation/blob/eeb1877c11b9c9cee4a1a0b1c9eaba842cd89b84/f1tenth-sim/urdf/macros_with_realsense.xacro

World

```
<light name='sun' type='directional'>
  <cast_shadows>1</cast_shadows>
  <pose frame=''>0 0 100 0 -0 0</pose>
  <diffuse>0.8 0.8 0.8 1</diffuse>
  <specular>0.1 0.1 0.1 1</specular>
  <attenuation>
    <range>1000</range>
    <constant>0.9</constant>
    <linear>0.01</linear>
    <quadratic>0.001</quadratic>
  </attenuation>
  <direction>-0.5 0.5 -1</direction>
</light>
```

Lights

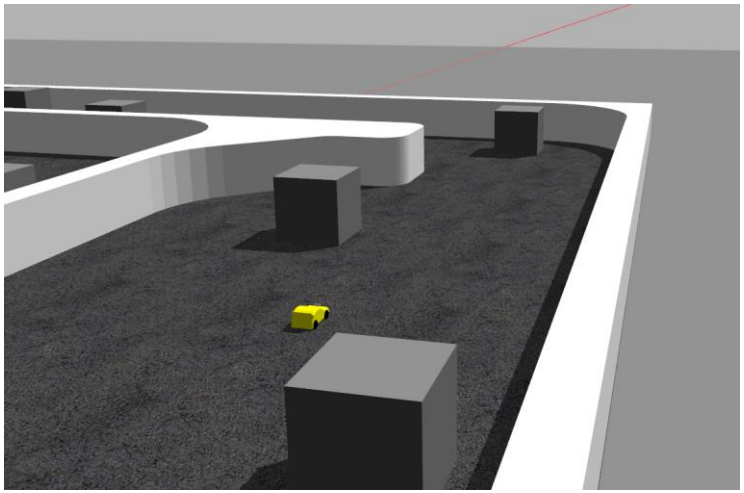
```
<gravity>0 0 -9.8</gravity>
<magnetic_field>6e-06 2.3e-05 -4.2e-05</magnetic_field>
<atmosphere type='adiabatic'/>
<physics name='default_physics' default='0' type='ode'>
  <max_step_size>0.001</max_step_size>
  <real_time_factor>1</real_time_factor>
  <real_time_update_rate>1000</real_time_update_rate>
</physics>
<scene>
  <ambient>0.4 0.4 0.4 1</ambient>
  <background>0.7 0.7 0.7 1</background>
  <shadows>1</shadows>
</scene>
```

Other properties

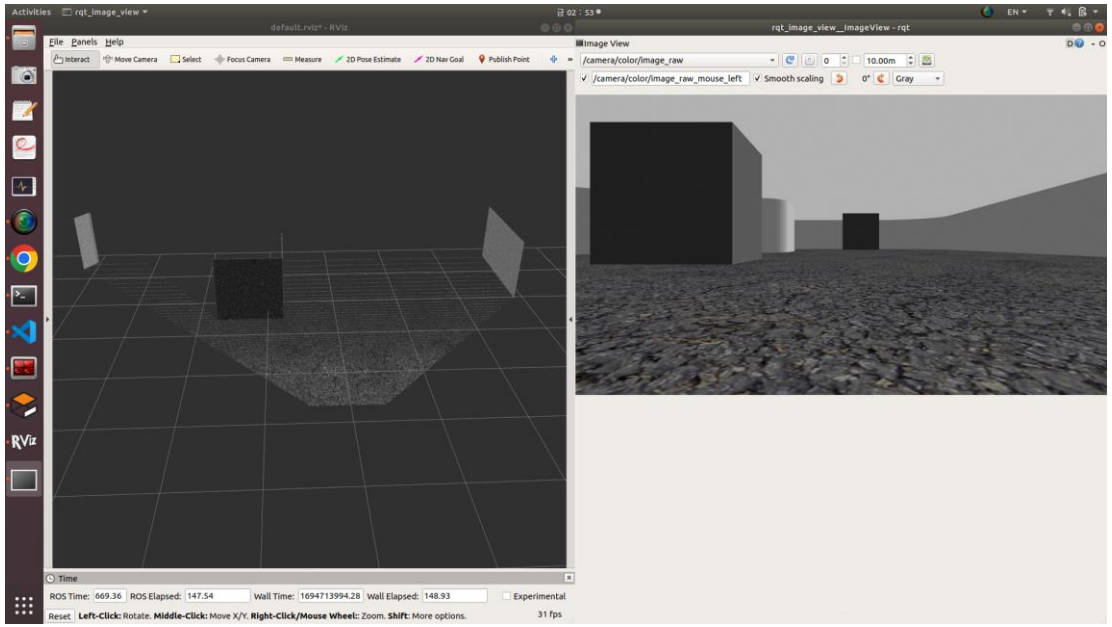
File path: https://github.com/Guri-cccc/EE405A-2023-F1-simulation/blob/eeb1877c11b9c9cee4a1a0b1c9eaba842cd89b84/f1tenth-sim/urdf/macros_with_realsense.xacro

World

roslaunch f1tenth_simulator simulator.launch



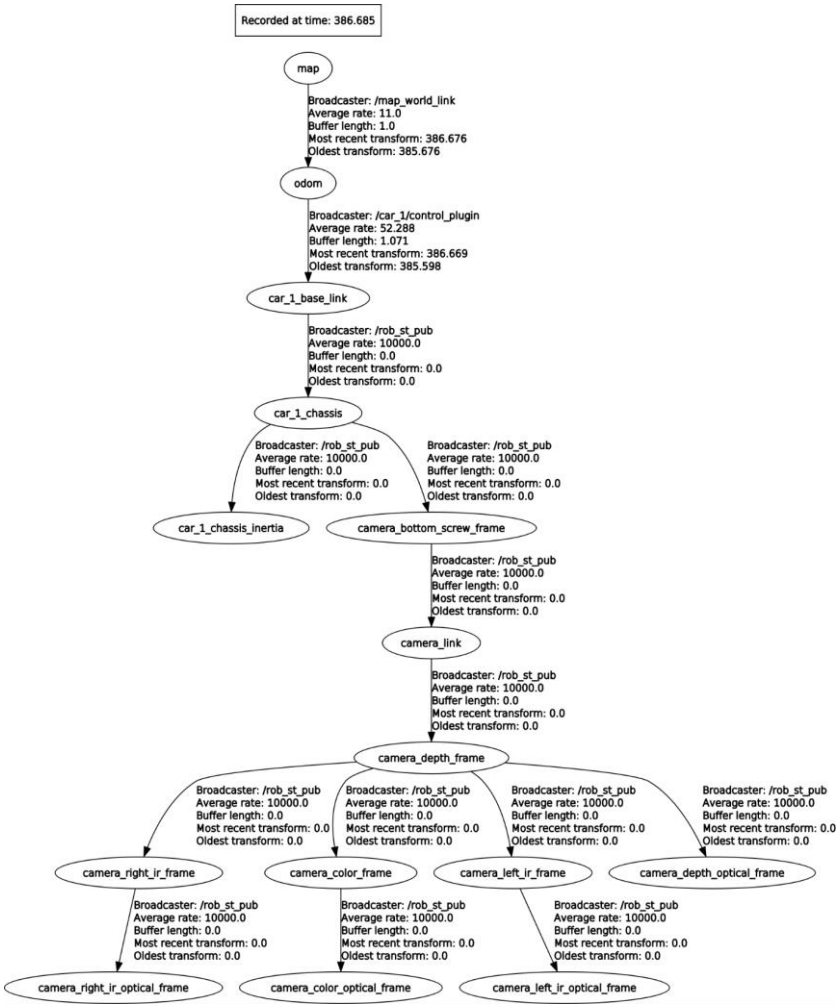
Gazebo gui



RVIZ and rqt_image_view

World

rosrun rqt_tf_tree rqt_tf_tree



TF

Q & A

Email : fingb20@kaist.ac.kr