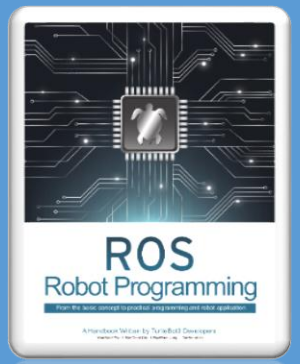
Mobile Robots

ROBOTIS

KAIST



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Textbook
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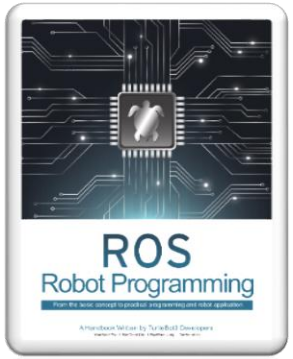
Contents



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Textbook
P. 278~311

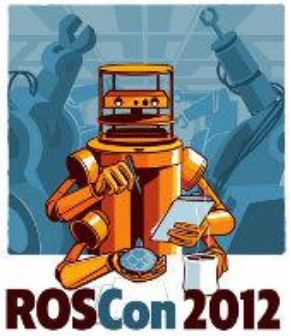
Turtle icons?

B C D E F G H I J K L

Turtle logo?

(symbol of turtle shell)

Turtle Posters?



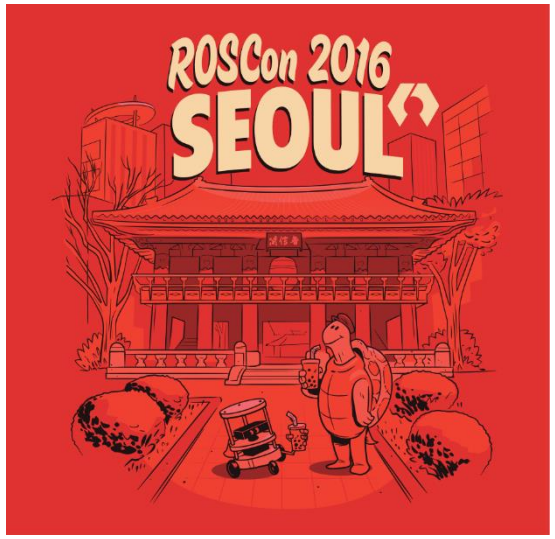
St. Paul, Minnesota, USA
19-20 May 2012

Stuttgart, Germany
11-12 May 2013

Hong Kong University
June 6, 2014

Chicago, Illinois, USA
September 12-13, 2014

Hamburg, Germany
May 3-4, 2015



Seoul, Korea
October 8th-9th, 2016

Vancouver, Canada
September 21-22, 2017

http://roscon.ros.org/

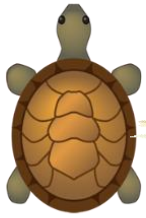
Turtle Distributions?

ROS 1.0

ROS

Switchyard

Box Turtle



Box Turtle

2007 — 2007.11 — 2010.01.22 — 2010.03.02

C Turtle

2010.08.02

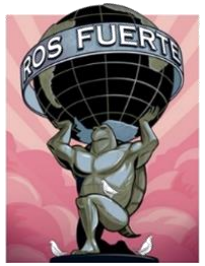
Diamondback

2011.03.02

Electric Emys

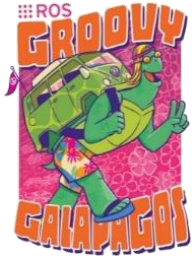
2011.08.30

Fuerte Turtle



2012.04.23

Groovy Galapagos



2012.12.31

Hydro Medusa

2013.09.04

Indigo Igloo

2014.07.22

Jade Turtle

2015.05.23

Kinetic Kame

2016.05.23

Lunar Loggerhead

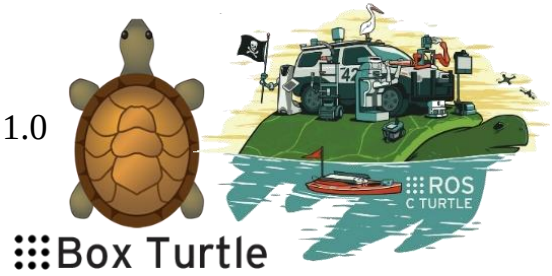
2017.05.23

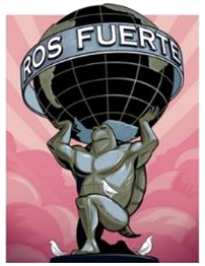
Turtle Distributions?

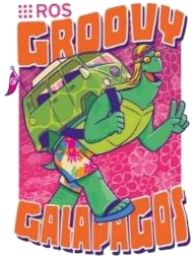
ROS 1.0

ROS

Switchyard







Box Turtle C Turtle Diamondback Electric Emys Fuerte Turtle Groovy Galapagos Hydro Medusa Indigo Igloo

2007 2007.11 2010.01.22 2010.03.02 2010.08.02 2011.03.02 2011.08.30 2012.04.23 2012.12.31 2013.09.04 2014.07.22

Jade Turtle Kinetic Kame Lunar Loggerhead

2015.05.23 2016.05.23 2017.05.23

WORLD TURTLE DAY
May 23rd

AMERICAN TORTOISE RESCUE

World Turtle Day?
(Release day of ROS)

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

Why Turtle?

'Turtle' comes from a robot Turtle that was created to control real robots using the 'Logo'(the educational computer programming language developed in 1967)

TurtleBot, originated from the Logo's Turtle, is designed to make it easier for people who are new to ROS to learn the computer programming language like Turtle Bot. As a robotics platform, it has become the standard platform of ROS that is widely used among developers and students.

Seymour Papert with a robot Turtle

http://el.media.mit.edu/logo-foundation/what_is_logo/logo_and_learning.html

TurtleBot

- ROS official robot platform
- Used in many labs, schools, DIY all over the world
- SLAM, Navigation, Gazebo, RViz Support!

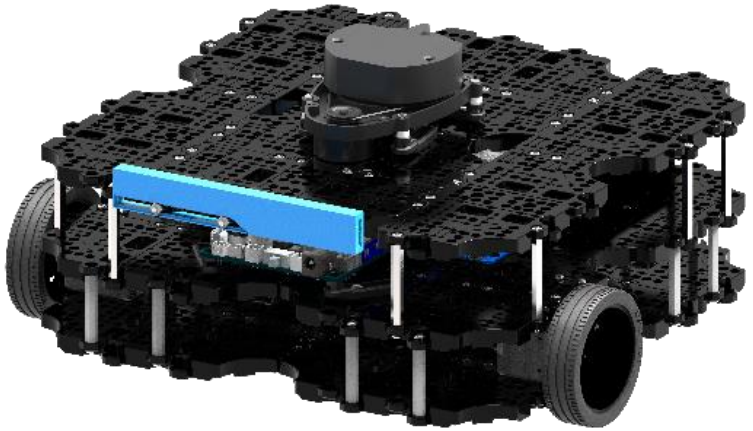
  http://wiki.ros.org/Robots/TurtleBot

TurtleBot 1

2010

TurtleBot 2

2012



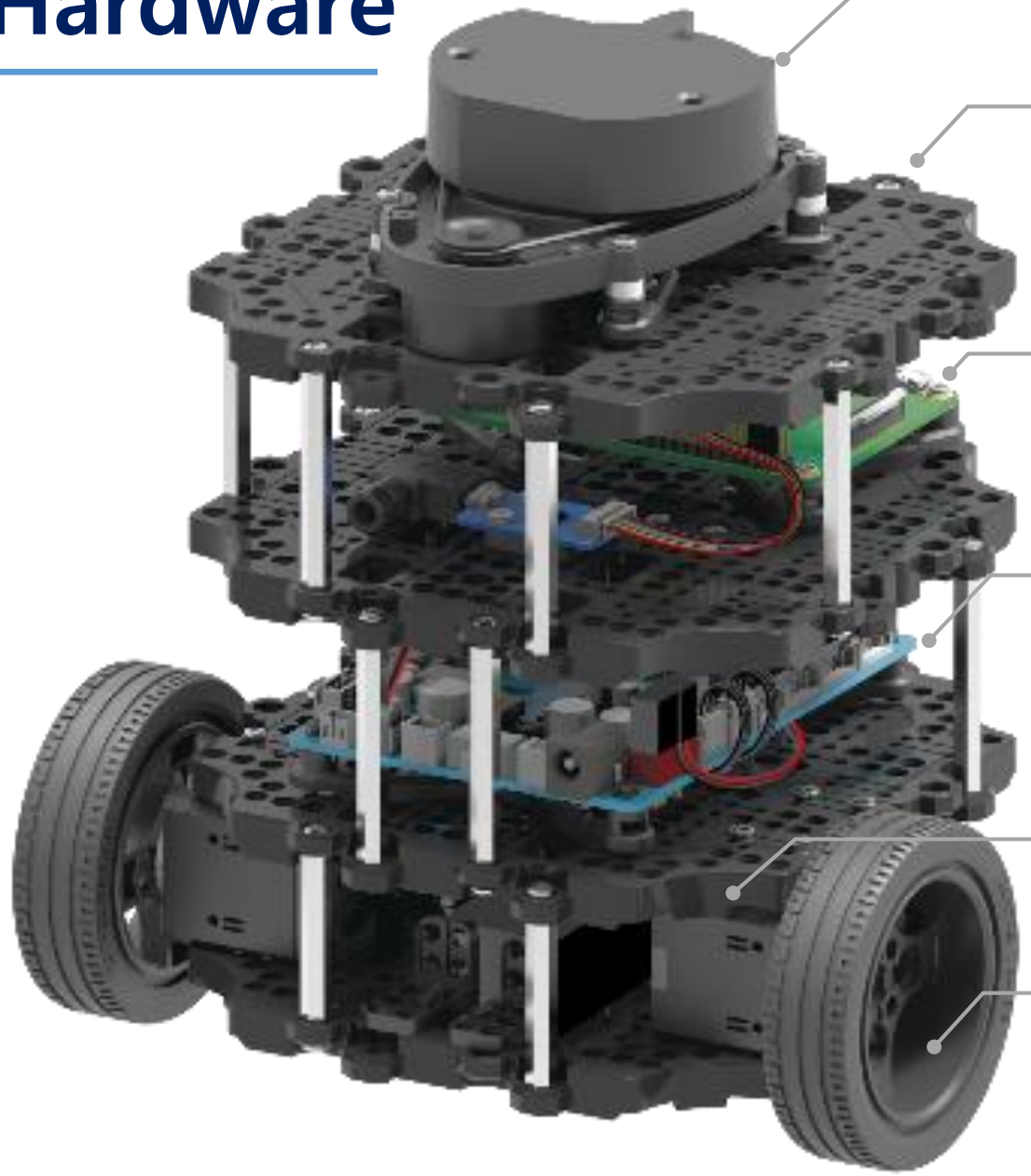
TurtleBot 3

2017

TurtleBot3

https://youtu.be/9OC3J53RUsk

TurtleBot3 Hardware



360° LiDAR for SLAM & Navigation

Scalable Structure

Single Board Computer
(Raspberry Pi)

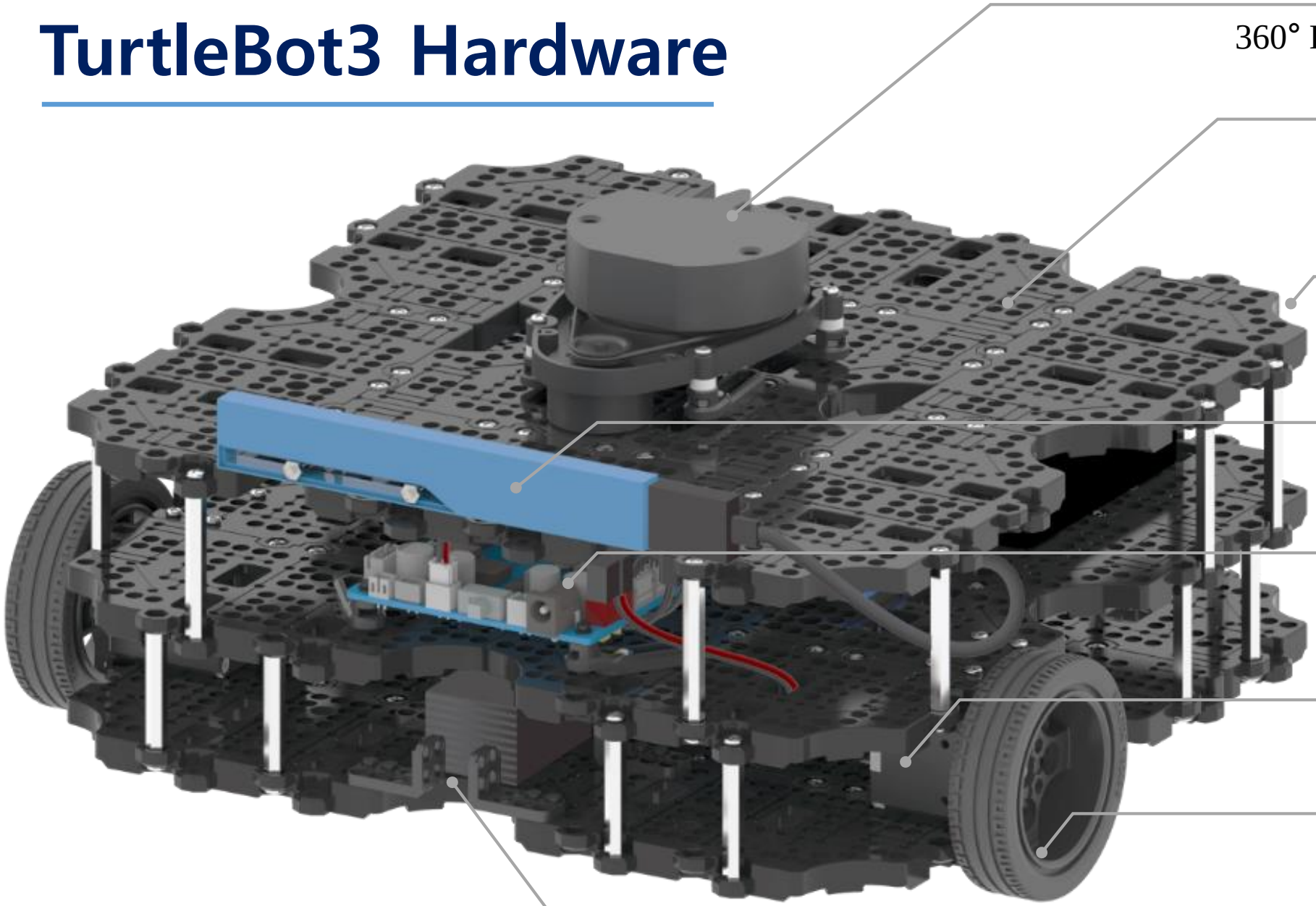
OpenCR
(32-bit ARM Cortex®-M7)

DYNAMIXEL x 2 for
Wheels

Sprocket Wheels for
Tire and Caterpillar

Li-Po Battery

TurtleBot3 Hardware



360° LiDAR for SLAM & Navigation

Single Board Computer
(Intel® Joule™)

Scalable Structure

Intel® RealSense™
for 3D Perception

OpenCR
(32-bit ARM Cortex®-M7)

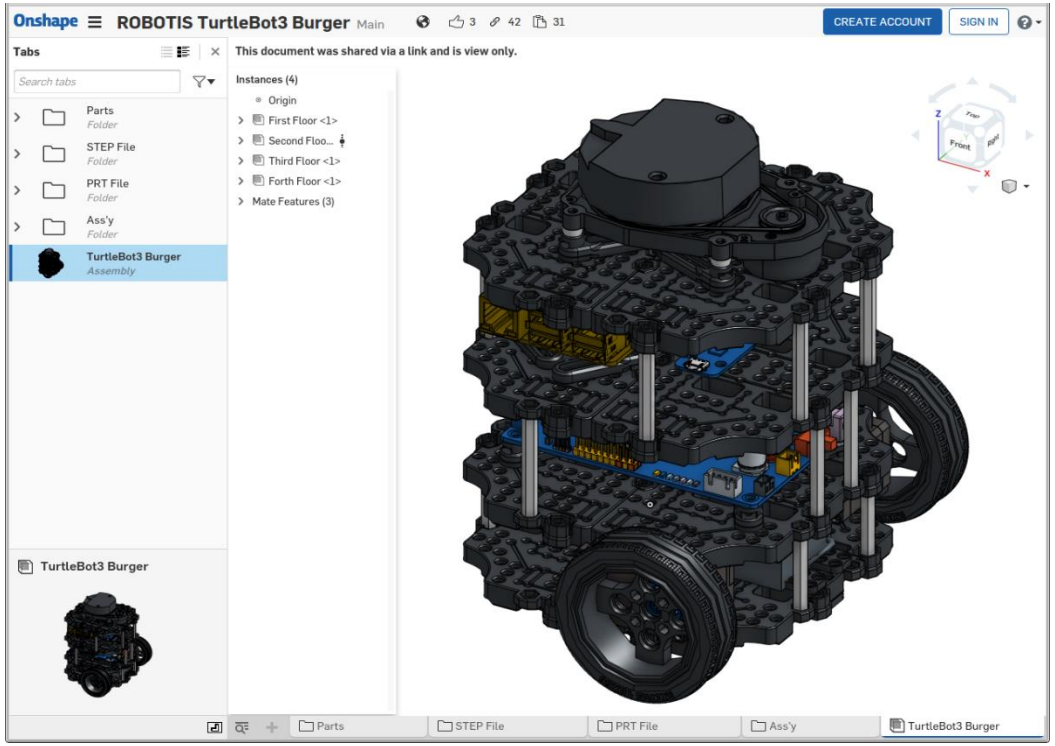
DYNAMIXEL x 2 for
Wheels

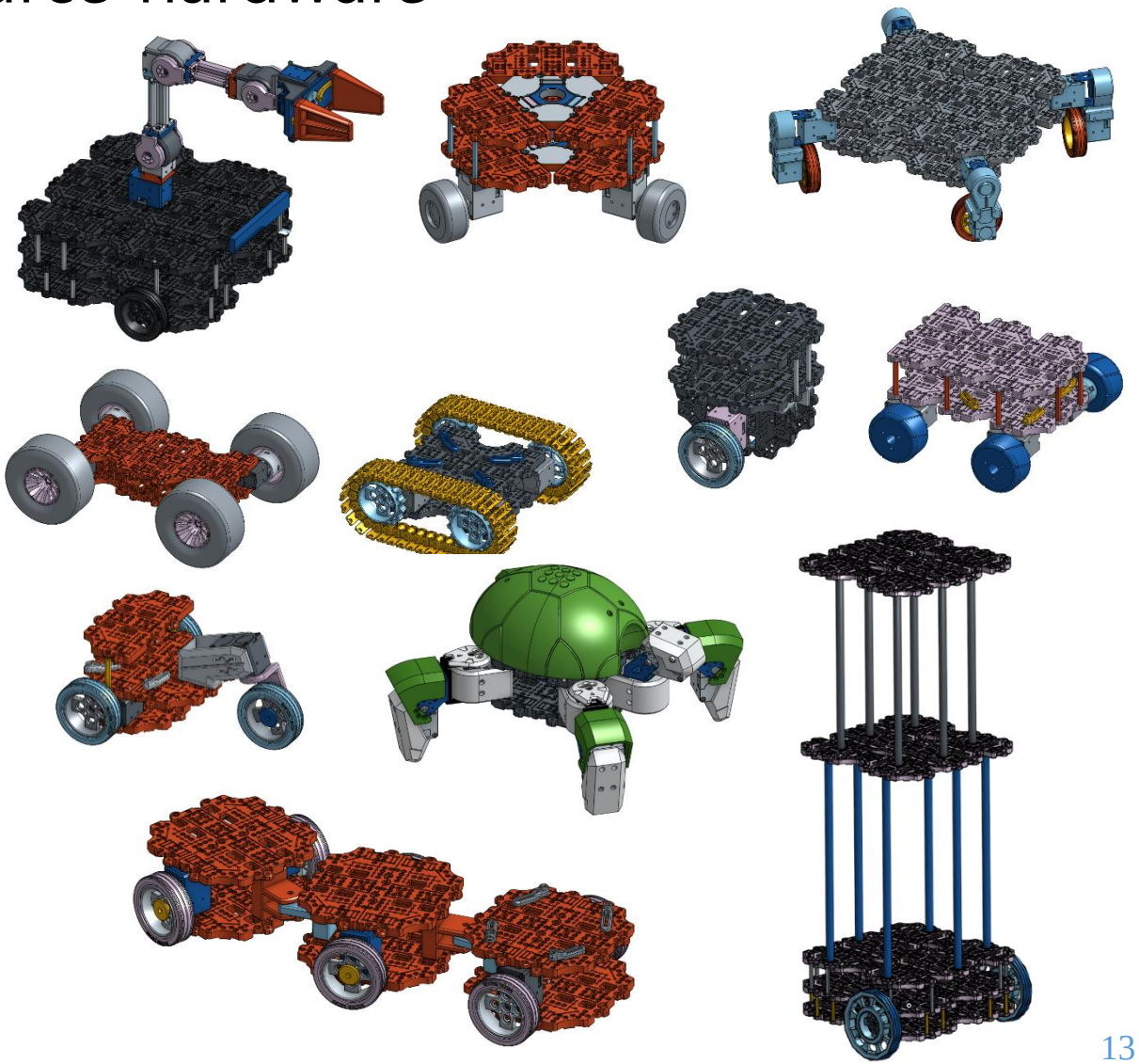
Sprocket Wheels for
Tire and Caterpillar

Li-Po Battery

TurtleBot3 Hardware (Open Hardware)

- Robot platform based on open source hardware
- Run in web browser (Onshape)
- 3D printable





TurtleBot3 Hardware (Open Hardware)

- TurtleBot3 Burger: http://www.robotis.com/service/download.php?no=676
- TurtleBot3 Waffle: http://www.robotis.com/service/download.php?no=677
- TurtleBot3 Waffle Pi: http://www.robotis.com/service/download.php?no=678

- TurtleBot3 Friends OpenManipulator Chain: http://www.robotis.com/service/download.php?no=679
- TurtleBot3 Friends Segway: http://www.robotis.com/service/download.php?no=680
- TurtleBot3 Friends Conveyor: http://www.robotis.com/service/download.php?no=681
- TurtleBot3 Friends Monster: http://www.robotis.com/service/download.php?no=682
- TurtleBot3 Friends Tank: http://www.robotis.com/service/download.php?no=683
- TurtleBot3 Friends Omni: http://www.robotis.com/service/download.php?no=684
- TurtleBot3 Friends Mecanum: http://www.robotis.com/service/download.php?no=685
- TurtleBot3 Friends Bike: http://www.robotis.com/service/download.php?no=686
- TurtleBot3 Friends Road Train: http://www.robotis.com/service/download.php?no=687
- TurtleBot3 Friends Real TurtleBot: http://www.robotis.com/service/download.php?no=688
- TurtleBot3 Friends Carrier: http://www.robotis.com/service/download.php?no=689

TurtleBot3 Software

- Robot platform based on open source hardware
- All software are released on Github

- https://github.com/ROBOTIS-GIT/robotis_tools → Ch3
- https://github.com/ROBOTIS-GIT/ros_turtorials → Ch4, 7, 13
- https://github.com/ROBOTIS-GIT/DynamixelSDK → Ch8, 10
- https://github.com/ROBOTIS-GIT/dynamixel-workbench → Ch8, 13
- https://github.com/ROBOTIS-GIT/dynamixel-workbench-msgs → Ch8, 13
- https://github.com/ROBOTIS-GIT/hls_lfcd_lds_driver → Ch8, 10, 11
- https://github.com/ROBOTIS-GIT/OpenCR → Ch9, 12
- https://github.com/ROBOTIS-GIT/turtlebot3 → Ch10, 11
- https://github.com/ROBOTIS-GIT/turtlebot3_msgs → Ch10, 11
- https://github.com/ROBOTIS-GIT/turtlebot3_simulations → Ch10, 11
- https://github.com/ROBOTIS-GIT/turtlebot3_applications → Ch10, 11
- https://github.com/ROBOTIS-GIT/turtlebot3_deliver → Ch12
- https://github.com/ROBOTIS-GIT/open_manipulator → Ch13

TurtleBot3 Development environment (software)

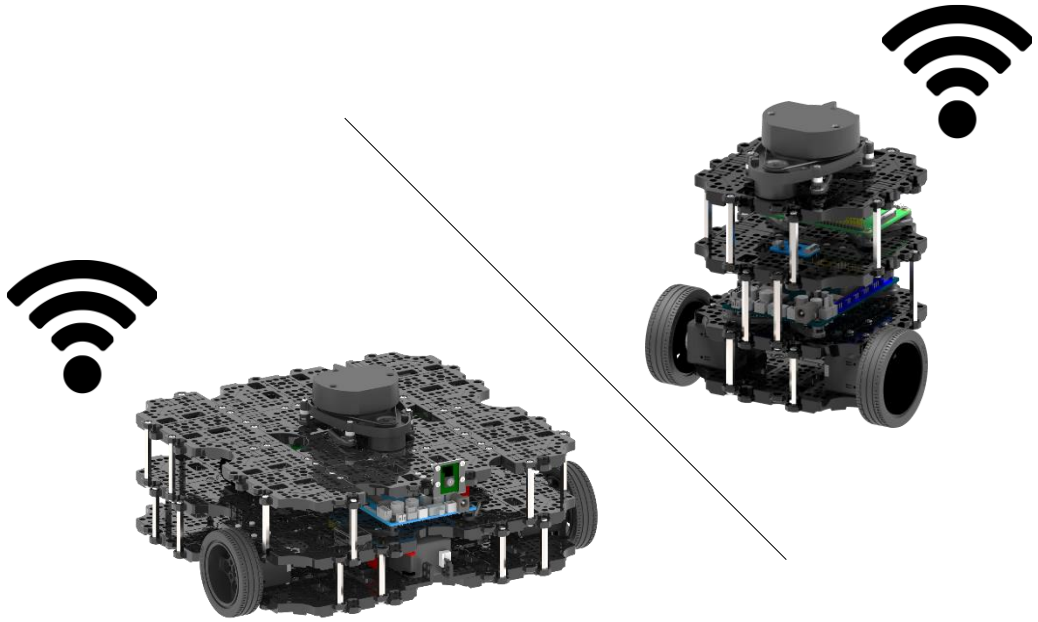
- See the Official Wiki for TurtleBot3
  - http://turtlebot3.robotis.com
- Install basic packages (SLAM, used in Navigation exercise / Gazebo)

```
$ sudo apt-get install ros-kinetic-joy ros-kinetic-teleop-twist-joy ros-kinetic-teleop-twist-keyboard ros-kinetic-laser-proc ros-kinetic-rgbd-launch ros-kinetic-depthimage-to-laserscan ros-kinetic-rosserial-arduino ros-kinetic-rosserial-python ros-kinetic-rosserial-server ros-kinetic-rosserial-client ros-kinetic-rosserial-msgs ros-kinetic-amcl ros-kinetic-map-server ros-kinetic-move-base ros-kinetic-urdf ros-kinetic-xacro ros-kinetic-compressed-image-transport ros-kinetic-rqt-image-view ros-kinetic-gmapping ros-kinetic-navigation
```

```
$ cd ~/catkin_ws/src/
$ git clone https://github.com/ROBOTIS-GIT/turtlebot3.git
$ git clone https://github.com/ROBOTIS-GIT/turtlebot3_msgs.git
$ git clone https://github.com/ROBOTIS-GIT/turtlebot3_simulations.git
$ cd ~/catkin_ws && catkin_make
```

TurtleBot3 Development environment (Network)

TurtleBot



Remote PC

ROS_MASTER_URI = **http://IP_OF_REMOTE_PC:11311**

ROS_HOSTNAME = **IP_OF_TURTLEBOT**

ROS_MASTER_URI = **http://IP_OF_REMOTE_PC:11311**

ROS_HOSTNAME = **IP_OF_REMOTE_PC**

* Example of running ROS Master on a remote PC

TurtleBot3 Remote control

- roscore operation [Remote PC]

```
$ roscore
```

- turtlebot3_robot.launch :Run the launch file [TurtleBot]

```
$ roslaunch turtlebot3_bringup turtlebot3_robot.launch --screen
```

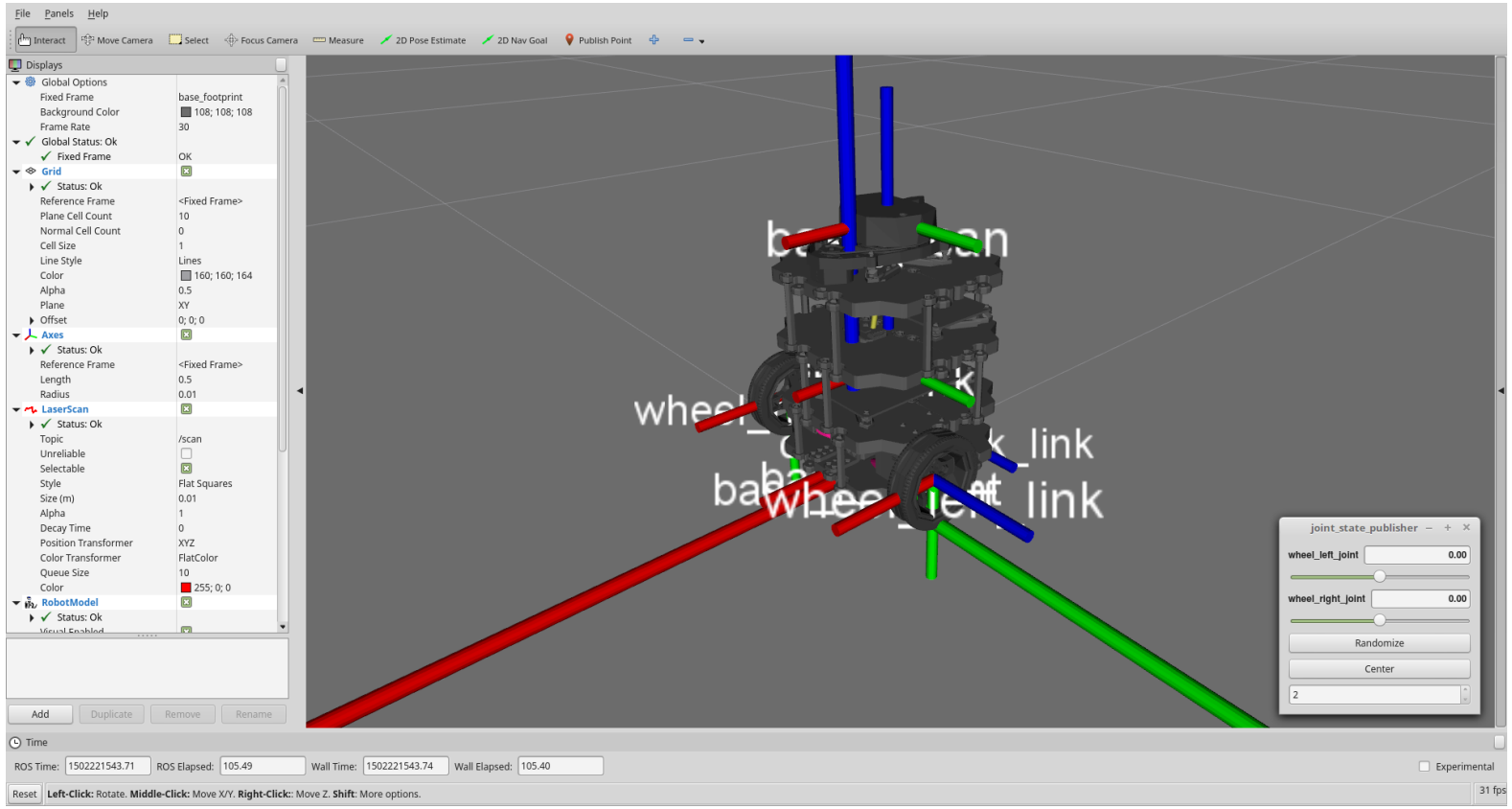
- turtlebot3_teleop_key.launch: Run the launch file [Remote PC]

```
$ roslaunch turtlebot3_teleop turtlebot3_teleop_key.launch --screen
```

TurtleBot3 Visualization

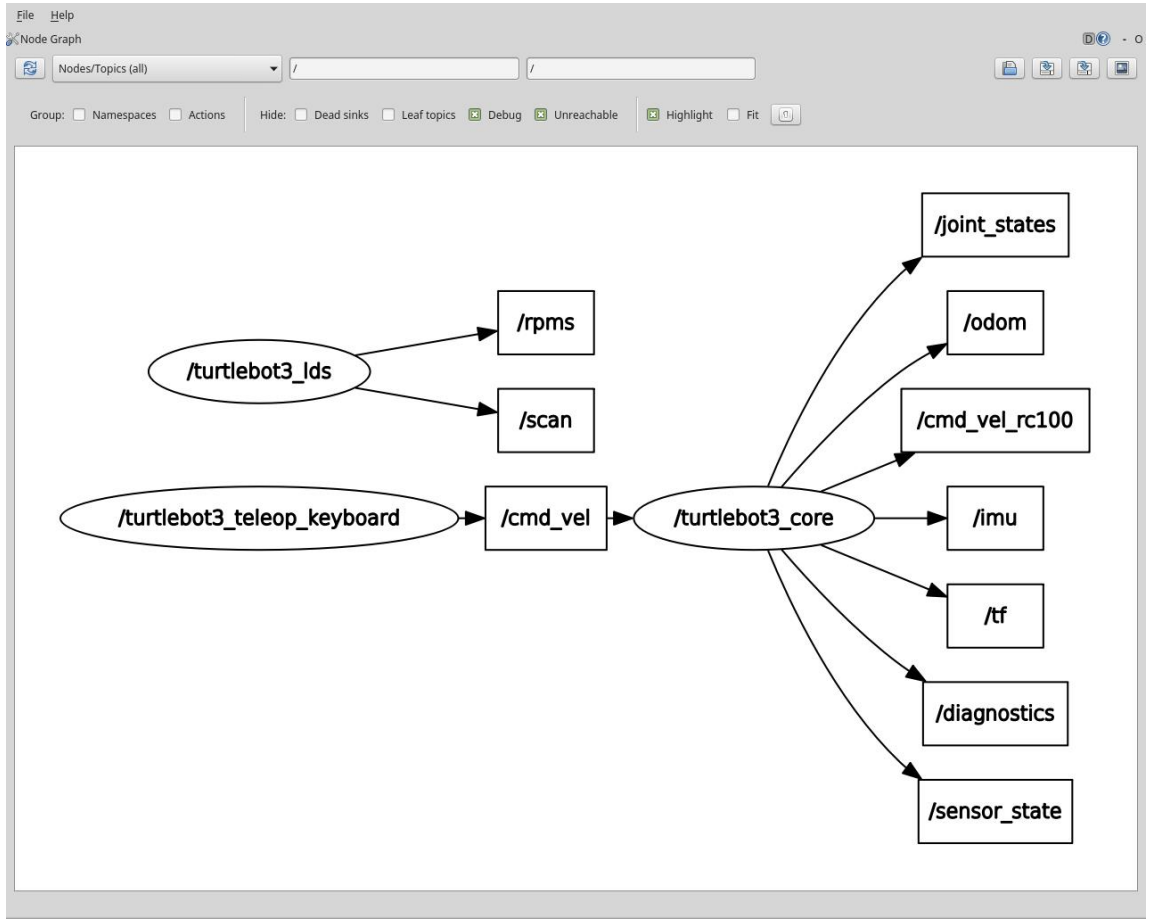
- Run RViz [Remote PC]]

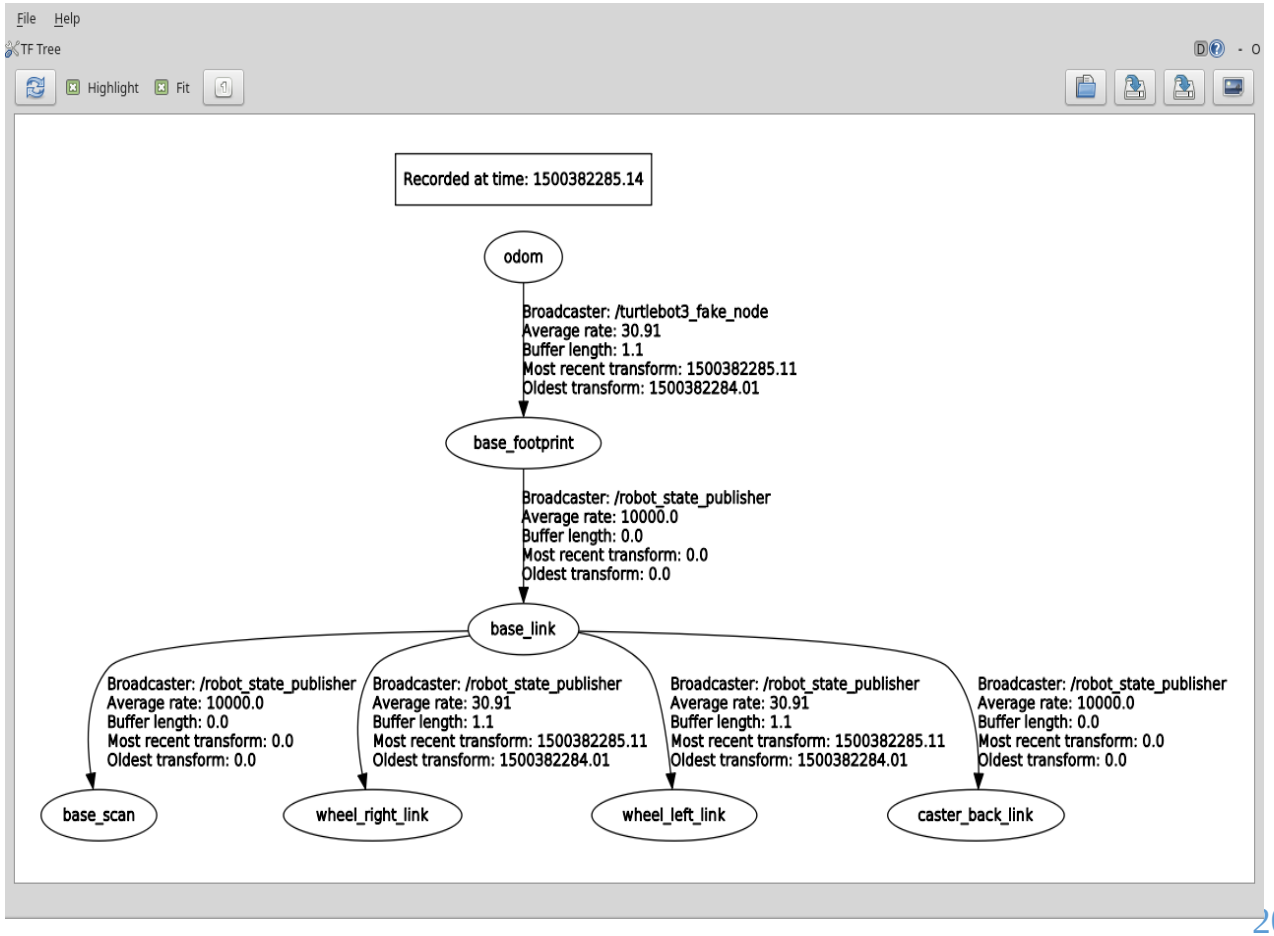
```
$ export TURTLEBOT3_MODEL=burger
$ roslaunch turtlebot3_bringup turtlebot3_model.launch
```



TurtleBot3 Topic and TF

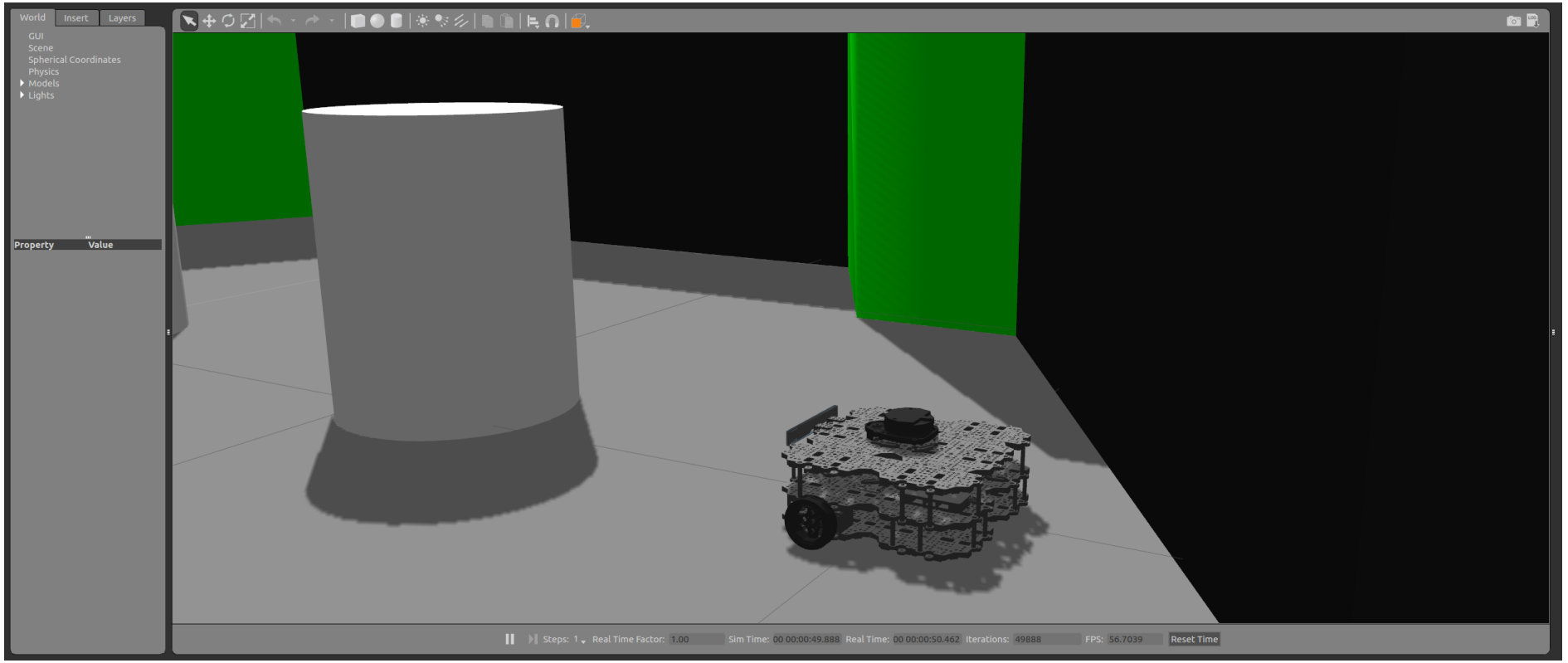
```
$ rqt_graph
$ rqt                [Plugins > Visualization > TF Tree]
```





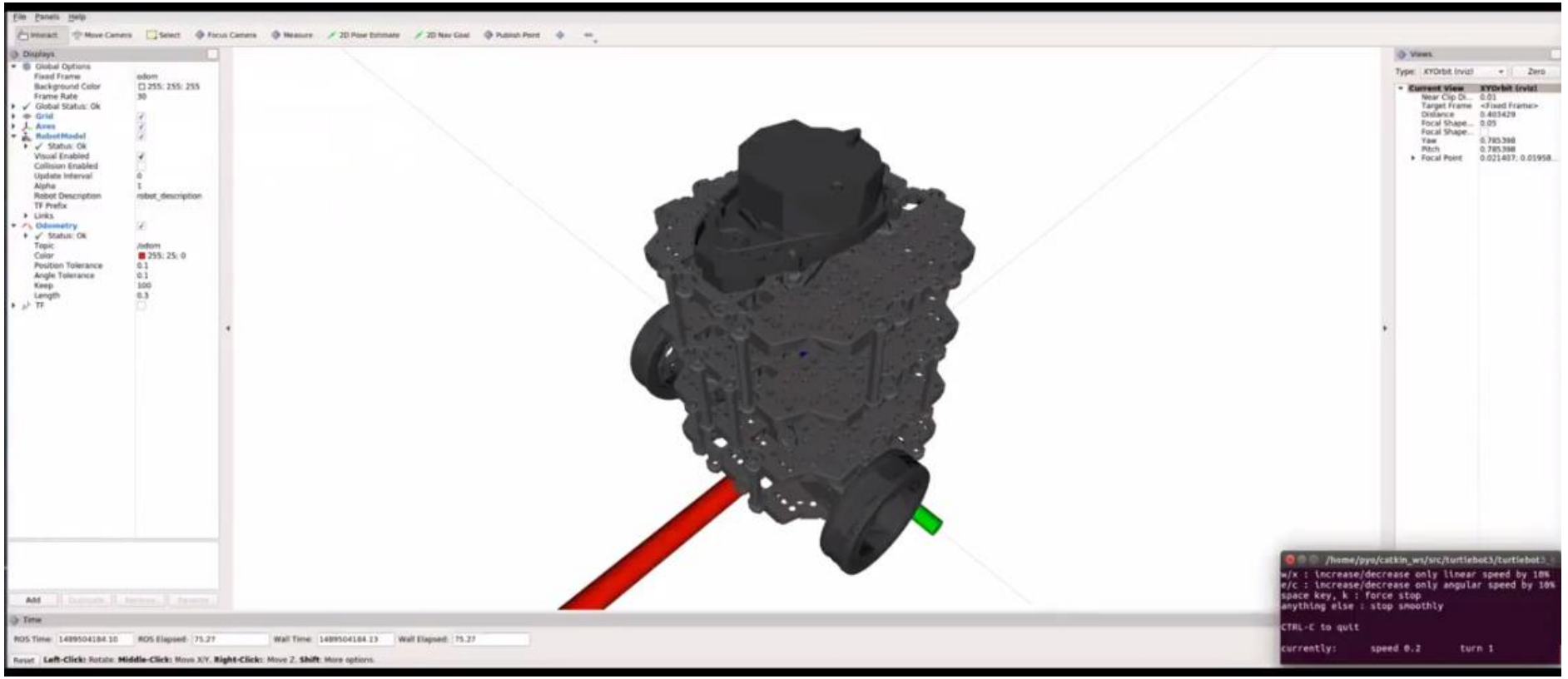
TurtleBot3 + simulation

- Two methods for simulation
  - Using RViz, a 3D visualization tool of ROS
  - Using 3D robot simulator Gazebo
  - http://turtlebot3.robotis.com/en/latest/simulation.html



Simulation with RViz as a viewer

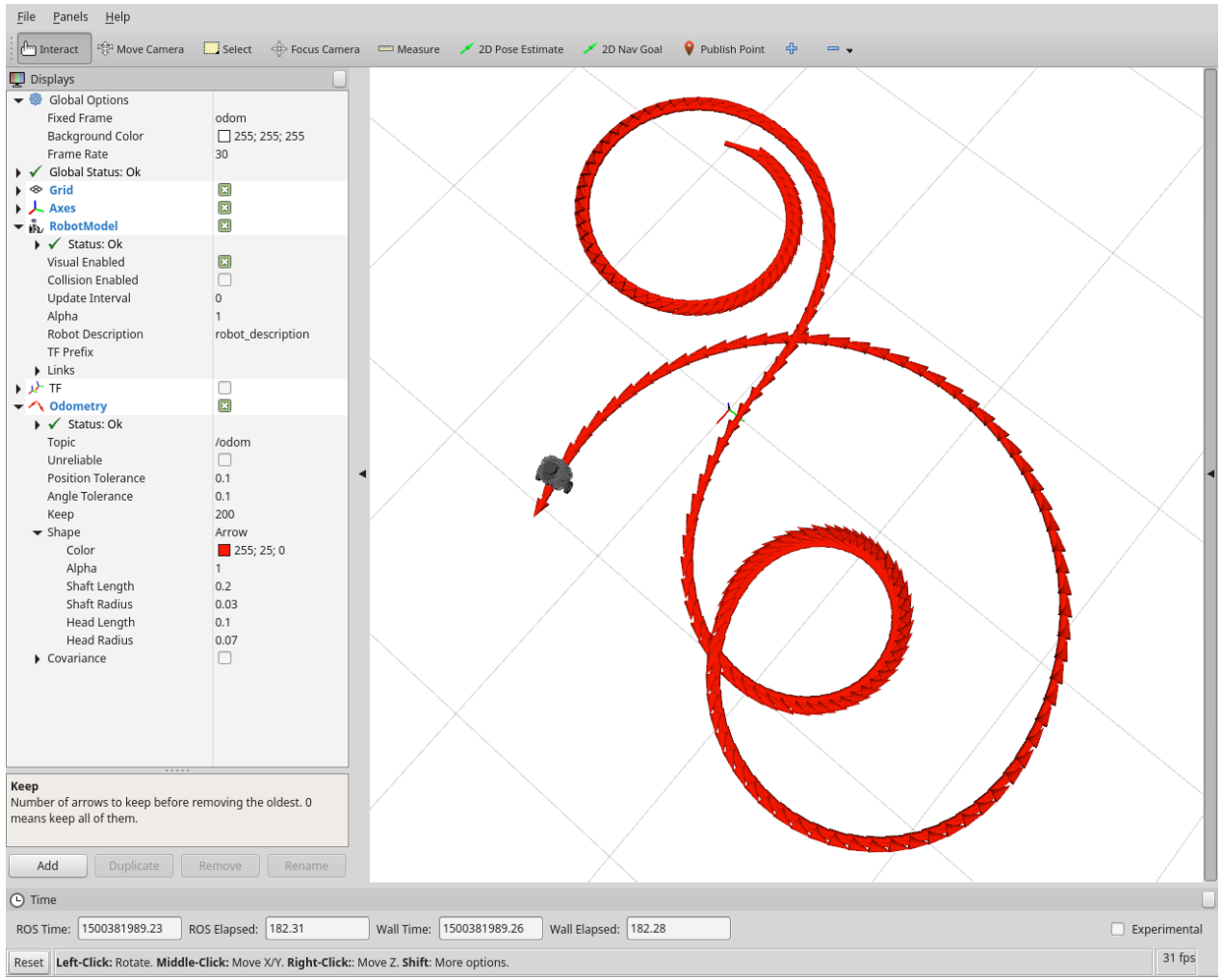
```
$ export TURTLEBOT3_MODEL=burger
$ roslaunch turtlebot3_fake turtlebot3_fake.launch

$ roslaunch turtlebot3_teleop turtlebot3_teleop_key.launch
```

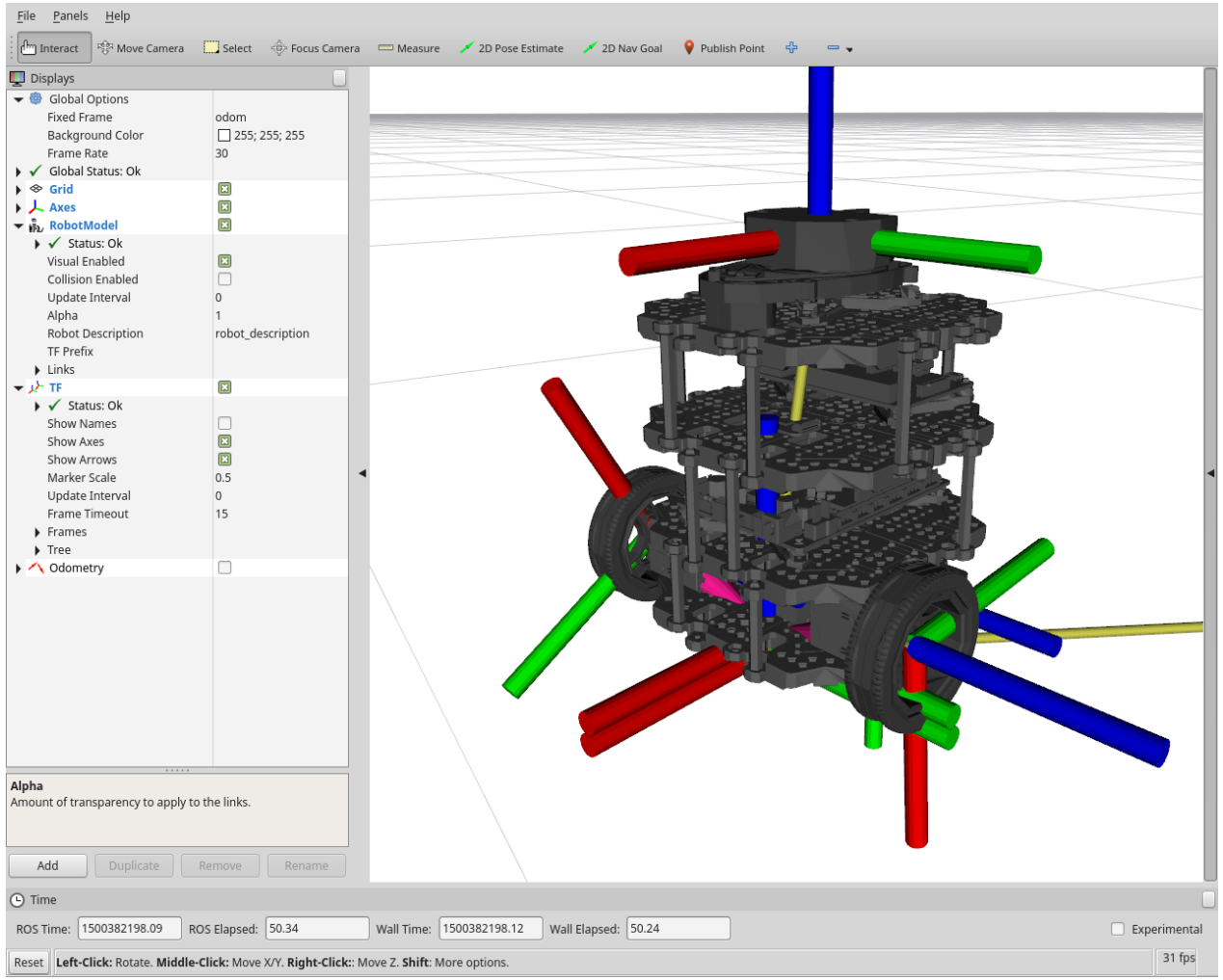


https://youtu.be/iHXZSLBJHMg

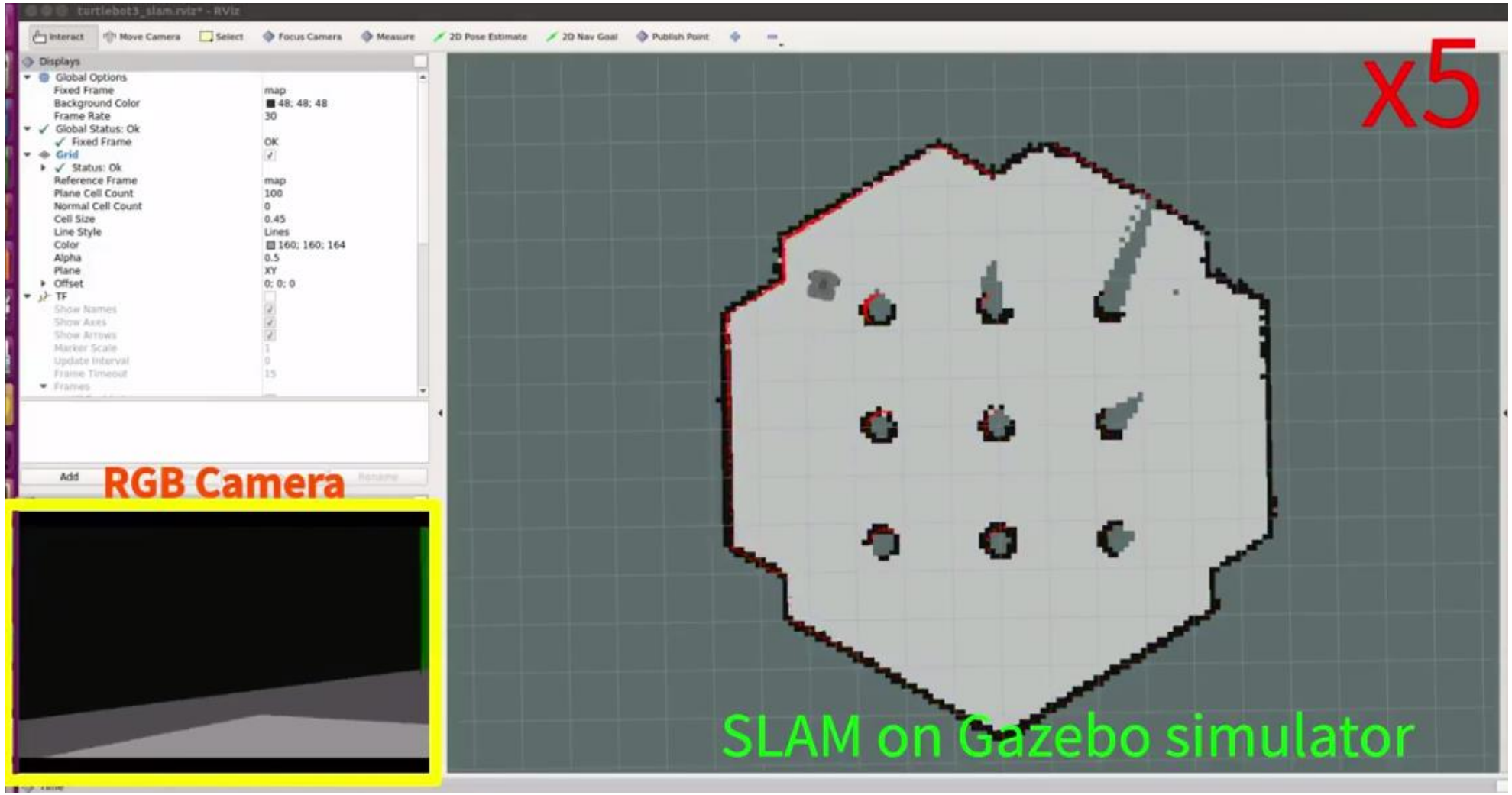
Simulation with RViz as a viewer

- Let's move the robot and check Odometry and tf!





Simulation with Gazebo / TurtleBot3 in Gazebo



https://youtu.be/xXM5r_SVkWM

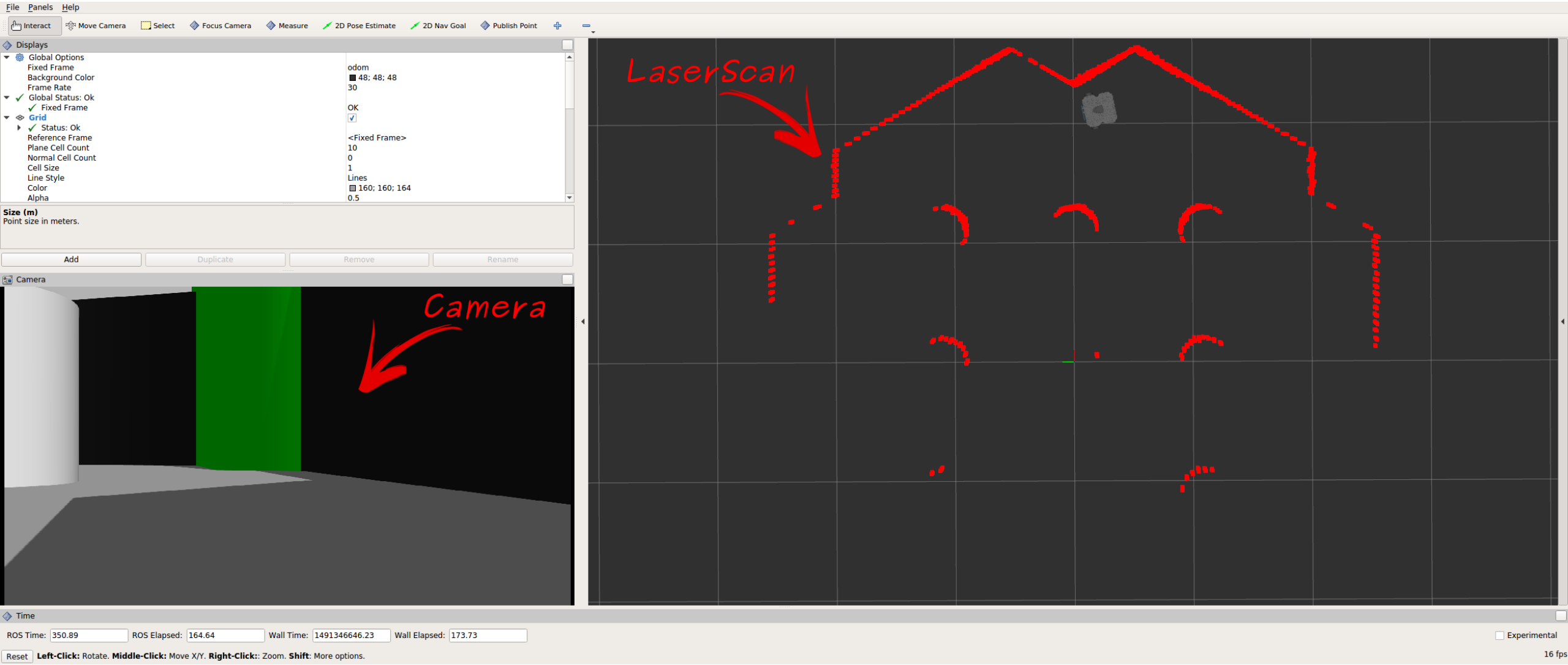
Run Virtual robot with Gazebo

```
$ roslaunch turtlebot3_gazebo turtlebot3_world.launch
```

```
$ roslaunch turtlebot3_teleop turtlebot3_teleop_key.launch
```

```
$ export TURTLEBOT3_MODEL=waffle_pi
$ roslaunch turtlebot3_gazebo turtlebot3_gazebo_rviz.launch
```

Run Virtual robot with Gazebo



Virtual SLAM with Gazebo

- **Run Gazebo**

```
$ export TURTLEBOT3_MODEL=waffle_pi
$ roslaunch turtlebot3_gazebo turtlebot3_world.launch
```

- **Run SLAM**

```
$ export TURTLEBOT3_MODEL=waffle_pi
$ roslaunch turtlebot3_slam turtlebot3_slam.launch
```

- **Run Rviz**

```
$ export TURTLEBOT3_MODEL=waffle_pi
$ rosrun rviz rviz -d `rospack find turtlebot3_slam`/rviz/turtlebot3_slam.rviz
```

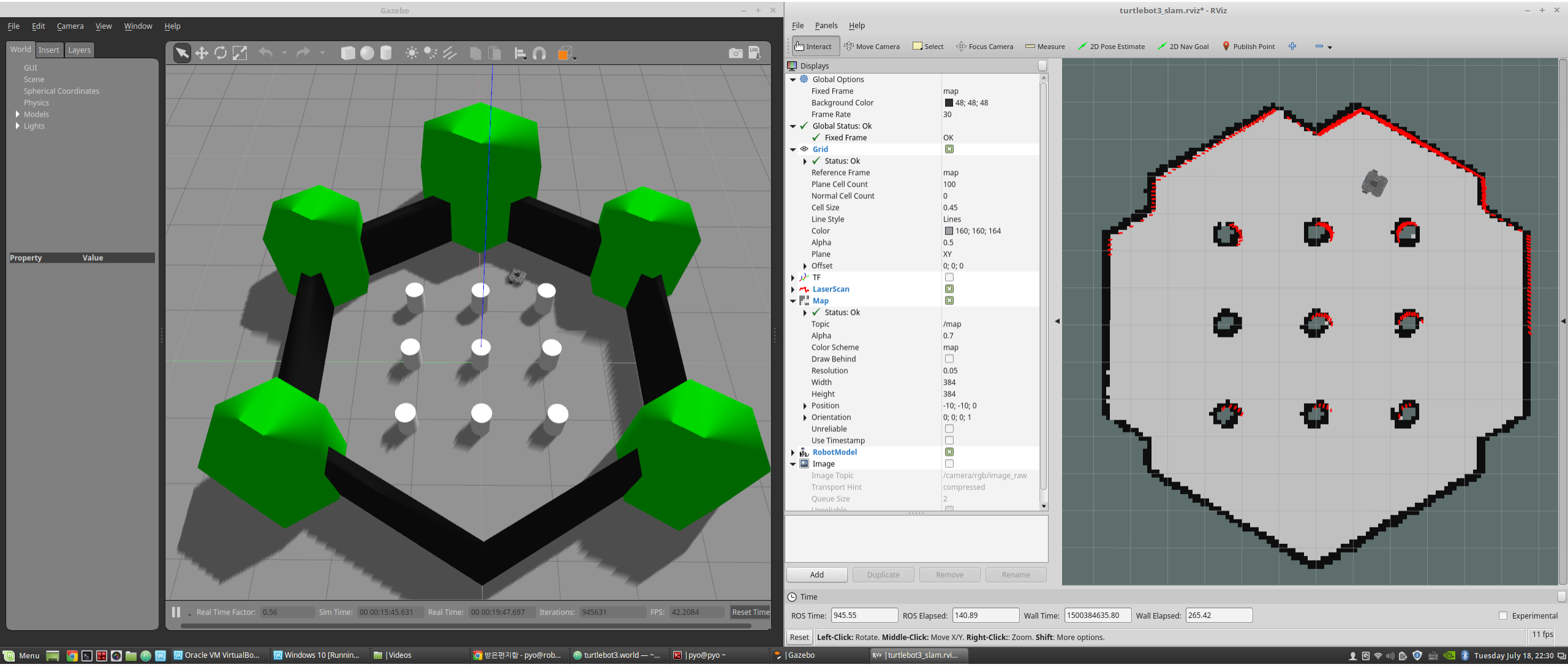
- **Run Turtlebot Teleoperation**

```
$ roslaunch turtlebot3_teleop turtlebot3_teleop_key.launch
```

- **Run Map Server**

```
$ rosrun map_server map_saver -f ~/map
```

Virtual SLAM with Gazebo



Virtual navigation with Gazebo

- **Run Gazebo**

```
$ export TURTLEBOT3_MODEL=waffle_pi
$ roslaunch turtlebot3_gazebo turtlebot3_world.launch
```

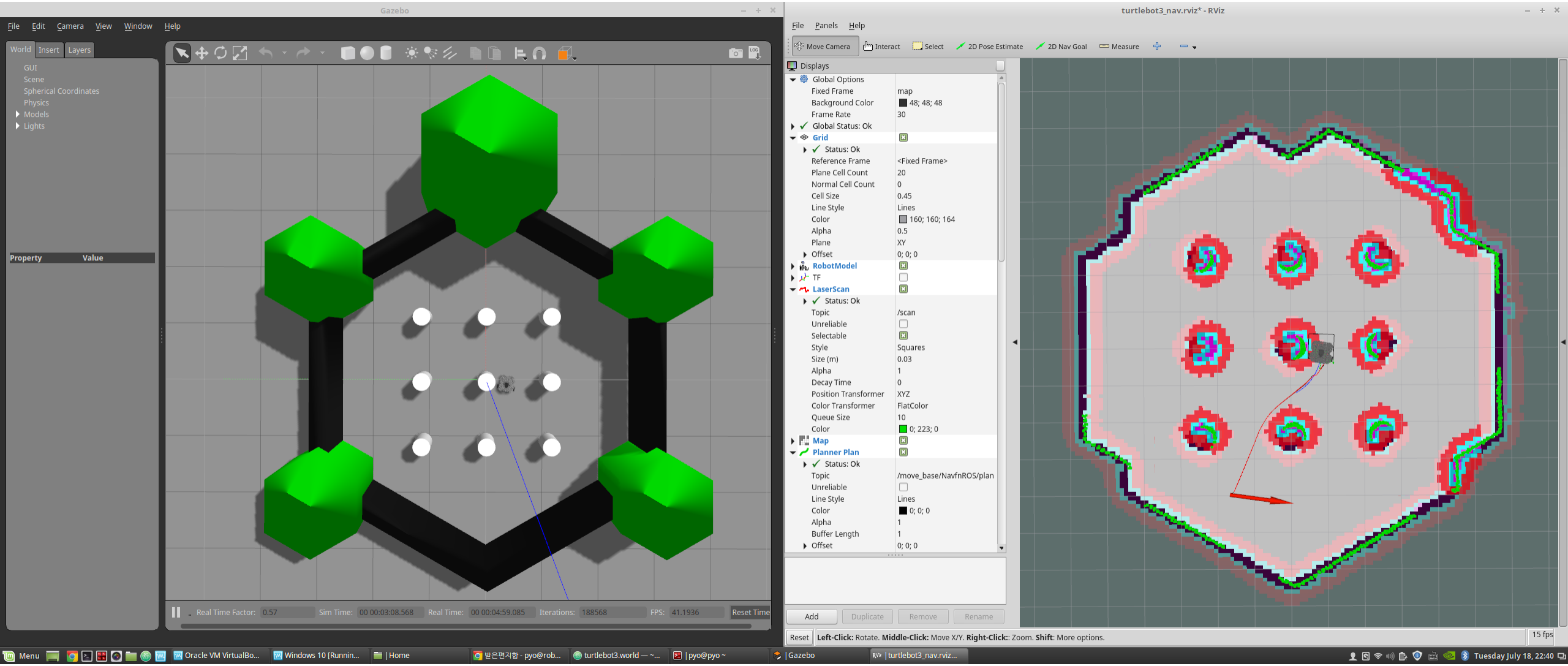
- **Run Navigation**

```
$ export TURTLEBOT3_MODEL=waffle_pi
$ roslaunch turtlebot3_navigation turtlebot3_navigation.launch map_file:=$HOME/map.yaml
```

- **Run Rviz and set destination**

```
$ export TURTLEBOT3_MODEL=waffle_pi
$ rosrun rviz rviz -d `rospack find turtlebot3_navigation`/rviz/turtlebot3_nav.rviz
```

Virtual navigation with Gazebo



Question Time!

Advertisement #1

✓ Download link

✓ Language:

English, Chinese, Japanese, Korean

“ROS Robot Programming”

A Handbook is written by TurtleBot3 Developers

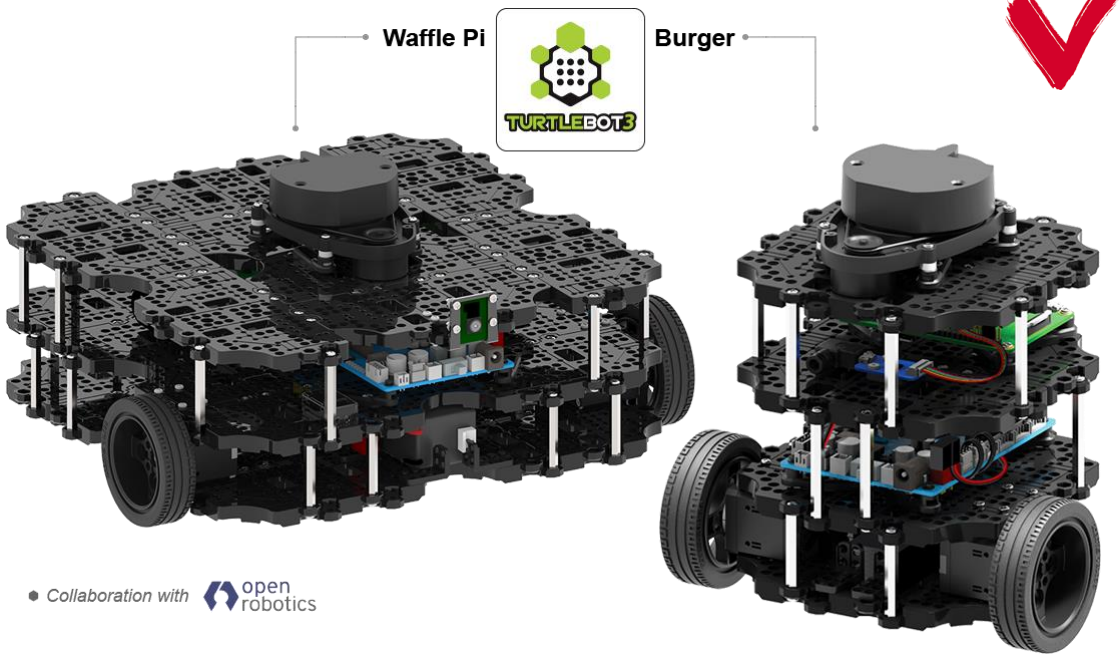
Advertisement #2

TURTLEBOT3

AI Research Starts Here
ROS Official Platform

TurtleBot3 is a new generation mobile robot that’s modular, compact and customizable. Let's explore ROS and create exciting applications for education, research and product development.

Direct Link



Advertisement #3

www.robotsource.org

The ‘RobotSource’ community is the space for people making robots.

We hope to be a community where we can share knowledge about robots, share robot development information and experiences, help each other and collaborate together. Through this community, we want to realize open robotics without disti nguishing between students, universities, research institutes and companies.

Join us in the Robot community ~

END.