iRobot Create Setup with ROS and Implement Odometeric Motion Model

Welcome

Lab 4

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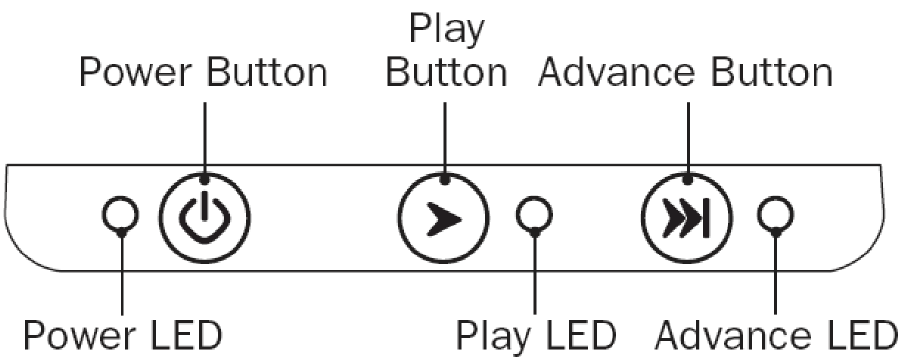
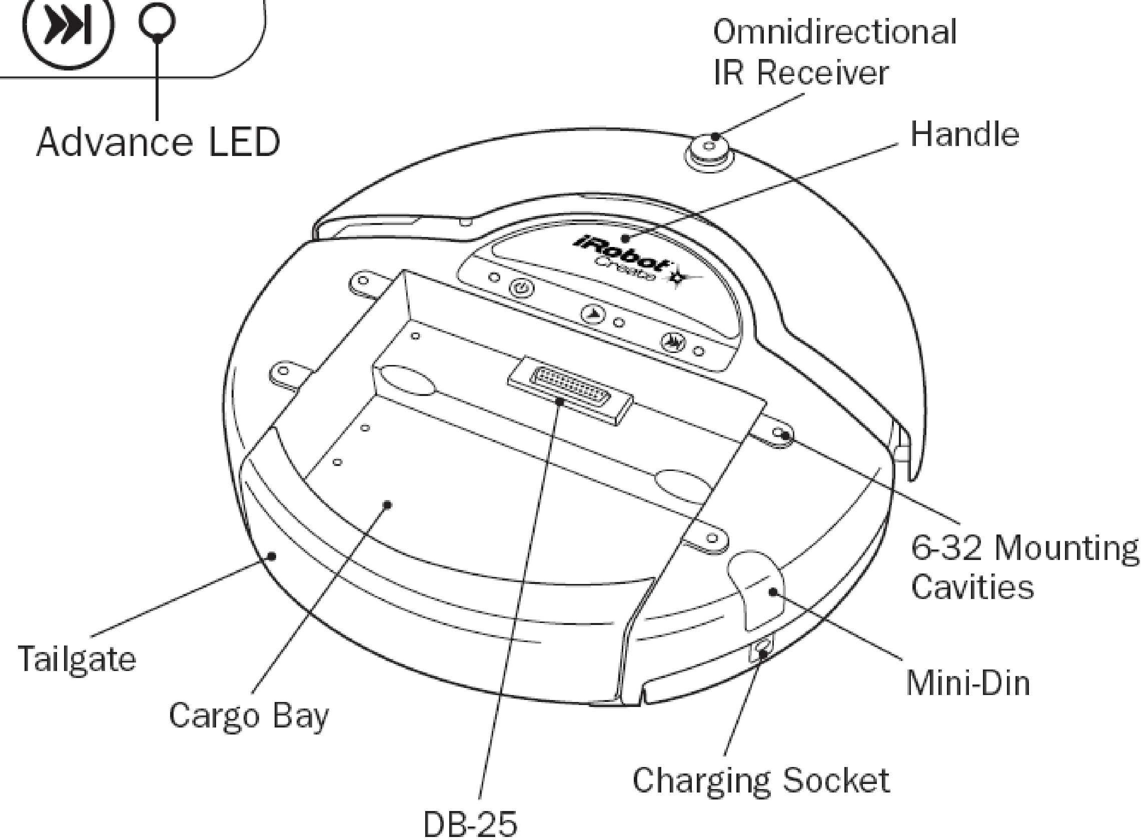
Today's Objectives

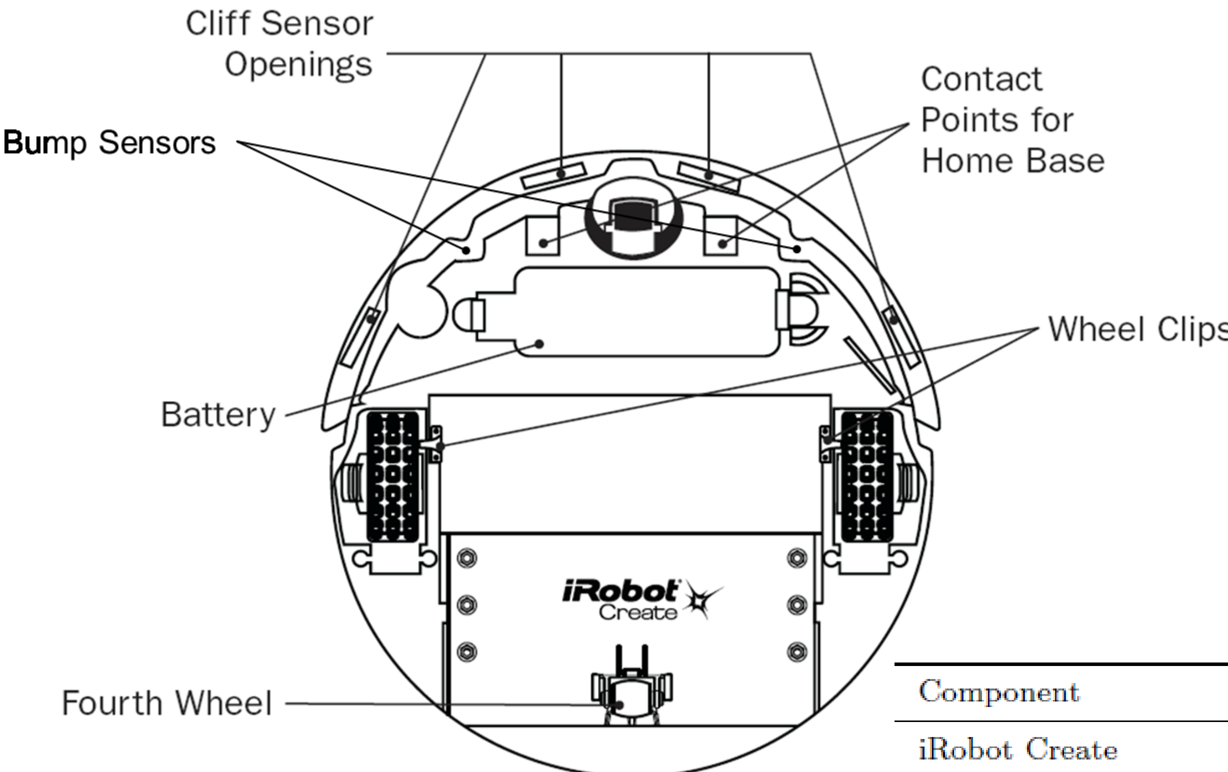
- Introduction to iRobot-Create
  - Hardware
  - Communication
- ROS with iRobot-Create Hardware
  - ROS driver nodes
  - Teleop Keyboard/Joystick
- ROS with iRobot-Create Gazebo Model
  - Odometry
  - Setting up wheel slippage and acceleration effects

iRobot Create - Hardware



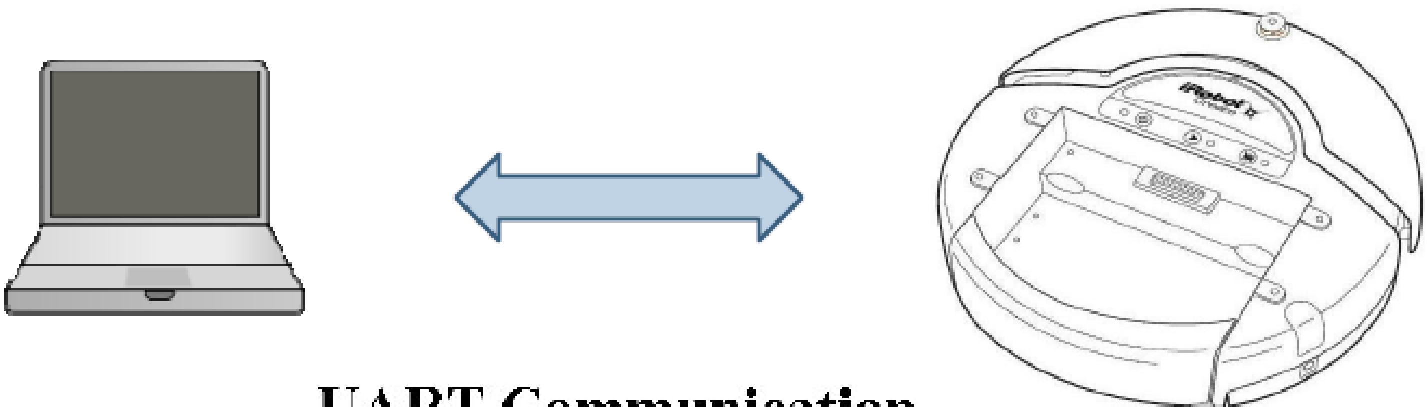


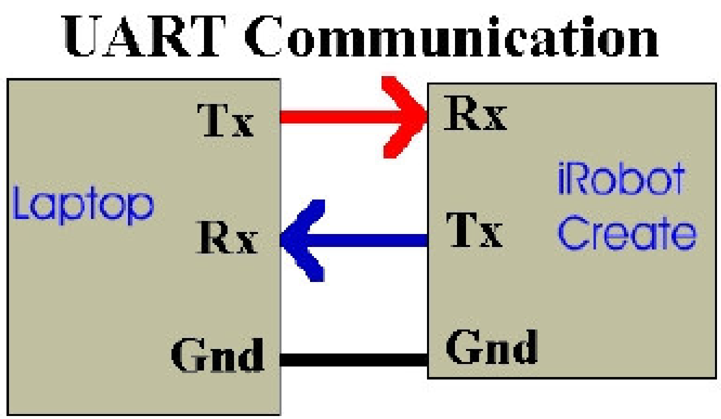
Hardware Components



Component	Price (USD)
iRobot Create	$129.00
iRobot Create w/ Battery	$219.00
iRobot Create w/ Premium Development Package	$299.00
BAM Wireless Accessory	$59.99
USB Bluetooth Radio	$39.95
Battery	$69.99
Battery Charger	$39.99
Command Module	$59.99

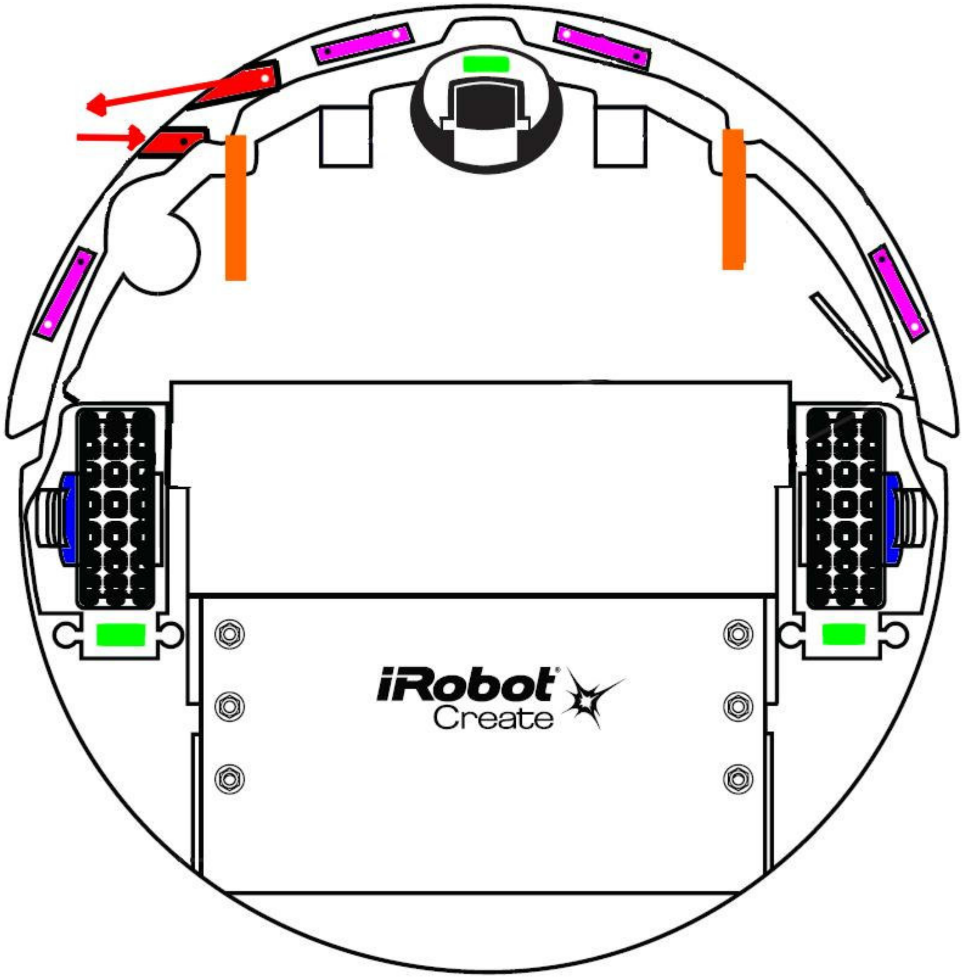
Communication between ROS and iRobot-Create





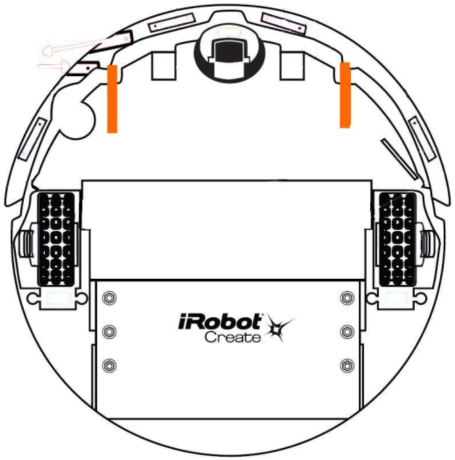
Sensor Locations

Sensor / Input	Number Available
Wheel Encoder	2
Wall Sensor IR	1
Omnidirectional IR	1
Cliff Sensor	4
Bump Sensor	2
Wheel Drop Sensors	3
Buttons	2
Digital Input	4
Analog Input	1

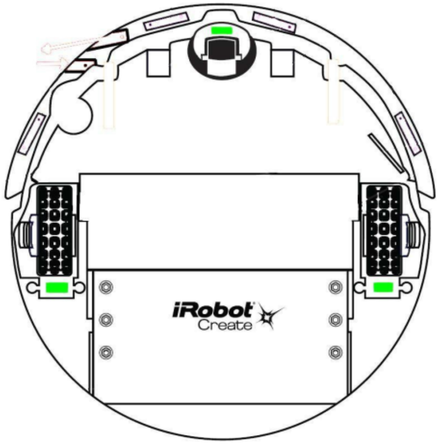


Bump/Wheel Drop Sensor

- Two digital signals
  - Left Bumper
  - Right Bumper

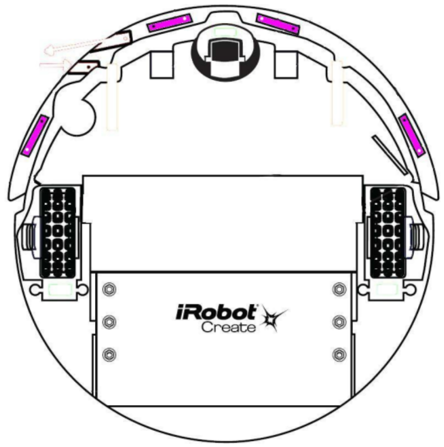


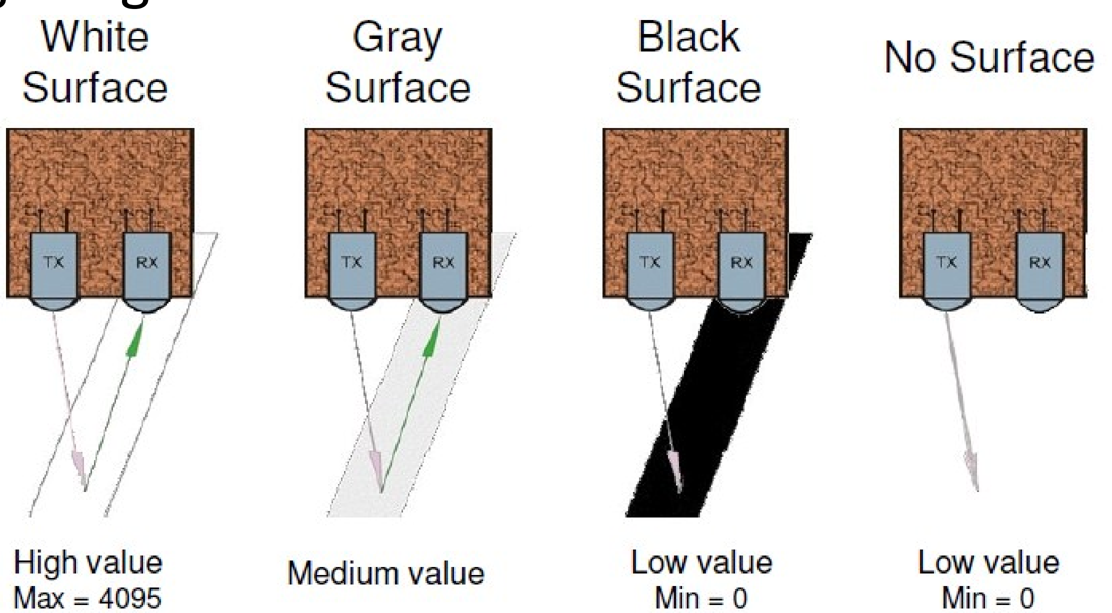
- Three digital inputs
  - Front Wheel Drop
  - Left Wheel Drop
  - Right Wheel Drop



Cliff Sensor

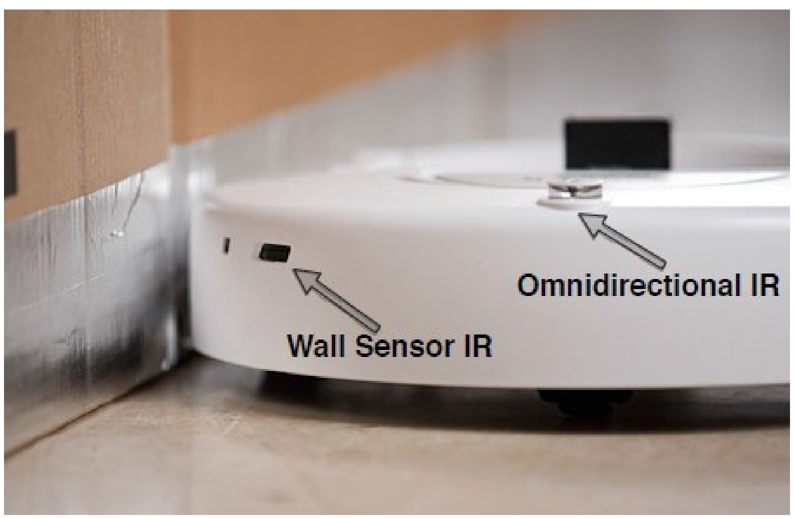
- Four analog inputs
  - Cliff Left Signal
  - Cliff Front Left Signal
  - Cliff Front Right Signal
  - Cliff Right Signal

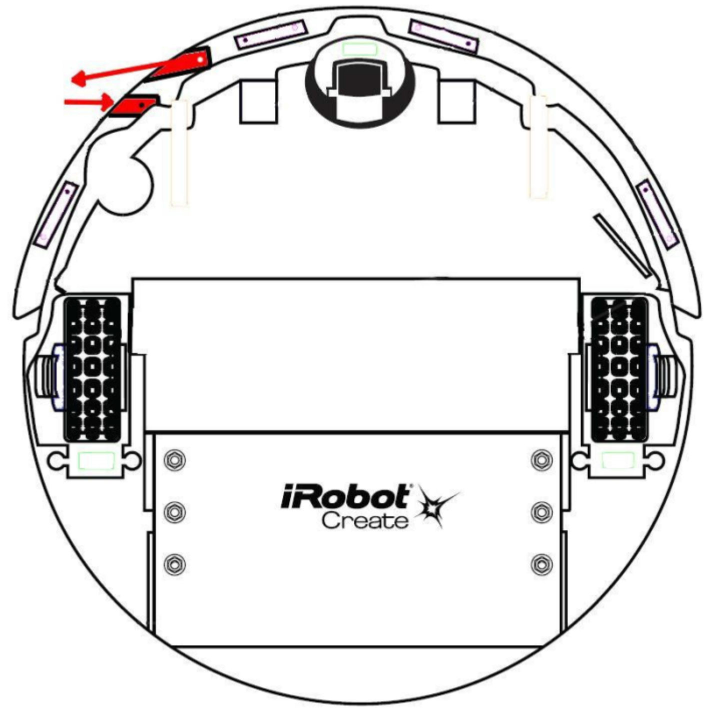




Wall Sensor

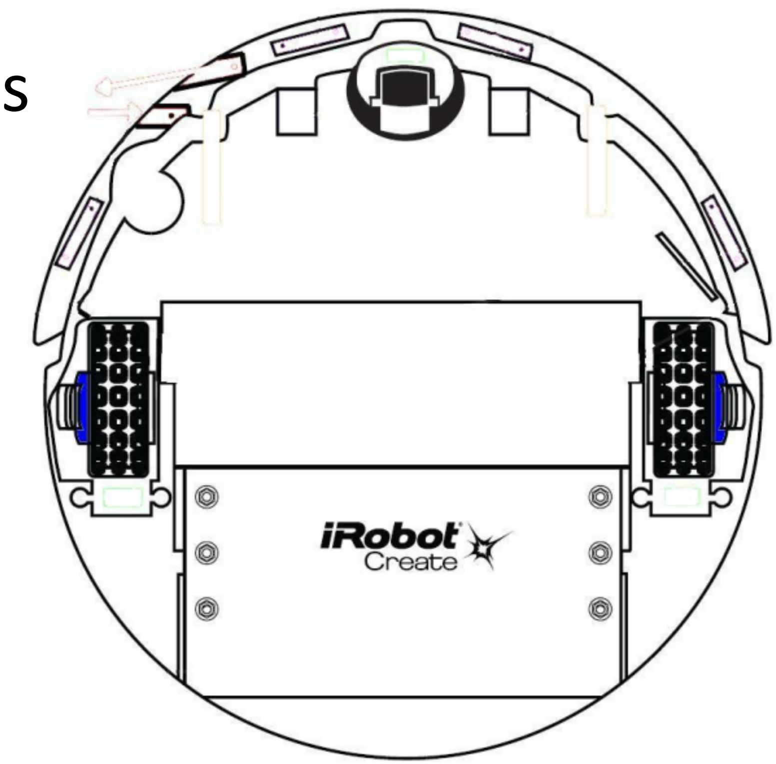
- Analog Sensor
  - Value relates to the distance between wall and Create
  - 0 = No wall seen





Wheel Encoder

- Digital Sensor
  - Distance since last reques
  - Angle since last request
  - Used internally to control wheel speed

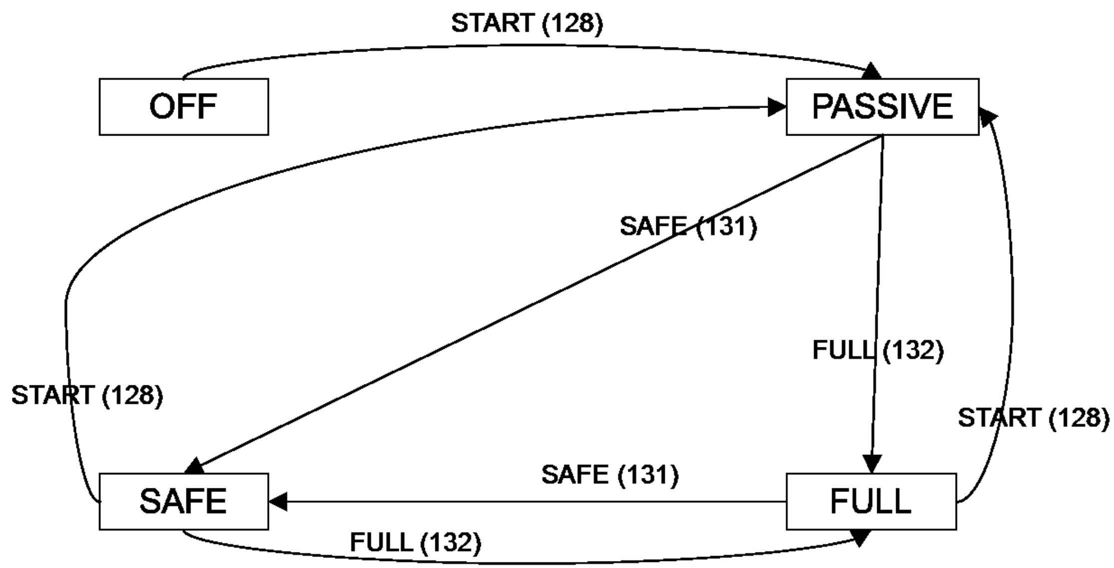


Overview

- Based on *Roomba* robotic vacuum cleaner
- Programmable with **open interface** of over 100 commands
- 32 internal and external sensors including bumpers and infrared
- Expansion port to add **microcontroller**, **Bluetooth**, and/or additional sensors

Modes

- OFF
  - Unresponsive (except START
  - Can charge
- PASSIVE
  - Sensor status commands
  - No Actuator commands
  - Can charge
- SAFE ⇐ **recommended!**
  - Sensor status commands
  - Actuator commands
    - But reverts to PASSIVE if moving *forward* and any cliff sensor is activated; any wheel drop sensor is activated; or the charger is plugged in
  - No Charging
- FULL
  - Sensor status commands
  - Actuator commands
  - No Charging



START	MODE	Opcode	Parameters

Programming (Microprocessor)

- *Command Module* plugs into expansion port
- 8-bit RISC microprocessor (~18 MHz)
- Upload C programs that send *Open Interface* commands and read sensor data
- Open source toolkit (Windows/Mac compatible)
- Four extra expansion ports to add custom hardware (sensors, LCD display, etc.)

- **Drive Create with specified velocity and radius (C function):**

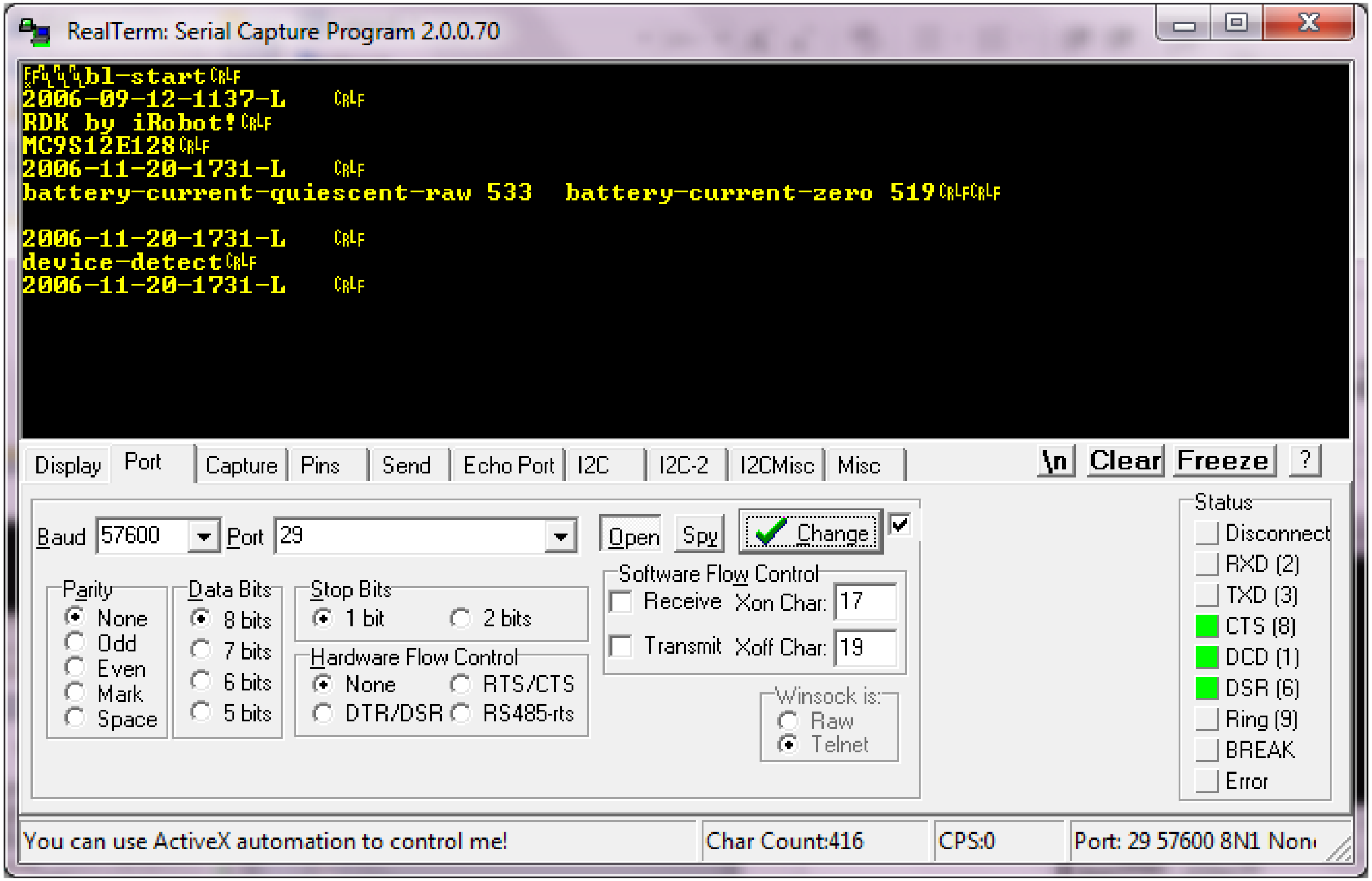
```
void drive(int16_t velocity, int16_t radius)
{
byteTx(CmdDrive);
    byteTx((uint8_t)((velocity >> 8) & 0x00FF));
    byteTx((uint8_t)(velocity & 0x00FF));
    byteTx((uint8_t)((radius >> 8) & 0x00FF));
    byteTx((uint8_t)(radius & 0x00FF));
}
```

Terminal Communication-Linux

- Send *Open Interface* commands via a virtual serial port: 57600 baud, 8 data bits, 1 stop bit
  - Linux stty –F /dev/ttyUSB0 57600 cs8 -cstopb
- Receive sensor data back as packets
- Using any scripting language (Perl, Python, etc.)
- Drive *Create* forward (OI script):

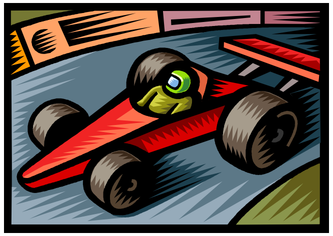
`128 131`	(Start in safe mode)
`137 0 100 128 0`	(Drive forward 100 mm/s)

Terminal Communication-Windows



Actuators: Drive

- DRIVE (137 <velocity$_{high}$> <velocity$_{low}$> <radius$_{high}$> <radius$_{low}$>)
  - 2 short (16 bit) parameters
  - Each represented by 2 bytes, high byte first (so a total of 5 bytes for this command)
- Parameter 1: **velocity** in mm/sec
  - -500 to +500 (-ve means "backwards")
- Parameter 2: **curve radius** in mm
  - -2000 to +2000 where -ve means clockwise and +ve means counterclockwise
  - 32768 means "go straight"
  - -1 and +1 mean spin in place clockwise, counterclockwise respectively



Motor Drive Command

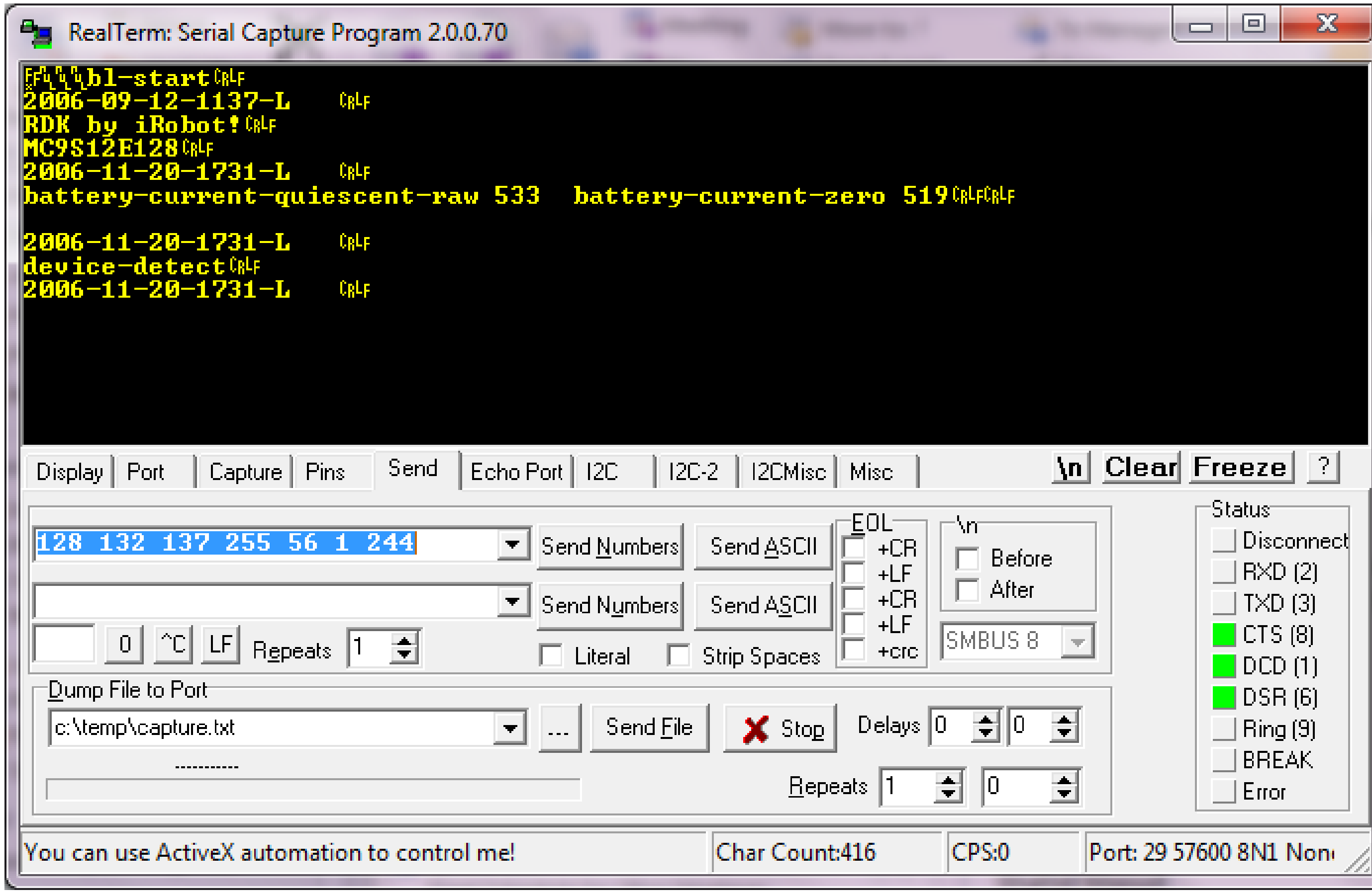
***Example*:**

To drive in reverse at a velocity of -200 mm/s while turning at a radius of 500mm, send the following serial byte sequence:

[128] [132] [137] [255] [56] [1] [244]

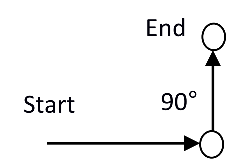
Velocity = -200 = hex FF38 = [hex FF] [hex 38] = [255] [56]

Radius = 500 = hex 01F4 = [hex 01] [hex F4] = [1] [244]

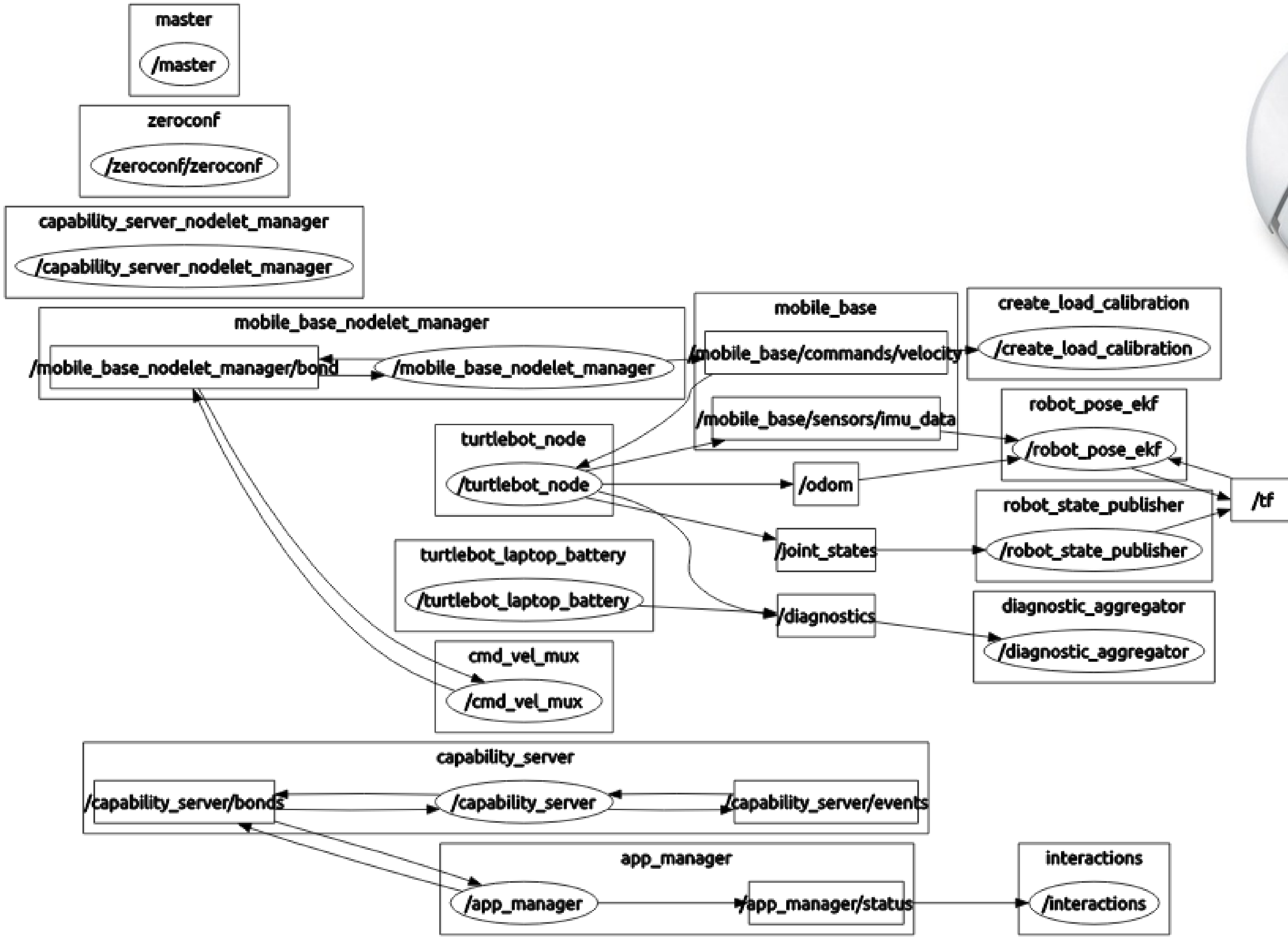


Task1: ROS with iRobot-Create Hardware

- Install turtlebot packages (Debs Installation only) found at {url}.
- Follow Robot configuration robot from {url} for Create base (contrast with Kuboki).
- Configure serial port and launch turtlebot_bringup after configuring it for Create base. {url} Only run TurtleBot Bringup (not Workstation bringup).
- Navigate the robot with turtlebot_teleop package for keyboard. {url}
- Echo odometery. Get familiar with rosbag.
- Visualize the odometery in RViz.
- Now perform the following task 6 times, and record each run in rosbag for latter analysis



iRobot-Create with ROS



ROS Communication with iRobot-Create

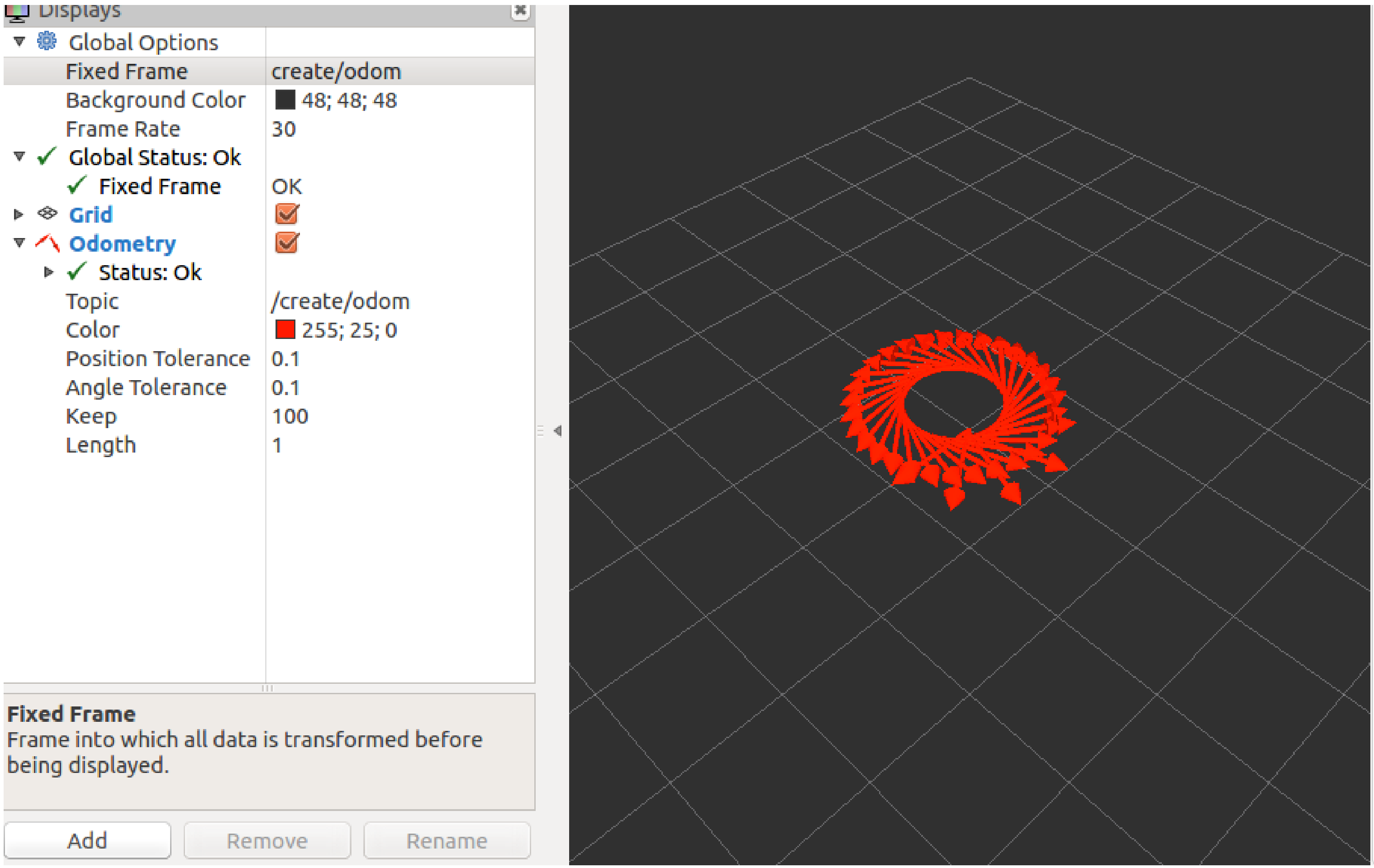
- After turtlebot package installation
- Configure stack for iRobot-Create
  - export TURTLEBOT_BASE=create
  - export TURTLEBOT_STACKS=circles
  - export TURTLEBOT_SERIAL_PORT=/dev/ttyUSB0
- Bringup
  - roslaunch turtlebot_bringup minimal.launch serialport:=/dev/ttyUSB0
  - Test: rostopic list
- Teleop
  - roslaunch turtlebot_teleop keyboard_teleop.launch
  - roslaunch turtlebot_teleop logitech.launch

Sensor and Odometry Topic

```
bumps_wheeldrops: 0
wall: False
cliff_left: False
cliff_front_left: False
cliff_front_right: False
cliff_right: False
virtual_wall: False
motor_overcurrents: 0
dirt_detector_left: 0
dirt_detector_right: 0
remote_opcode: 255
buttons: 0
distance: 0.0
angle: 0.0
charging_state: 0
voltage: 15224
current: -169
temperature: 21
charge: 2699
capacity: 2702
wall_signal: 0
cliff_left_signal: 1052
cliff_front_left_signal: 2108
cliff_front_right_signal: 1204
cliff_right_signal: 888
user_digital_outputs: 1
user_digital_inputs: 0
user_analog_input: 5
charging_sources_available: 0
oi_mode: 3
song_number: 0
song_playing: False
number_of_stream_packets: 0
requested_velocity: 0
requested_radius: 0
requested_right_velocity: 0
requested_left_velocity: 0
---
^Chamza@hamza-laptop:~$ rostopic echo /mobile_base/sensors/core
```

```
/opt/ros/hydro/share/gazebo_ros/launch/em...    ahmad@ahmad-laptop: ~
pose:
  pose:
    position:
      x: -0.00487205904455
      y: -1.49355393522
      z: 0.000946513831449
    orientation:
      x: -3.36661727843e-05
      y: -0.000227964754744
      z: -0.000167602912964
      w: 0.999999959404
twist:
  twist:
    linear:
      x: 0.000761776303189
      y: 0.00015526727852
      z: 0.0
    angular:
      x: 0.0
      y: 0.0
      z: 5.54694543396e-06
---
ahmad@ahmad-laptop:~$ rostopic echo -c --noarr /create/odom
```

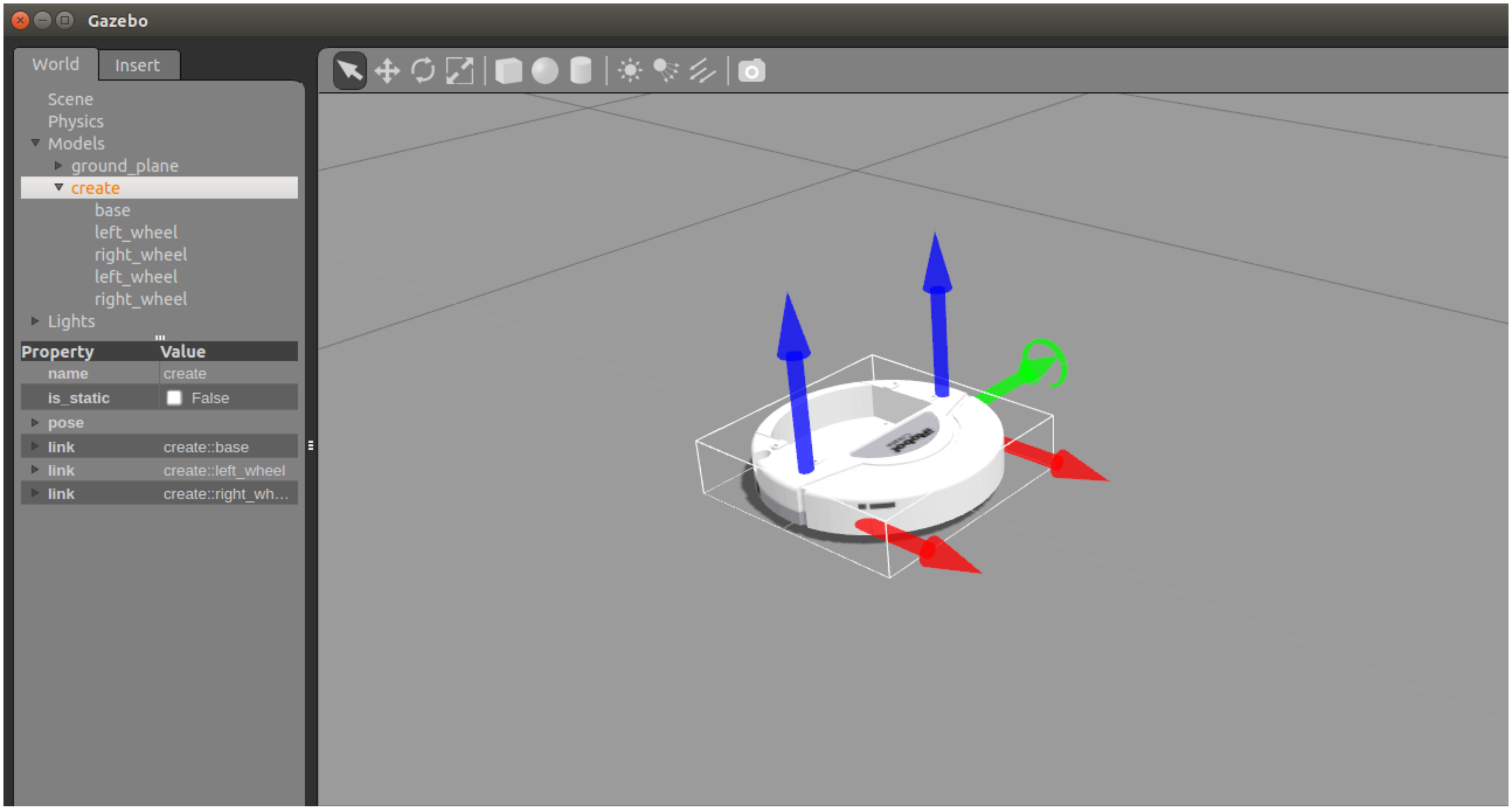
RViz


Displays
Global Options
Fixed Frame
create/odom
Background Color
48; 48; 48
Frame Rate
30
Global Status: Ok
Fixed Frame
OK
Grid
Odometry
Status: Ok
Topic
/create/odom
Color
255; 25; 0
Position Tolerance
0.1
Angle Tolerance
0.1
Keep
100
Length
1
Fixed Frame
Frame into which all data is transformed before being displayed.
Add
Remove
Rename

Task2: ROS with iRobot-Create Gazebo Model

- Spawning iRobot Create in Gazebo. [Launch gazebo with gazebo_ros package]
- Incorporate differential-drive plugin to get the iRobot odometery data published as ROS topic (like done in Lab 2). Also add the following tags within the odometery plugin tag:
  - **<wheelAcceleration>0</wheelAcceleration>**
  - **<odometrySource>encoder</odometrySource>**
- Modify the left and right wheel mu and mu2 inside the <ode> tag. These two parameters represent the coulombs friction coefficient of friction. The value can be between 0 and Infinity, where zero means a frictionless surface (Maximum slippage).
- Using turtlebot_teleop, navigate the robot along a L-shaped path. [Translate, Rotate]
  - rosrun turtlebot_teleop turtlebot_teleop_key
- Record and replay the simulated experiment dataset (odometery) in RViz to get graded.

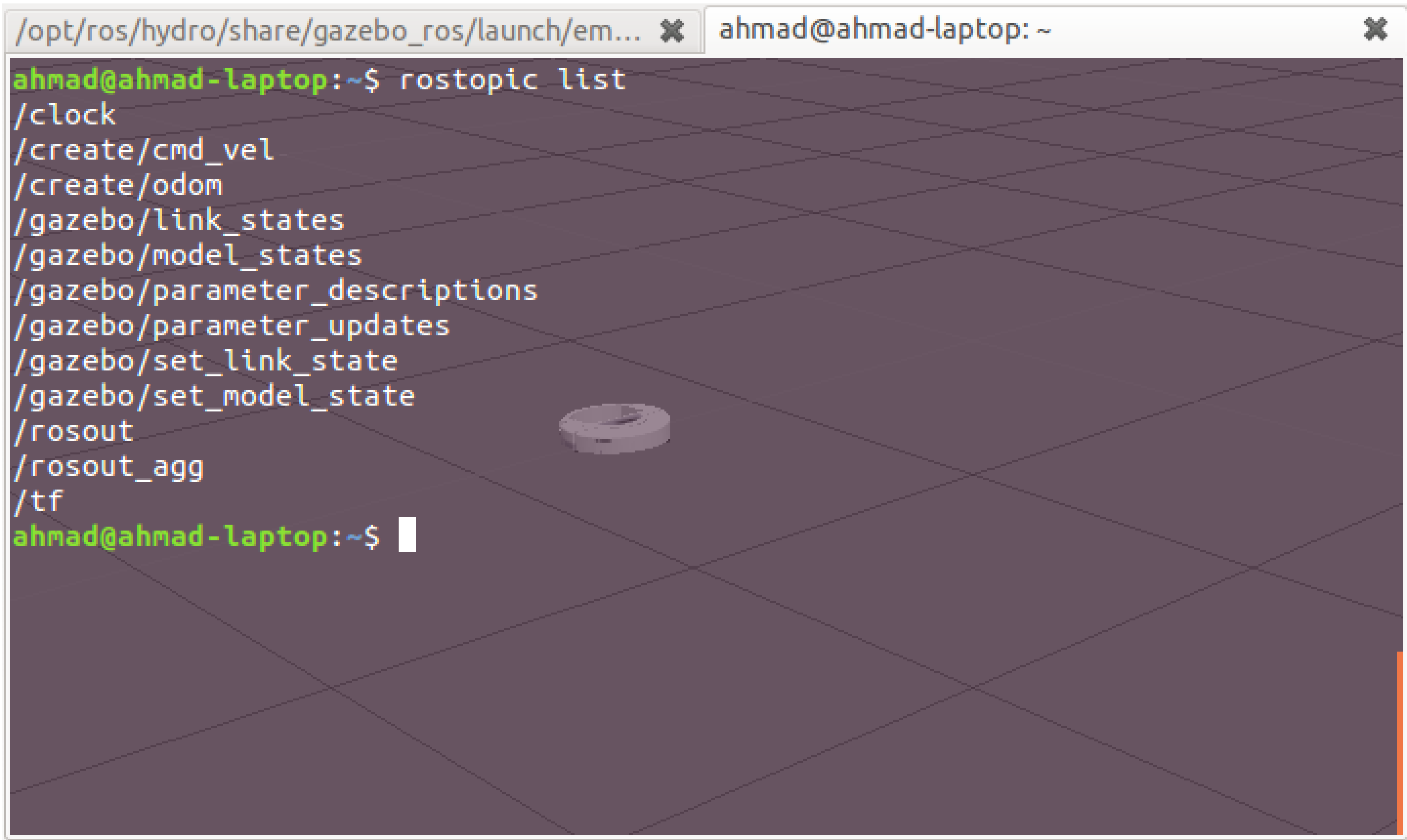
Gazebo Model of iRobot-Create



Odometry Plugin

```
<plugin name="differential_drive_controller" filename="libgazebo_ros_diff_drive.so">
<robotNamespace>/irobot</robotNamespace>
<publishWheelTF>false</publishWheelTF>
<publishWheelJointState>true</publishWheelJointState>
<alwaysOn>true</alwaysOn>
<updateRate>10</updateRate>
<leftJoint>left_wheel</leftJoint>
<rightJoint>right_wheel</rightJoint>
<wheelSeparation>0.283</wheelSeparation>
<wheelDiameter>0.066</wheelDiameter>
 <wheelTorque>5.0</wheelTorque>
<wheelAcceleration>0</wheelAcceleration>
<commandTopic>cmd_vel</commandTopic>
 <odometryTopic>odom</odometryTopic>
<odometryFrame>odom</odometryFrame>
<odometrySource>encoder</odometrySource>
<robotBaseFrame>/base_footprint</robotBaseFrame>
</plugin>
```

Odometry/Cmd_vel Topics Published by Simulated model



Wheel Slippage in Gazebo

```
<link name="left_wheel">
        ...
  <surface>
    <friction>
      <ode>
        <mu>10</mu>
        <mu2>10</mu2>
        <fdir1>0 0 0</fdir1>
        <slip1>0</slip1>
        <slip2>0</slip2>
      </ode>
    </friction>
  </surface>
        ...
</link>
```

```
<link name="right_wheel">
        ...
  <surface>
    <friction>
      <ode>
        <mu>10</mu>
        <mu2>10</mu2>
        <fdir1>0 0 0</fdir1>
        <slip1>0</slip1>
        <slip2>0</slip2>
      </ode>
    </friction>
  </surface>
        ...
</link>
```

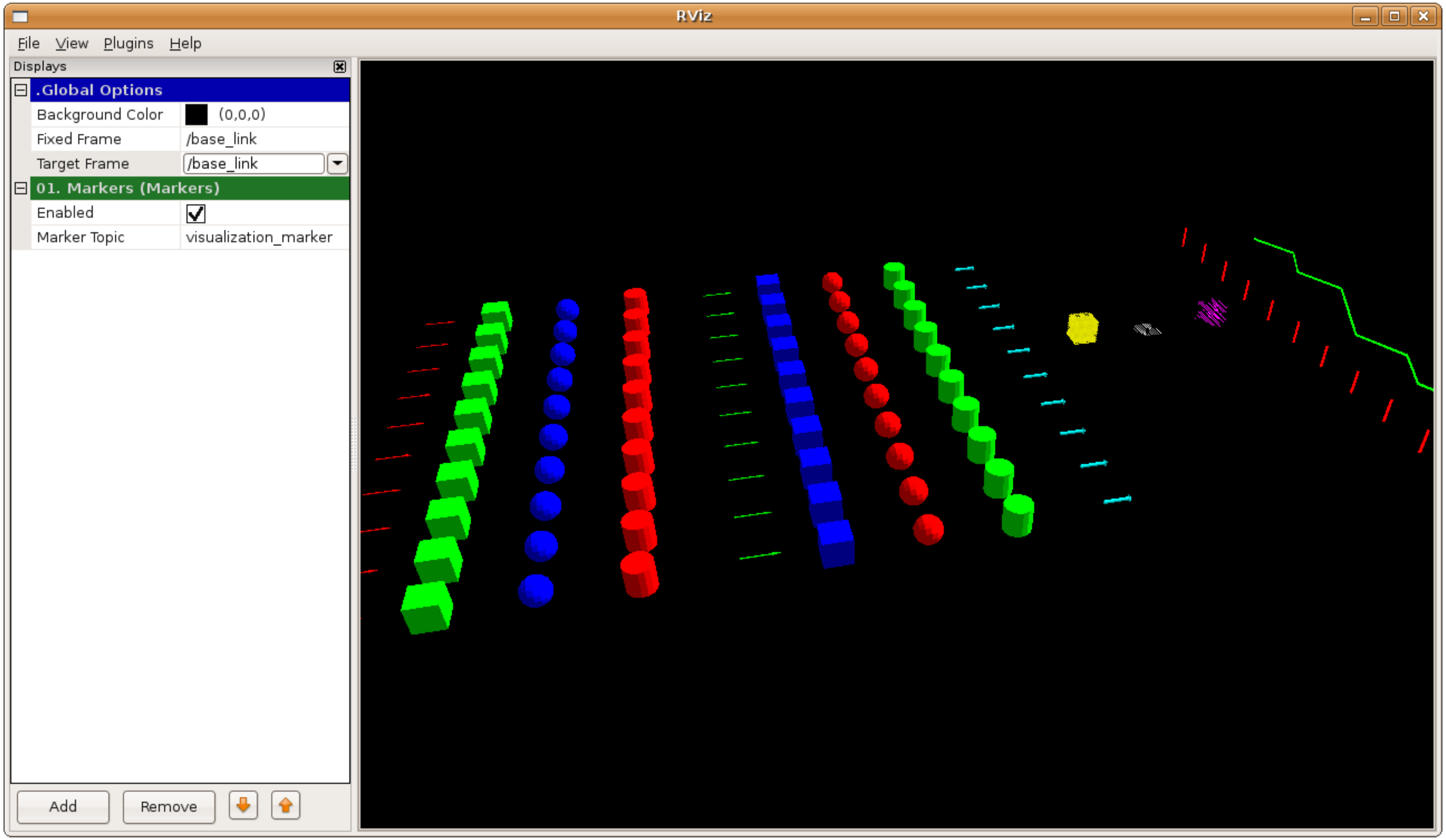
Utility Code – ROS Timers

```
#include "ros/ros.h"
void callback1(const ros::TimerEvent&)
{
  ROS_INFO("Callback 1 triggered");
}

void callback2(const ros::TimerEvent&)
{
  ROS_INFO("Callback 2 triggered");
}

int main(int argc, char **argv)
{
  ros::init(argc, argv, "talker");
  ros::NodeHandle n;
  ros::Timer timer1 = n.createTimer(ros::Duration(0.1), callback1);
  ros::Timer timer2 = n.createTimer(ros::Duration(1.0), callback2);
  ros::spin();
  return 0;
}
```

Custom Objects Visualization in RViz



Utility Code – Marker

```
#include <ros/ros.h>
#include <visualization_msgs/Marker.h>
int main( int argc, char** argv )
{
  ...
    ros::Publisher marker_pub =
n.advertise<visualization_msgs::Marker>("visualization_marker", 1);
    visualization_msgs::Marker marker;
    marker.header.stamp = ros::Time::now();
    marker.type = visualization_msgs::Marker::CUBE;
    marker.action = visualization_msgs::Marker::ADD;
    marker.pose.position.x = 0;
    marker.pose.position.y = 0;
    marker.pose.position.z = 0;
    ...
    marker.lifetime = ros::Duration();
    marker_pub.publish(marker);
  ...
}
```

Lab Assignment

- Implement a ROS node to timely publish /cmd_vel topic for trajectory following (L-shaped) 1m x 1m. Move the robot using this node and visualize in Gazebo. [You will need to implement ros::Timer so that you can keep track of duration of publishing data]
- Read published (noisy) odometry and convert the data into $(\delta_{rot1}, \delta_{trans}, \delta_{rot2})$ convention, in the same node.
- Also read create model's position and orientation states from /gazebo/model_states as ground truth. At this point, you will have *(x, x', u)* as learned in Lecture 3.
  - *x : Initial pose of robot [from model states]*
  - *x' : Final pose of robot [from model states]*
  - *u : Odometry (rot, trans, rot) [from step 2]*
- Publish the final pose of robot (*u*) as a Points type marker in visualization_msgs::Marker. {url}
- Write code (inside the same node) for repeating steps 1-4 (run L-shaped trajectory 100 times, collect data and put final pose as points in the same visualization_msgs::Marker message).
  - In each iteration, there will be some error between ground truth pose (obtained through model_states) and odometeric data (obtained from noisy /odom)
- Plot the 2D points where the robot arrives at end of each trajectory in RViz. [Use *MarkerArray*] [You will get a scatter of points, as well as the desired 2D point]
- Find the mean and variance of $(\delta_{rot1}, \delta_{trans}, \delta_{rot2})$ from sampled data.
- **BONUS:** Graphically plot an oval gray region on the 2D plot of scattered points, that shows mean point and two-standard-deviations confidence region around the mean.