Notes:

Please note that after building, sourcing, and starting the simulation, run this command:

```
> ros2 run py_pubsub pubsub
```

Section 1: Launch the Simulation

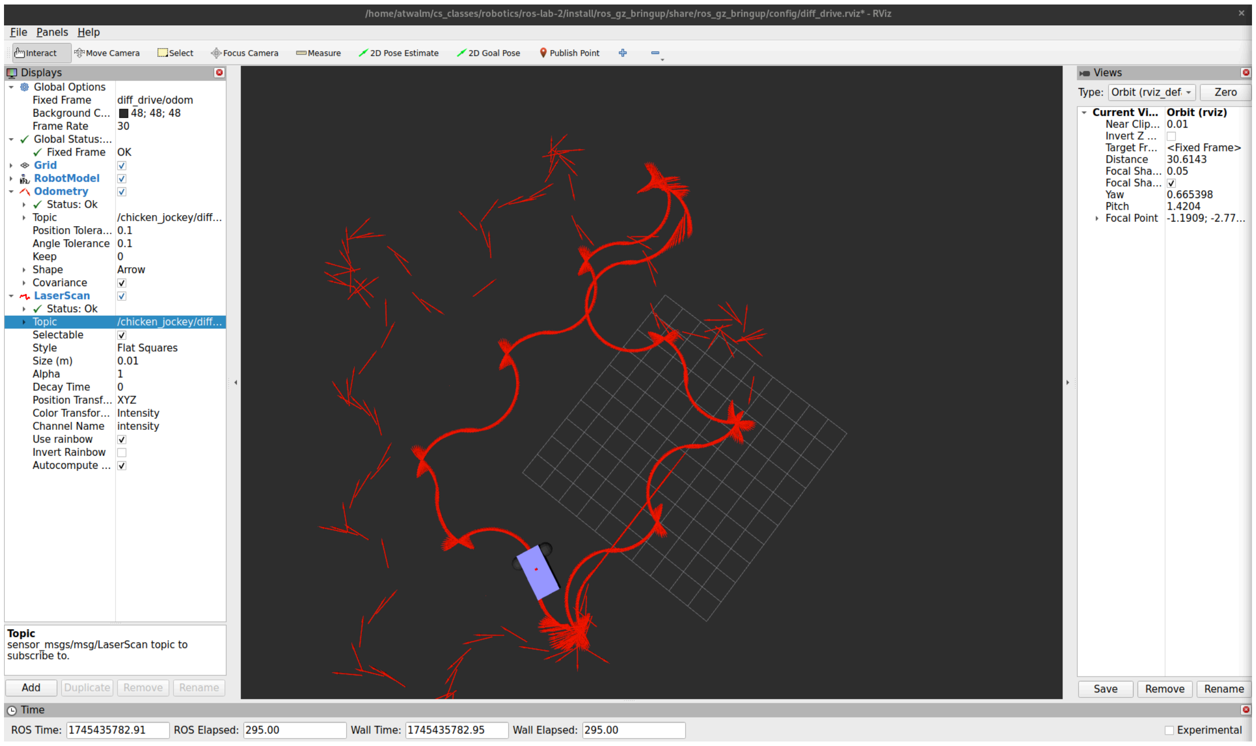
Methods: For this section, I ran the provided commands. There were no decisions on my part. In regards to the question, I noticed that as the robot moved around the simulated space, the output of the second command continuously changed to reflect how close or how far the robot was from obstacles.

Results: I learned that the `/diff_drive/scan` topic provides real-time data and represents the robot's distance from obstacles.

Section 2: Wall-Following Strategy

Methods: For this section, I began by implementing the strategy outlined in the README figure. However, there were some issues. The robot would often stray too far from the left walls and infinitely rotate in the center of the room. So, I adjusted the values such that the robot would stay closer to the left walls. Additionally, I split the, "If obstacle is in front or obstacle is ≤ 2.3 to left," condition from the README figure. This would allow each condition to trigger its own effect. If an obstacle is in front, I apply negative angular speed to make the robot back up and correct its position. It is worth mentioning that I applied too much rotational speed, causing the robot to "over-rotate" and "shimmy" along the left walls. This led to unpredictable behavior, as the robot would sometimes go into the bottom room, get stuck in said room's doorway, or skip said room entirely.Also, please note that it is impossible for any robot to reach the left room, as the doorway is too small. Finally, I changed the angles in "model.sdf" to focus both the front and the left.

Results: I learned that a "bang-bang" controller is somewhat unreliable, as it switches between states abruptly. The robot would act erratically, such as "shimmying" along the walls. This led to the robot getting stuck in the bottom room, often in its doorway. I believe a PID controller would have been a better choice for this robot.



/home/atwalm/cs_classes/robotics/ros-lab-2/install/ros_gz_bringup/share/ros_gz_bringup/config/diff_drive.rviz* - RViz

Global Options	
Fixed Frame	diff_drive/odom
Background C...	■ 48; 48; 48
Frame Rate	30
✓ Global Status:...	
✓ Fixed Frame	OK
Grid	✓
RobotModel	✓
Odometry	✓
✓ Status: Ok	
Topic	/chicken_jockey/diff...
Position Tolera...	0.1
Angle Tolerance	0.1
Keep	0
Shape	Arrow
Covariance	✓
LaserScan	✓
✓ Status: Ok	
Topic	/chicken_jockey/diff...
Selectable	✓
Style	Flat Squares
Size (m)	0.01
Alpha	1
Decay Time	0
Position Transf...	XYZ
Color Transfor...	Intensity
Channel Name	intensity
Use rainbow	✓
Invert Rainbow	☐
Autocompute ...	✓

Topic
sensor_msgs/msg/LaserScan topic to subscribe to.

Type: Orbit (rviz_def. Zero

Current Vi...	**Orbit (rviz)**
Near Clip...	0.01
Invert Z ...	☐
Target Fr...	<Fixed Frame>
Distance	30.6143
Focal Sha...	0.05
Focal Sha...	✓
Yaw	0.665398
Pitch	1.4204
Focal Point	-1.1909; -2.77...

ROS Time: 1745435782.91 ROS Elapsed: 295.00 Wall Time: 1745435782.95 Wall Elapsed: 295.00

Section 3: Changing "model.sdf"

Methods: For this section, I changed the "model.sdf" as requested. There were no decisions on my part.

Results: For (a), shortening the maximum range to 1.0 drastically impacted my wall-following strategy. The robot immediately rotated left, hit the wall, backed up, and looped this cycle. Eventually, it would slide up along said wall, and get trapped on the corner. Setting the maximum range to 1.0 meant that the robot can only see 1.0 units ahead and to the left. As a result of my logic, the robot constantly believed it was colliding, which caused the loop. I believe that by adjusting the values in my conditions, I can account for the robot having a maximum sensing range of 1.0.

For (b), changing the standard deviation of the sensor noise didn't seem to impact my wall-following strategy. The robot performed normally. I believe this is because my thresholds were somewhat tight. A sensor filter would be suitable for compensating for large noise levels.

For (c):

I first changed the mean to be 0.5. The robot immediately rotated left and hit the wall. It slid along said well and got caught in the corner of the doorway. Eventually, it rotated its way out of the corner and continuously rammed into the top wall. Then, I changed the mean to 1.0. Again, it immediately rotated left and hit the wall. The robot continued to ram said wall. The same behavior occurred when I changed the mean to 5.0. Generally speaking, as I increased the mean value, the robot was prone to rotating left and repeatedly smacking into the wall.

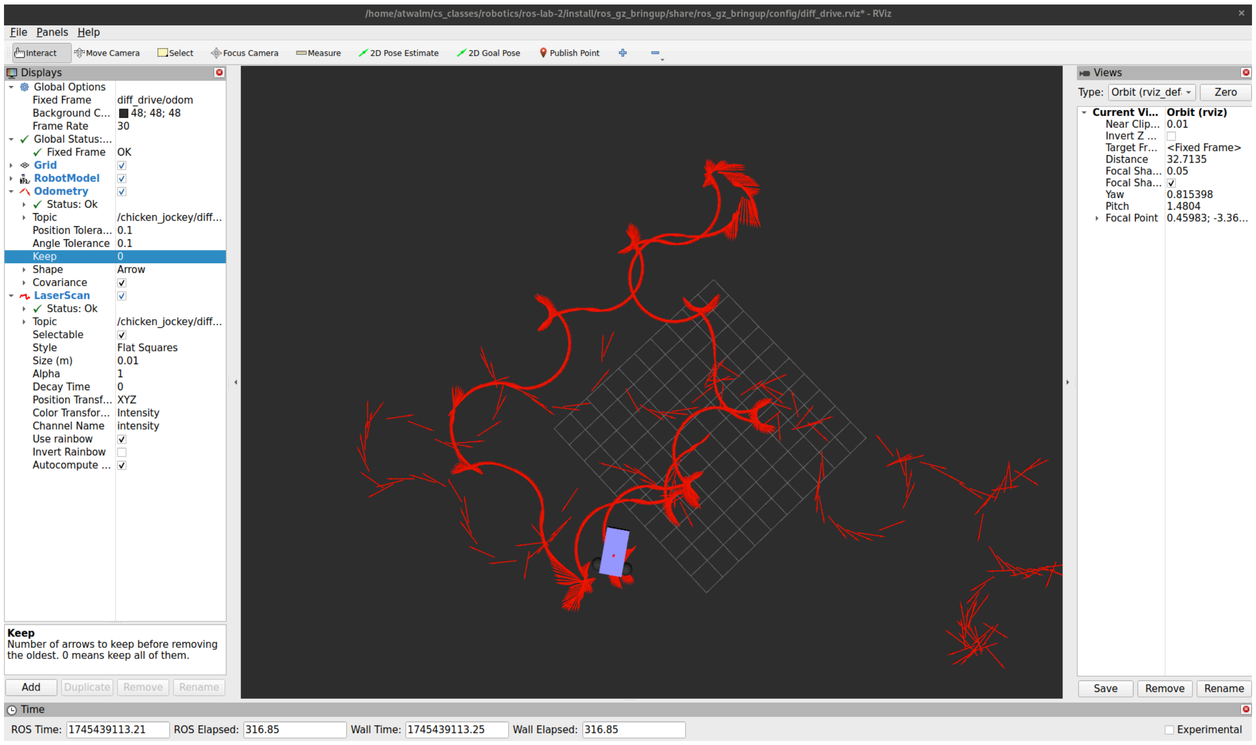
I first changed the mean to be -0.5. The robot immediately rotated right, right away! Then, it would move normally. When I changed the mean to -1.0, it had a similar behavior. At -5.0, the robot would endlessly rotate right in the middle of the room. Occasionally, it would go straight or rotate left. However, it would eventually end up in the middle of the room, continuously rotating right again. Generally speaking, as I decreased the mean value, the robot was prone to repeatedly rotating right in the center of the room. In other words, it was doing donuts.

Section 4: Low-Pass Filter

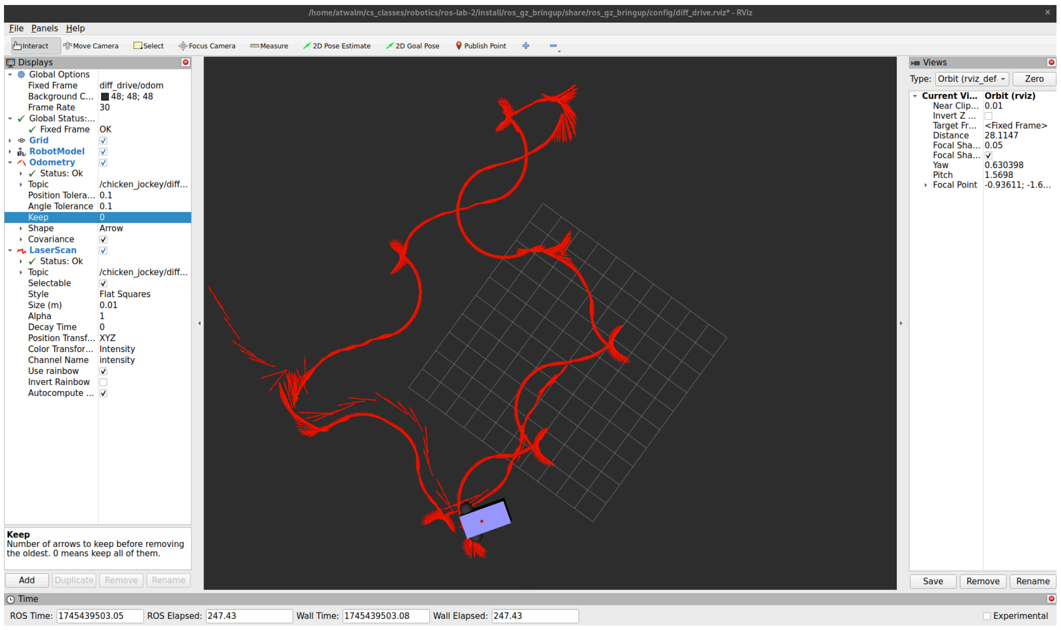
Methods: For this section, I implemented a low-pass filter on my rangefinder data in my wall-following code, using the formula from the slides. The only notable decision I made was setting the cutoff frequency to 0.4. I wanted a balance of reducing noise and retaining enough sensor data.

Results: For (a):

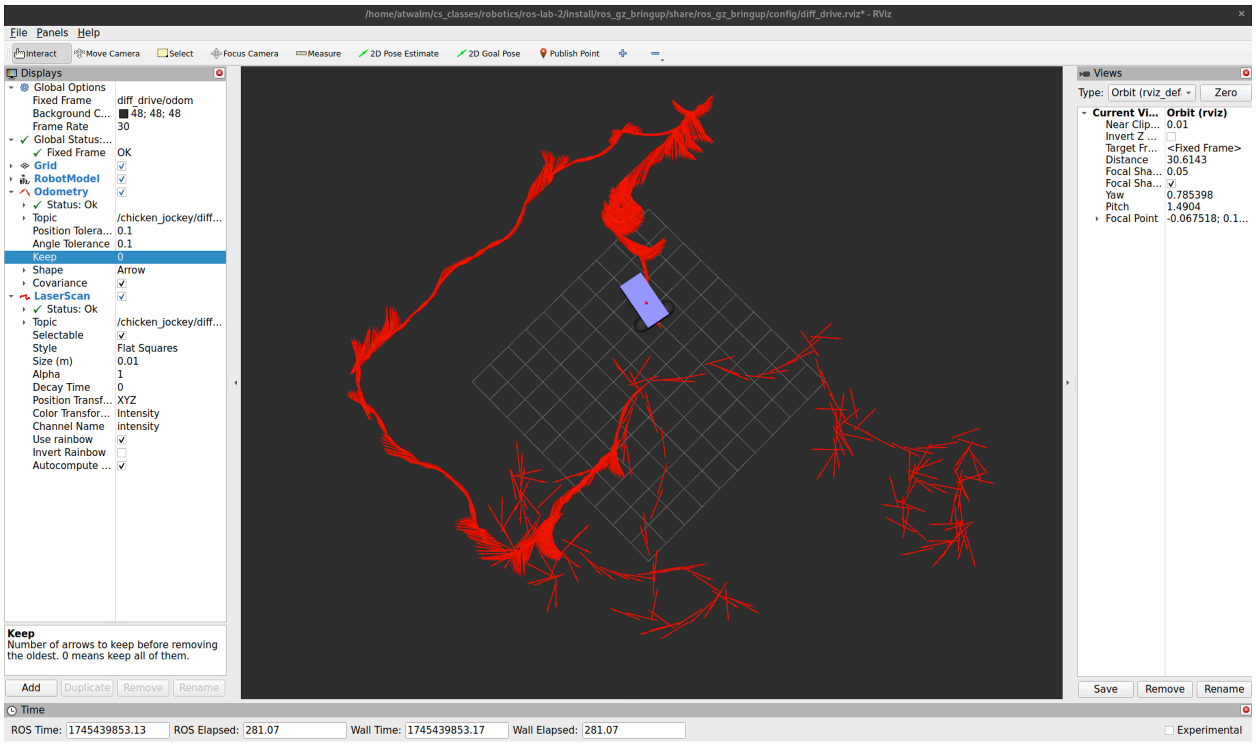
I changed the standard deviation of the sensor noise to 0.5. Initially, the robot rotated right, went straight, rotated left, hit the wall, backed up, rotated left, etc. Also, by comparing the image below to the image prior, the robot performed fairly similarly, but rotated far more (compare the “roundness” of the red arrows).


```
/home/atwalm/cs_classes/robotics/ros-lab-2/install/ros_gz_bringup/share/ros_gz_bringup/config/diff_drive.rviz* - RViz

Displays
  Global Options
    Fixed Frame          diff_drive/odom
    Background C...      ■ 48; 48; 48
    Frame Rate           30
  ✓ Global Status:...
    ✓ Fixed Frame        OK
  Grid                   ✓
  RobotModel             ✓
  Odometry               ✓
    ✓ Status: Ok
    Topic                /chicken_jockey/diff...
    Position Tolera...   0.1
    Angle Tolerance      0.1
    Keep                 0
    Shape                Arrow
    Covariance           ✓
  LaserScan              ✓
    ✓ Status: Ok
    Topic                /chicken_jockey/diff...
    Selectable           ✓
    Style                Flat Squares
    Size (m)             0.01
    Alpha                1
    Decay Time           0
    Position Transf...   XYZ
    Color Transfor...    Intensity
    Channel Name         intensity
    Use rainbow          ✓
    Invert Rainbow       ☐
    Autocompute ...      ✓

Keep
Number of arrows to keep before removing
the oldest. 0 means keep all of them.

Views
Type: Orbit (rviz_def
  Current Vi...          Orbit (rviz)
    Near Clip...         0.01
    Invert Z ...         ☐
    Target Fr...         <Fixed Frame>
    Distance             32.7135
    Focal Sha...         0.05
    Focal Sha...         ✓
    Yaw                  0.815398
    Pitch                1.4804
    Focal Point          0.45983; -3.36...

Time
ROS Time: 1745439113.21   ROS Elapsed: 316.85   Wall Time: 1745439113.25   Wall Elapsed: 316.85
```

Then, I changed it to 1.0. With this higher noise level, the robot seemed to have stabilized, compared to both the image above and the image without a low-pass filter (refer to Section 2). There was far less “shimmying.” This implies that at higher noise levels, the wall-following code might be compensating better.


```
/home/atwalm/cs_classes/robotics/ros-lab-2/install/ros_gz_bringup/share/ros_gz_bringup/config/diff_drive.rviz* - RViz

Displays
  Global Options
    Fixed Frame          diff_drive/odom
    Background C...      ■ 48; 48; 48
    Frame Rate           30
  ✓ Global Status:...
    ✓ Fixed Frame        OK
  Grid                   ✓
  RobotModel             ✓
  Odometry               ✓
    ✓ Status: Ok
    Topic                /chicken_jockey/diff...
    Position Tolera...   0.1
    Angle Tolerance      0.1
    Keep                 0
    Shape                Arrow
    Covariance           ✓
  LaserScan              ✓
    ✓ Status: Ok
    Topic                /chicken_jockey/diff...
    Selectable           ✓
    Style                Flat Squares
    Size (m)             0.01
    Alpha                1
    Decay Time           0
    Position Transf...   XYZ
    Color Transfor...    Intensity
    Channel Name         intensity
    Use rainbow          ✓
    Invert Rainbow       ☐
    Autocompute ...      ✓

Keep
Number of arrows to keep before removing
the oldest. 0 means keep all of them.

Views
Type: Orbit (rviz_def
  Current Vi...          Orbit (rviz)
    Near Clip...         0.01
    Invert Z ...         ☐
    Target Fr...         <Fixed Frame>
    Distance             28.1147
    Focal Sha...         0.05
    Focal Sha...         ✓
    Yaw                  0.630398
    Pitch                1.5698
    Focal Point          -0.93611; -1.6...

Time
ROS Time: 1745439503.05   ROS Elapsed: 247.43   Wall Time: 1745439503.08   Wall Elapsed: 247.43
```

Finally, I changed it to 5.0. The robot was considerably slower in moving around the room. Additionally, the robot would get hung up at corners and doorways (referring to the sheer amount of arrows in said locations). It would eventually move, but it would take the robot some time to properly adjust.



/home/atwalm/cs_classes/robotics/ros-lab-2/install/ros_gz_bringup/share/ros_gz_bringup/config/diff_drive.rviz* - RViz

Displays

Global Options	
Fixed Frame	diff_drive/odom
Background C...	■ 48; 48; 48
Frame Rate	30
✓ Global Status:...	
✓ Fixed Frame	OK
Grid	✓
RobotModel	✓
Odometry	✓
✓ Status: Ok	
Topic	/chicken_jockey/diff...
Position Tolera...	0.1
Angle Tolerance	0.1
Keep	0
Shape	Arrow
Covariance	✓
LaserScan	✓
✓ Status: Ok	
Topic	/chicken_jockey/diff...
Selectable	✓
Style	Flat Squares
Size (m)	0.01
Alpha	1
Decay Time	0
Position Transf...	XYZ
Color Transfor...	Intensity
Channel Name	intensity
Use rainbow	✓
Invert Rainbow	☐
Autocompute ...	✓

Keep
Number of arrows to keep before removing the oldest. 0 means keep all of them.

Views

Type: Orbit (rviz_def...

Current Vi...	**Orbit (rviz)**
Near Clip...	0.01
Invert Z ...	☐
Target Fr...	<Fixed Frame>
Distance	30.6143
Focal Sha...	0.05
Focal Sha...	✓
Yaw	0.785398
Pitch	1.4904
Focal Point	-0.067518; 0.1...

Time

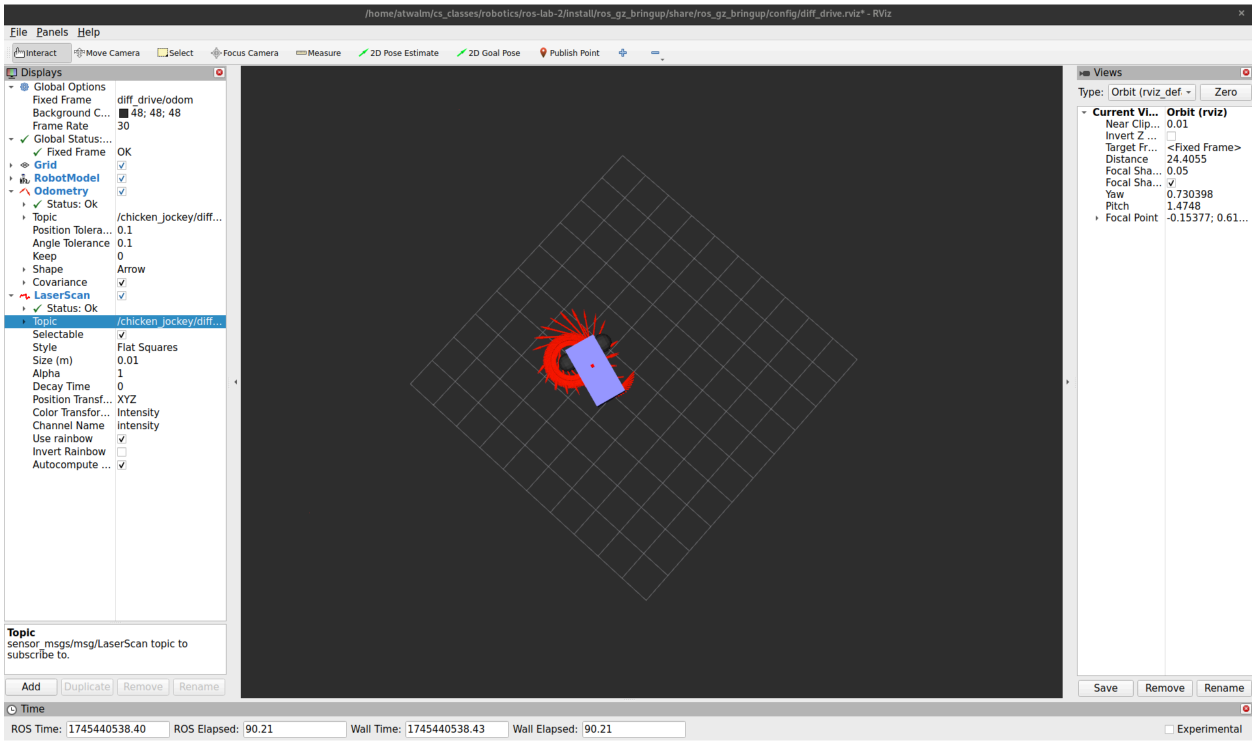
ROS Time: 1745439853.13 ROS Elapsed: 281.07 Wall Time: 1745439853.17 Wall Elapsed: 281.07 ☐ Experimental

For (b):

*** Note that I changed both the maximum and minimum velocities for both linear and angular at the bottom of "model.sdf" and in my wall-following code.*

*** Also, I acknowledge that it would have been more thorough to first change the linear velocity on its own, then the angular velocity. However, for my sanity, I combined both.*

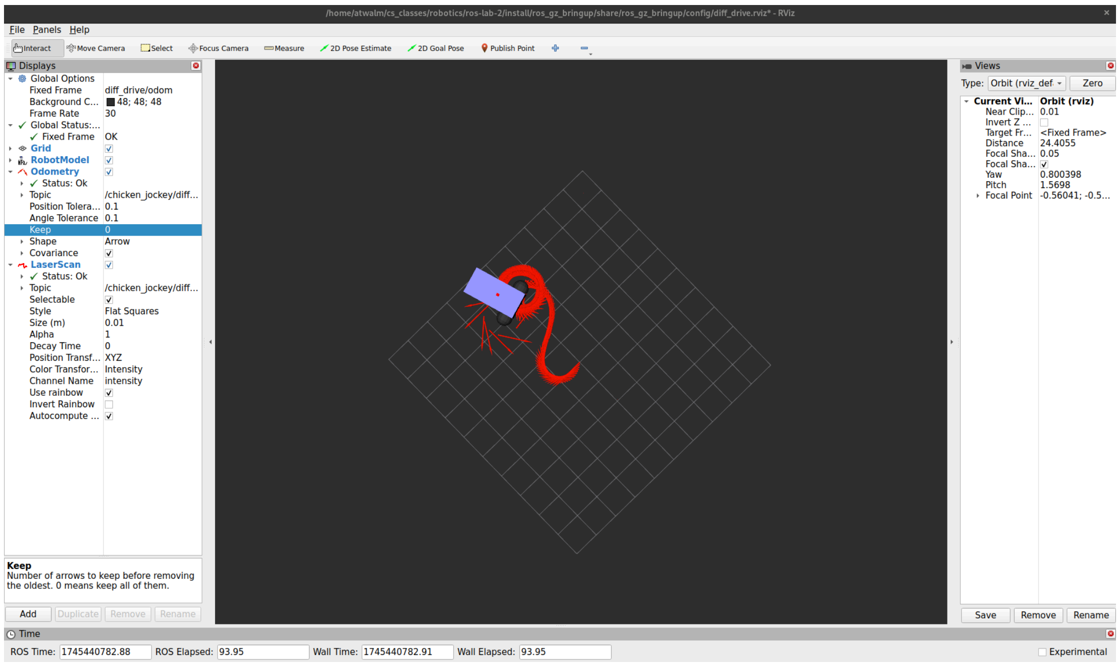
First, I changed my maximum linear velocity to 1, my minimum linear velocity to -1, my maximum angular velocity to 2, and my minimum angular velocity to -2. In this situation, the robot first rotates right, then starts to spin. It forever drifts in the center of the room, like Tokyo Drift!



/home/atwalm/cs_classes/robotics/ros-lab-2/install/ros_gz_bringup/share/ros_gz_bringup/config/diff_drive.rviz* - RViz

```
Displays
Global Options
  Fixed Frame          diff_drive/odom
  Background C...      48; 48; 48
  Frame Rate           30
Global Status:...
  Fixed Frame          OK
Grid                   ✓
RobotModel             ✓
Odometry               ✓
  Status: Ok
  Topic                /chicken_jockey/diff...
  Position Tolera...   0.1
  Angle Tolerance      0.1
  Keep                 0
  Shape                Arrow
  Covariance           ✓
LaserScan              ✓
  Status: Ok
  Topic                /chicken_jockey/diff...
  Selectable           ✓
  Style                Flat Squares
  Size (m)             0.01
  Alpha                1
  Decay Time           0
  Position Transf...   XYZ
  Color Transfor...    Intensity
  Channel Name         intensity
  Use rainbow          ✓
  Invert Rainbow
  Autocompute ...      ✓

Topic
sensor_msgs/msg/LaserScan topic to subscribe to.

Views
Type: Orbit (rviz_def
Current Vi...   Orbit (rviz)
  Near Clip...  0.01
  Invert Z ...
  Target Fr...  <Fixed Frame>
  Distance      24.4055
  Focal Sha...  0.05
  Focal Sha...  ✓
  Yaw           0.730398
  Pitch         1.4748
  Focal Point   -0.15377; 0.61...

Time
ROS Time: 1745440538.40  ROS Elapsed: 90.21  Wall Time: 1745440538.43  Wall Elapsed: 90.21  Experimental
```

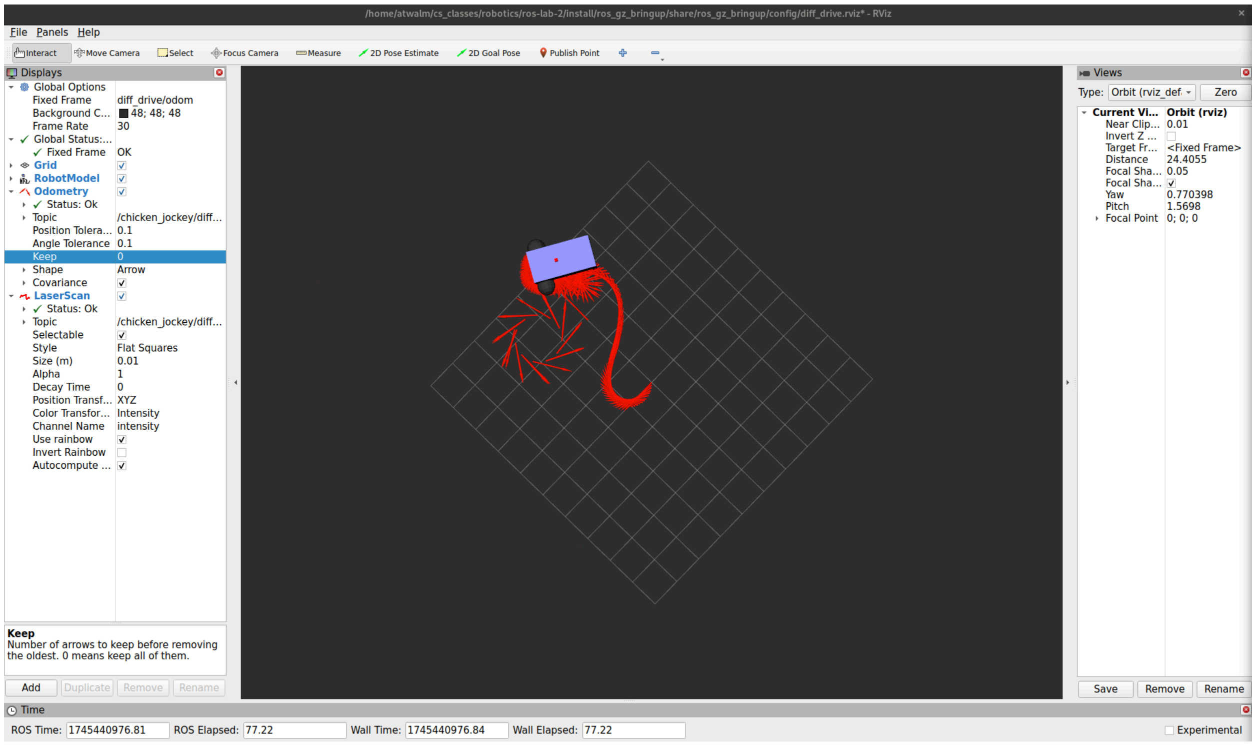
I changed my maximum linear velocity to 2, my minimum linear velocity to -2, my maximum angular velocity to 3, and my minimum angular velocity to -3. Again, it had similar behavior as above. It first rotated right, then it started to spin. It forever drifts in the center of the room. It is worth noting that the rotations are wider.



/home/atwalm/cs_classes/robotics/ros-lab-2/install/ros_gz_bringup/share/ros_gz_bringup/config/diff_drive.rviz* - RViz

```
Displays
Global Options
  Fixed Frame          diff_drive/odom
  Background C...      48; 48; 48
  Frame Rate           30
Global Status:...
  Fixed Frame          OK
Grid                   ✓
RobotModel             ✓
Odometry               ✓
  Status: Ok
  Topic                /chicken_jockey/diff...
  Position Tolera...   0.1
  Angle Tolerance      0.1
  Keep                 0
  Shape                Arrow
  Covariance           ✓
LaserScan              ✓
  Status: Ok
  Topic                /chicken_jockey/diff...
  Selectable           ✓
  Style                Flat Squares
  Size (m)             0.01
  Alpha                1
  Decay Time           0
  Position Transf...   XYZ
  Color Transfor...    Intensity
  Channel Name         intensity
  Use rainbow          ✓
  Invert Rainbow
  Autocompute ...      ✓

Keep
Number of arrows to keep before removing the oldest. 0 means keep all of them.

Views
Type: Orbit (rviz_def
Current Vi...   Orbit (rviz)
  Near Clip...  0.01
  Invert Z ...
  Target Fr...  <Fixed Frame>
  Distance      24.4055
  Focal Sha...  0.05
  Focal Sha...  ✓
  Yaw           0.800398
  Pitch         1.5698
  Focal Point   -0.56041; -0.5...

Time
ROS Time: 1745440782.88  ROS Elapsed: 93.95  Wall Time: 1745440782.91  Wall Elapsed: 93.95  Experimental
```

I changed my maximum linear velocity to 3, my minimum linear velocity to -3, my maximum angular velocity to 4, and my minimum angular velocity to -4. Again, it had the same behavior as above. It first rotated right, then it started to spin. It forever drifts in the center of the room. It is worth noting that the rotations are wider.



Global Options	
Fixed Frame	diff_drive/odom
Background C...	■ 48; 48; 48
Frame Rate	30
✓ Global Status:...	
✓ Fixed Frame	OK
Grid	✓
RobotModel	✓
Odometry	✓
✓ Status: Ok	
Topic	/chicken_jockey/diff...
Position Tolera...	0.1
Angle Tolerance	0.1
Keep	0
Shape	Arrow
Covariance	✓
LaserScan	✓
✓ Status: Ok	
Topic	/chicken_jockey/diff...
Selectable	✓
Style	Flat Squares
Size (m)	0.01
Alpha	1
Decay Time	0
Position Transf...	XYZ
Color Transfor...	Intensity
Channel Name	intensity
Use rainbow	✓
Invert Rainbow	☐
Autocompute ...	✓

Keep
Number of arrows to keep before removing the oldest. 0 means keep all of them.

Type: Orbit (rviz_def

Current Vi...	**Orbit (rviz)**
Near Clip...	0.01
Invert Z ...	☐
Target Fr...	<Fixed Frame>
Distance	24.4055
Focal Sha...	0.05
Focal Sha...	✓
Yaw	0.770398
Pitch	1.5698
Focal Point	0; 0; 0

ROS Time: 1745440976.81 ROS Elapsed: 77.22 Wall Time: 1745440976.84 Wall Elapsed: 77.22

Next Steps: As mentioned before, my wall-following strategy is far from perfect. It does its job stylishly, but to make it more efficient, I believe a PID controller would be more suitable.