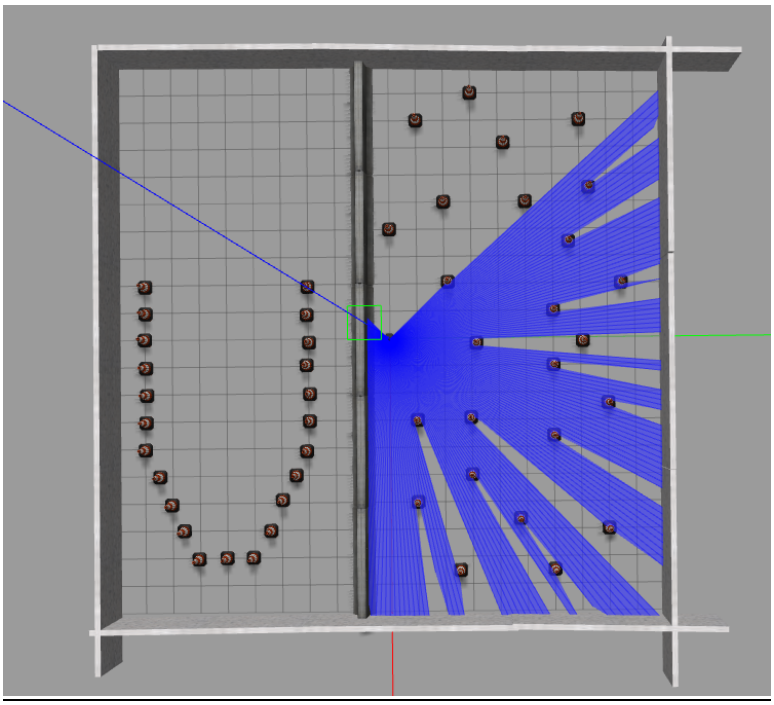
ELEE 4200/5200: Autonomous Mobility Robotics
Term I, 2019
Homework 6: Drive Robot to Avoid Obstacles

Guidelines:

- Due date: Thursday, October 31, 2019 by 12 Noon.
- You are permitted to work in groups of no more than two students. State the full names and T# of the students in the group on the cover page of every document that you submit. Only one report needs to be submitted per group!
- Submit the report by responding to this assignment posting in Blackboard. The submission should at least include the following documents, bundled together into a single zip file with the name *YourNameHW6* (use one of the group member's names).
    - The main report in 'pdf' form (using the LaTeX template provided).
    - The MATLAB program code (as an m-file, so that it can be executed!).
    - Support documents like videos, etc.
- A separate hard copy (printout) of the 'pdf' report with MATLAB code listing; staple all pages together and follow the TA's instructions on how to submit the hardcopy. If you don't submit the hard copy, you will not get a grade for this homework!
- Each group must work on its own in completing this assignment! Feel free to consult with others in developing solution ideas, but the final code implemented must be your work product alone. Refer to the Syllabus, where the policy on academic integrity is clearly outlined, our classroom discussions on this topic, and consult with me and/or the TAs if you have any questions!

Goals:

- To understand the nature and structure of LIDAR data in general; to understand the specific difference between the Kinect Lidar and Hokuyo Lidar views.
- To drive a robot around continuously, while avoiding obstacles, with the help of LIDAR data; to understand the effect of parameter settings on the robot's obstacle avoidance behavior.
- To accomplish the task while using both LIDAR units (Kinect & Hokuyo with field of views of +/- 30^0 and +/-135^0 respectively) and observe the difference in robot behavior between the two.
- To learn how to create your own Gazebo world and use it for simulations. However, a specific Gazebo world file (like the one shown in Figure 1) is being uploaded to Blackboard for this assignment and you are required to use it.



Specific Tasks:

You are required to compare the behavior of the Turtlebot with two different LIDAR sensor views. This requires careful program construction and observation, followed by appropriate comparison of the test results and discussion. There are two separate tasks:

Task A: "Random Walk"

a) Construct a program in MATLAB that drives a simulated Turtlebot with a Hokuyo LIDAR continuously around a Gazebo environment, while avoiding hitting any obstacles. Set the initial position of the robot using the following command:
$ rosservice call /gazebo/set_model_state '{model_state: { model_name: mobile_base, pose: { position: {x: 6, y: 7 , z: 0 }, orientation: { x: 0, y: 0 , z: 1, w: 0 } }, twist: { linear: {x: 0 , y: 0 , z: 0 } , angular: {x: 0 , y: 0 , z: 0 } } , reference_frame: world } }'

b) Repeat, this time using the Kinect LIDAR and the same starting pose.

c) Compare robot behavior corresponding to the two cases above. When comparing robot behavior for the two cases, it would make sense if the robots are allowed to run for the same length of time. Try to make your comments precise and to the point!

Task B: "Concave or U-shaped Trap"

d) Move over to the U-trap part of the course. Set the initial position of the robot using the following command:
$ rosservice call /gazebo/set_model_state '{model_state: { model_name: mobile_base, pose: { position: {x: -9, y: -6 , z: 0 }, orientation: { x: 0, y: 0 , z: 0, w: 0 } }, twist: { linear: {x: 0 , y: 0 , z: 0 } , angular: {x: 0 , y: 0 , z: 0 } } , reference_frame: world } }'

e) Use the Hokuyo LIDAR data and run the robot so that it is able to exit the U-trap.
f) Repeat (e), this time using the Kinect LIDAR data. Again, the task is to exit the U-trap.
g) Compare robot behavior for parts (e) & (f).

Other related information (read carefully!):

- Instructions are provided later in this document in the "Appendix" on how to incorporate the specified world file into your plans.
- You must start the Turtlebot within the Gazebo environment at the locations provided. This is the best way of being able to repeat the robot runs as well as properly comparing runs using the Hokuyo and Kinect.
- Produce some good videos of robot runs and include them in your submission.
- Some sources are provided below from which you can get ideas on constructing your program. However, you are still responsible for explaining how you arrived at your program and the attendant robot behavior. An important point to note is that *the process of arriving at the results is more important than obtaining results that appear correct, but you don't have any idea of how you got them!* This is embodied in the following sequence of actions – an algorithmic idea translated correctly to code, examination of the attendant behavior of the robot in multiple experiments, modification of the algorithm to change or correct behavior desirably, then repeat this sequence as necessary.
- In the assigned Task A, there is a risk (though small, because the obstacle density is not that high!) of the robot finding itself in a trap. This situation is not necessarily one in which the robot is stationary; it is possible for it to be in a repetitive or oscillatory condition, where it essentially makes no progress. These situations, if encountered, can be handled by an "escape" behavior (maybe randomly determined – example: each time you back up in a different way, if the previous move does not get you "unstuck"!). A simple escape behavior is incorporated in [1] below.
- You can build your program using the following sources of information:
  - The "Jackal_New.m" file found within [2] is a source of information to get ideas on building your own program. Specifically, it works by figuring out the location and angle of the closest obstacle in front of it and taking appropriate evasive action.
  - Reference [1] is another source from which you can draw inspiration, in particular the "Receive Scan Data" and "Simple Obstacle Avoidance" sections. Feel free to incorporate your own ideas on top of the basic concept embedded in these two program sources!
- For the Turtlebot the "kinect scan" sensor represents the conversion of camera views into a pseudo laser scan view, through a software program interface. There are inherent limitations with the Kinect-based laser scan arrangement due to the limitations of the Kinect camera. These are explained in [1] in which only the "kinect scan" is available. Most important, the horizontal field-of-view is limited to +/- 30^0, which makes algorithm design

more challenging! An additional Hokuyo Lidar sensor is added to our Turtlebot with a +/- 270^0 field of view.

References

1. https://www.mathworks.com/help/robotics/examples/explore-basic-behavior-of-the-turtlebot.html
2. https://www.clearpathrobotics.com/2015/03/matlab-robotics-system-toolbox-and-ros/

APPENDIX: Process for Incorporating the new world file

The launch command that you may have been using so far is:
$ roslaunch turtlebot_gazebo turtlebot_world.launch

This corresponds to the following structure:
$ (launch command) (package folder) (launch file referencing specific world file)

Do the following first:

- Locate the "turtlebot_gazebo" folder within your directory structure.
- Within this folder there should be two directories – "launch" & "worlds". They should contain the "turtlebot_world.launch" file and the "empty.world" respectively.
- Copy the new world file for this assignment ("obstacle_avoid.world") to the "worlds" directory (using the "cp" command and appropriate path prefixes). You will need "sudo" permission to do this!

The new launch command to use is (both lines below with a space at the end of first line):
$ roslaunch turtlebot_gazebo turtlebot_world.launch
world_file:="/opt/ros/kinetic/share/turtlebot_gazebo/worlds/obstacle_avoid.world"
Essentially the command extension (highlighted above) substitutes the new world file for the old world file!
Included below is the listing of the "turtlebot_world.launch" file in case you are curious about the background of how all of this works. However, your curiosity will only be completely satisfied if you read through the relevant sections from Jason O'Kane's "A Gentle Introduction to ROS"!
Essentially the use of "default" in the second line of the launch file enables the above substitution; if "value" had been used instead (see its usage in third line), we would not have been able to do it like this!
File: "turtlebot_world.launch"

```
<launch>
  <arg name="world_file"  default="$(env TURTLEBOT_GAZEBO_WORLD_FILE)"/>

  <arg name="base"      value="$(optenv TURTLEBOT_BASE kobuki)"/> <!-- create, roomba -->
  <arg name="battery"   value="$(optenv TURTLEBOT_BATTERY /proc/acpi/battery/BAT0)"/>  <!--
/proc/acpi/battery/BAT0 -->
  <arg name="gui" default="true"/>
  <arg name="stacks"    value="$(optenv TURTLEBOT_STACKS hexagons)"/>  <!-- circles, hexagons -->
```

```
  <arg name="3d_sensor" value="$(optenv TURTLEBOT_3D_SENSOR kinect)"/>  <!-- kinect, asus_xtion_pro -->

  <include file="$(find gazebo_ros)/launch/empty_world.launch">
    <arg name="use_sim_time" value="true"/>
    <arg name="debug" value="false"/>
    <arg name="gui" value="$(arg gui)" />
    <arg name="world_name" value="$(arg world_file)"/>
  </include>

  <include file="$(find turtlebot_gazebo)/launch/includes/$(arg base).launch.xml">
    <arg name="base" value="$(arg base)"/>
    <arg name="stacks" value="$(arg stacks)"/>
    <arg name="3d_sensor" value="$(arg 3d_sensor)"/>
  </include>

  <node pkg="robot_state_publisher" type="robot_state_publisher" name="robot_state_publisher">
    <param name="publish_frequency" type="double" value="30.0" />
  </node>

  <!-- Fake laser -->
  <node pkg="nodelet" type="nodelet" name="laserscan_nodelet_manager" args="manager"/>
  <node pkg="nodelet" type="nodelet" name="depthimage_to_laserscan"
        args="load depthimage_to_laserscan/DepthImageToLaserScanNodelet laserscan_nodelet_manager">
    <param name="scan_height" value="10"/>
    <param name="output_frame_id" value="/camera_depth_frame"/>
    <param name="range_min" value="0.45"/>
    <remap from="image" to="/camera/depth/image_raw"/>
    <remap from="scan" to="/scan"/>
  </node>
</launch>
```