Sim.I.am: A Robot Simulator

Coursera: Control of Mobile Robots

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Contents

1 Introduction

This manual is going to be your resource for using the simulator with the programming assignments featured in the Coursera course, *Control of Mobile Robots* (and included at the end of this manual). It will be updated from time to time whenever new features are added to the simulator or any corrections to the course material are made.

1.1 Installation

Download `simiam-coursera-week-X.zip` (where X is the corresponding week number for the assignment) from the course page on Coursera under *Programming Assignments*. Make sure to download a new copy of the simulator **before** you start a new week's programming assignment, or whenever an announcement is made that a new version is available. It is important to stay up-to-date, since new versions may contain important bug fixes or features required for the programming assignment.

Unzip the `.zip` file to any directory.

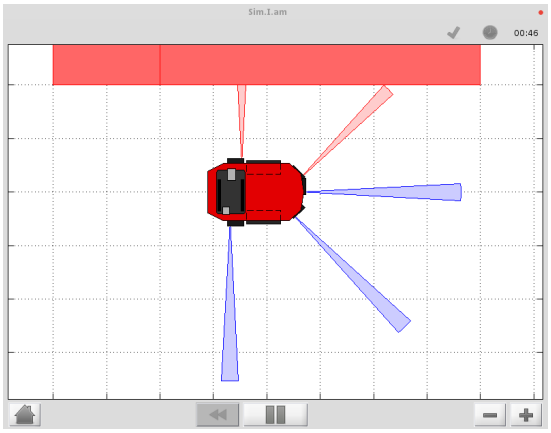
1.2 Requirements

You will need a reasonably modern computer to run the robot simulator. While the simulator will run on hardware older than a Pentium 4, it will probably be a very slow experience. You will also need a copy of MATLAB.

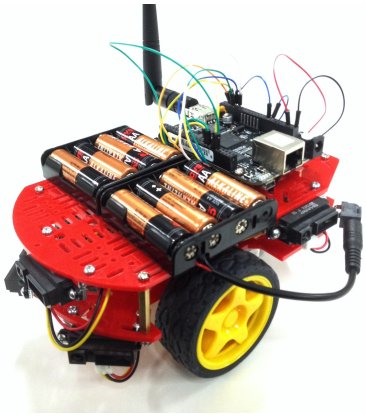
Thanks to support from MathWorks, a license for MATLAB and all required toolboxes is available to all students for the duration of the course. Check the *Getting Started with MATLAB* section under *Programming Assignments* on the course page for detailed instructions on how to download and install MATLAB on your computer.

1.3 Bug Reporting

If you run into a bug (issue) with the simulator, please create a post on the discussion forums in the *Programming Assignments* section. Make sure to leave a detailed description of the bug. Any questions or issues with MATLAB itself should be posted on the discussion forums in the *MATLAB* section.



(a) Simulated QuickBot



(b) Actual QuickBot

Figure 1: The QuickBot mobile robot in and outside of the simulator.

2 Mobile Robot

The mobile robot you will be working with in the programming exercises is the QuickBot. The QuickBot is equipped with five infrared (IR) range sensors, of which three are located in the front and two are located on its sides. The QuickBot has a two-wheel differential drive system (two wheels, two motors) with a wheel encoder for each wheel. It is powered by two 4x AA battery packs on top and can be controlled via software on its embedded Linux computer, the BeagleBone Black. You can build the QuickBot yourself by following the hardware lectures in this course.

Figure 2 shows the simulated and actual QuickBot mobile robot. The robot simulator recreates the QuickBot as faithfully as possible. For example, the range, output, and field of view of the simulated IR range sensors match the specifications in the datasheet for the actual Sharp GP2D120XJ00F infrared proximity sensors on the QuickBot.

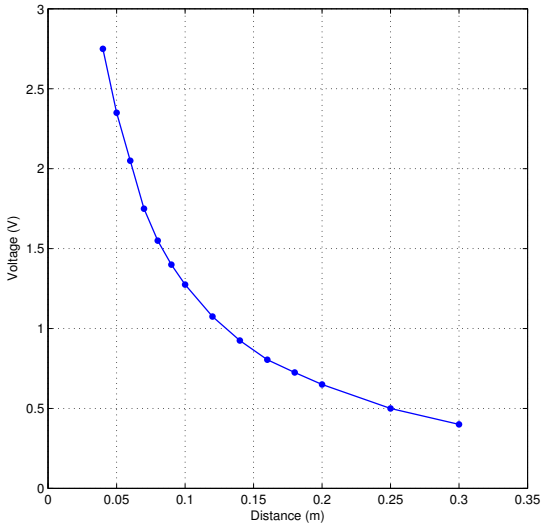
2.1 IR Range Sensors

You will have access to the array of five IR sensors that encompass the QuickBot. The orientation (relative to the body of the QuickBot, as shown in figure 1a) of IR sensors 1 through 5 is $90°, 45°, 0°, -45°, -90°$, respectively.I R range sensors are effective in the range 0.04 m to 0.3 m only. However, the IR sensors return raw values in the range of $[0.4, 2.75]V$ instead of the measured distances. Figure 2a demonstrates the function that maps these sensors values to distances. To complicate matters slightly, the BeagleBone Black digitizes the analog output voltage using a voltage divider and a 12-bit, 1.8V analog-to-digital converter (ADC). Figure 2b is a look-up table to demonstrate the relationship between the ADC output, the analog voltage from the IR proximity sensor, and the approximate distance that corresponds to this voltage.

Any controller can access the IR array through the `robot` object that is passed into its `execute` function. For example,

```
ir_distances = robot.get_ir_distances();
for i=1:numel(robot.ir_array)
  fprintf('IR #%d has a value of %d', i, robot.ir_array(i).get_range());
  fprintf('or %0.3f meters.\n', ir_distances(i));
end
```

It is assumed that the function `get_ir_distances` properly converts from the ADC output to an analog output voltage, and then from the analog output voltage to a distance in meters. The conversion from ADC output to analog output voltage is simply,



(a) Analog voltage output when an object is between 0.04m and 0.3m in the IR proximity sensor's field of view.

Distance (m)	Voltage (V)	ADC Out
0.04	2.750	1375
0.05	2.350	1175
0.06	2.050	1025
0.07	1.750	875
0.08	1.550	775
0.09	1.400	700
0.10	1.275	637
0.12	1.075	537
0.14	0.925	462
0.16	0.805	402
0.18	0.725	362
0.20	0.650	325
0.25	0.500	250
0.30	0.400	200

(b) A look-up table for interpolating a distance (m) from the analog (and digital) output voltages.

Figure 2: A graph and a table illustrating the relationship between the distance of an object within the field of view of an infrared proximity sensor and the analog (and digital) ouptut voltage of the sensor.

$$V_{\text{ADC}} = \frac{1000 \cdot V_{\text{analog}}}{2} = 500 \cdot V_{\text{analog}}$$

Converting from the the analog output voltage to a distance is a little bit more complicated, because a) the relationships between analog output voltage and distance is not linear, and b) the look-up table provides a coarse sample of points on the curve in Figure 2a. MATLAB has a `polyfit` function to fit a curve to the values in the look-up table, and a `polyval` function to interpolate a point on that fitted curve. The combination of the these two functions can be use to approximate a distance based on the analog output voltage. For more information, see Section **??**.

It is important to note that the IR proximity sensor on the actual QuickBot will be influenced by ambient lighting and other sources of interference. For example, under different ambient lighting conditions, the same analog output voltage may correspond to different distances of an object from the IR proximity sensor. This effect of ambient lighting (and other sources of noise) is **not** modelled in the simulator, but will be apparent on the actual hardware.

2.2 Differential Wheel Drive

Since the K3 has a differential wheel drive (i.e., is not a unicyle), it has to be controlled by specifying the angular velocities of the right and left wheel (v_r, v_l), instead of the linear and angular velocities of a unicycle (v, ω). These velocities are computed by a transformation from (v, ω) to (v_r, v_ℓ). Recall that the dynamics of the unicycle are defined as,

$$\begin{aligned} \dot{x} &= vcos(\theta) \\ \dot{y} &= vsin(\theta) \\ \dot{\theta} &= \omega. \end{aligned} \tag{1}$$

The dynamics of the differential drive are defined as,

$$\begin{aligned}\dot{x} &= \frac{R}{2}(v_r + v_\ell)cos(\theta) \\ \dot{y} &= \frac{R}{2}(v_r + v_\ell)sin(\theta) \\ \dot{\theta} &= \frac{R}{L}(v_r - v_\ell),\end{aligned} \tag{2}$$

where R is the radius of the wheels and L is the distance between the wheels.

The speed of the QuickBot can be set in the following way assuming that the `uni_to_diff` function has been implemented, which transforms (v, ω) to (v_r, v_ℓ):

```
v = 0.15; % m/s
w = pi/4; % rad/s
% Transform from v,w to v_r,v_l and set the speed of the robot
[vel_r, vel_l] = obj.robot.dynamics.uni_to_diff(robot,v,w);
obj.robot.set_speeds(vel_r, vel_l);
```

The maximum angular wheel velocity for the QuickBot is approximately ?. The maximum angular wheel velocities correspond to a maximum linear and angular velocity of ?. It is important to note that if the QuickBot is controlled ot move at maximum linear velocity, it is not possible to achieve any angular velocity, because the angular velocity of the wheel will have been maximized. Therefore, there exists a tradeoff between the linear and angular velocity of the QuickBot: *the faster the robot should turn, the slower it has to move forward.*

2.3 Wheel Encoders

Each of the wheels is outfitted with a wheel encoder that increments or decrements a tick counter depending on whether the wheel is moving forward or backwards, respectively. Wheel encoders may be used to infer the relative pose of the robot. This inference is called **odometry**. The relevant information needed for odometry is the radius of the wheel (32.5mm), the distance between the wheels (99.25mm), and the number of ticks per revolution of the wheel (16 ticks/rev). For example,

```
R = robot.wheel_radius; % radius of the wheel
L = robot.wheel_base_length; % distance between the wheels
tpr = robot.encoders(1).ticks_per_rev; % ticks per revolution for the right wheel

fprintf('The right wheel has a tick count of %d\n', robot.encoders(1).state);
fprintf('The left wheel has a tick count of %d\n', robot.encoders(2).state);
```

For more information about odometry, see Section **??**.

3 Simulator

Start the simulator with the `launch` command in MATLAB from the command window. It is important that this command is executed inside the unzipped folder (but not inside any of its subdirectories).

Figure 3: Simulator

Figure 3 is a screenshot of the graphical user interface (GUI) of the simulator. The GUI can be controlled by the bottom row of buttons (or their equivalent keyboard shortcuts). The first button is the *Home* button `[h]` and returns you to the home screen. The second button is the *Rewind* button and resets the simulation. The third button is the *Play* button `[p]`, which can be used to play and pause the simulation. The set of *Zoom* buttons `[[,]]` or the mouse scroll wheel allows you to zoom in and out to get a better view of the simulation. The set of *Pan* buttons `[left,right,up,down]` can be used to pan around the environment, or alternatively, Clicking, holding, and moving the mouse allows you to pan too. *Track* button `[c]` can be used to toggle between a fixed camera view and a view that tracks the movement of the robot. You can also simply click on a robot to follow it.

4 Programming Exercises

The following sections serve as a tutorial for getting through the simulator portions of the programming exercises. Places where you need to either edit or add code is marked off by a set of comments. For example,

```
%% START CODE BLOCK %%
  [edit or add code here]
%% END CODE BLOCK %%
```

To start the simulator with the `launch` command from the command window, it is important that this command is executed inside the unzipped folder (but not inside any of its subdirectories).

4.1 Week 1

This week's exercises will help you learn about MATLAB and robot simulator:

1. Since the assignments in this course involve programming in MATLAB, you should familiarize yourself with MATLAB (both the environment and the language). Review the resources posted in the "Getting Started with MATLAB" section on the *Programming Assignments* page.

2. Familiarize yourself with the simulator by reading this manual and downloading the robot simulator posted on the *Programming Assignments* section on the Coursera page.