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*Suggested Progression of Lesson*

**Introduction**

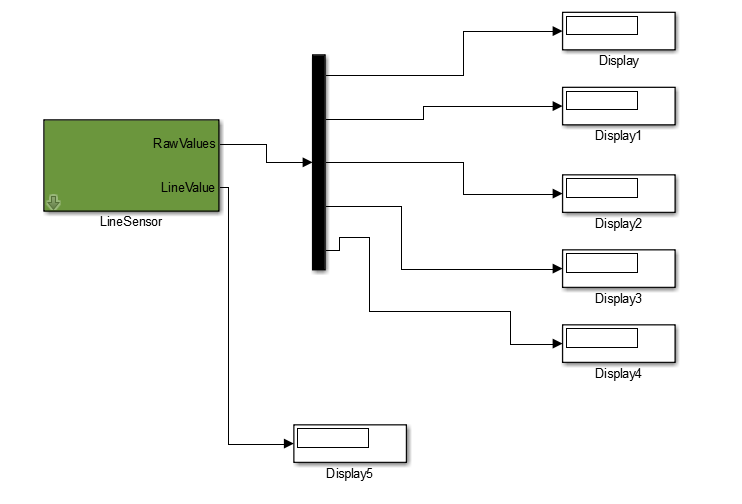
Video Reference: [Unit4a\_LineFollowingComplete.mov](https://www.youtube.com/watch?v=an2q7YK7Sd4)

*For more information, reference the “Instructor Reference Lesson 1 Unit 4” document in the Unit 4 Instructor Reference folder*

*Introductory Exercises:*

External Mode Line Sensor Testing:

Example Model: ExternalModeRawSensorCheck.slx



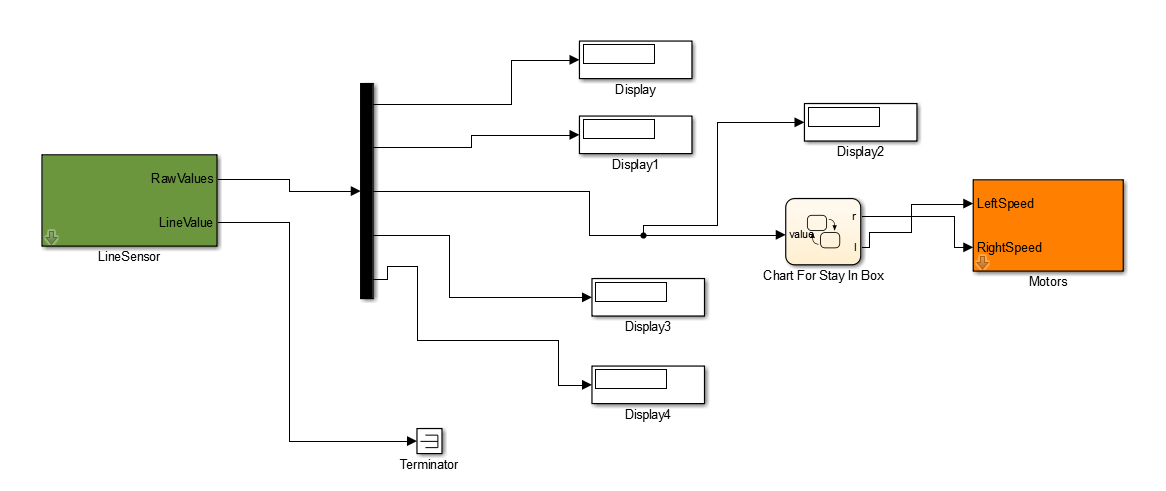
Create the following model and run on your MiniQ robot in “external mode”. This will allow you to view the individual sensor readings without going into the serial monitor app. Record the values for each sensor when over black and also when over the color white. Record these values for later use.

*Explanation of Raw values vs. LineValue:*

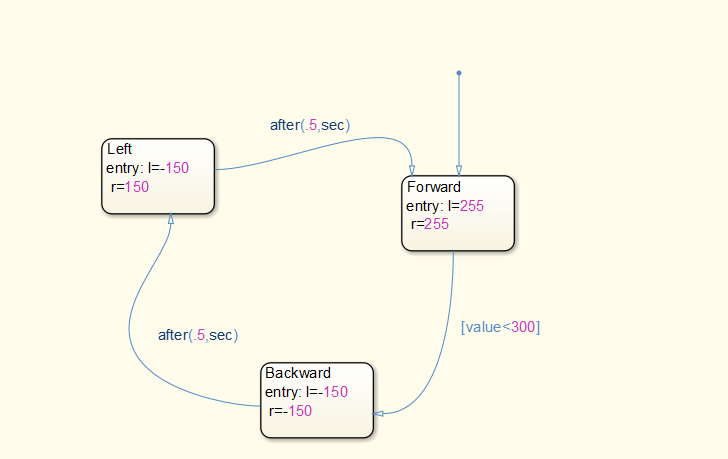
There are two different types of readings that the LineSensor block outputs. The RawValue readings provide a reflected light intensity value for an individual sensor ranging from an analog value of 0-1023. Using these values is helpful if we wish to utilize only one of the five sensors at the bottom of the miniQ robot. Alternatively, the LineValue gives you a reading of where the line is relative to any of the 5 sensors. For example, a line value of 3 means the line is located closest to the middle sensor, numbered “3”. If the Line sensor value indicates 5 then the line is most likely positioned to the farthest outside sensor, numbered “5.”

*“Stay in Box” Cleaning Bot:*

Example Model: StayInBox.slx



The objective of this robot is to stay within an area outlined by black tape. Every time the robot hits and edge it turns and continue moving around in the boxed out area without exiting. A chart is created to take the center most sensor’s input.



Here a combination of an input value called “value” is used to decide if the robot hit the black tape. For my model, the raw value for this was <300. That value may very well be different for you which is why it is important to take some initial readings for the sensors using external mode first.

After hitting an edge the robot backs up for a certain period of time and then initiates a turn.

Activities to consider: create a robot which stays within the box and accelerates towards objects placed on the board. This way the robot acts as a “cleaning” robot by pushing objects outside of the squared area. This process can be timed to make the activity more game like.

**Study 5**

*Note: Below is a copy of Study 5. For print-outs, the original document can be found in the Unit 4 folder*

Standards Covered: (a), (b), (c)**,** (d)**,** (e), (f)

Sequence:

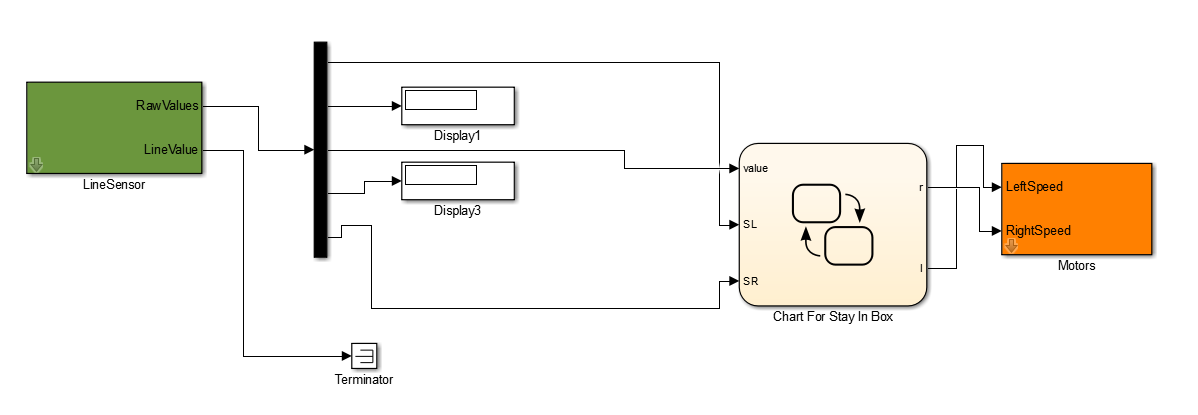
1. Set up a taped box and have multiple MiniQ robots run in the area using StayInBox.slx**.** See whose robot can stay in the square the longest. *(20 min)*
2. Watch the video- Dawn of the Killer Robots: *(30 min)* <https://www.youtube.com/watch?v=5qBjFZV19p0>
3. Discussion: *(40 min)*
4. Define the term ethics.
5. What are the ethical considerations of building military grade robots?
6. Should there be rules in place for what can and can’t be developed in robotics? Why or why not?

**Optional: Taking It Further: Stay in Box with Extra Sensors**

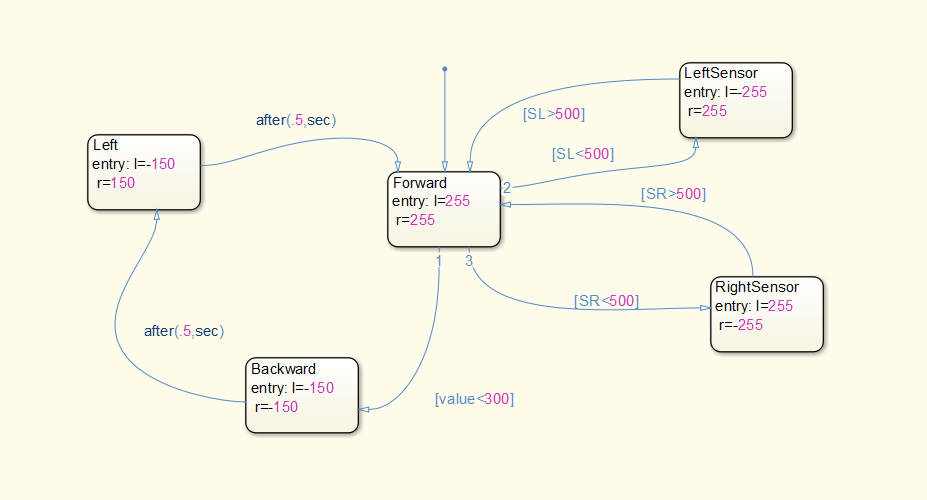
*For more information, reference the “Instructor Reference Lesson 2 Unit 4” document in the Unit 4 Instructor Reference folder*

Example Model: StayInBoxExtraLineSensors.slx

Using the sensors on the ends can be factored into the “Stay in Box” Simulink model as follows



In the chart, SL stands for the leftmost line sensor on the MiniQ robot while SR is the rightmost sensor.

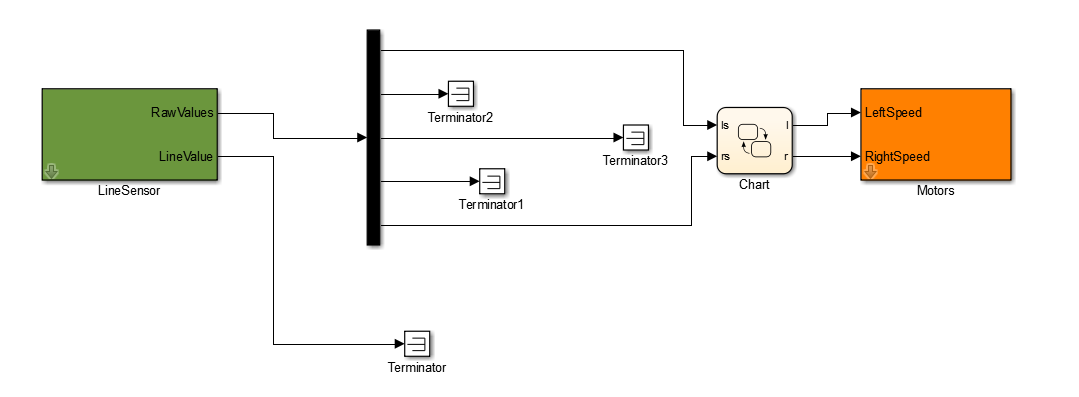


**Two Sensor Line Following**

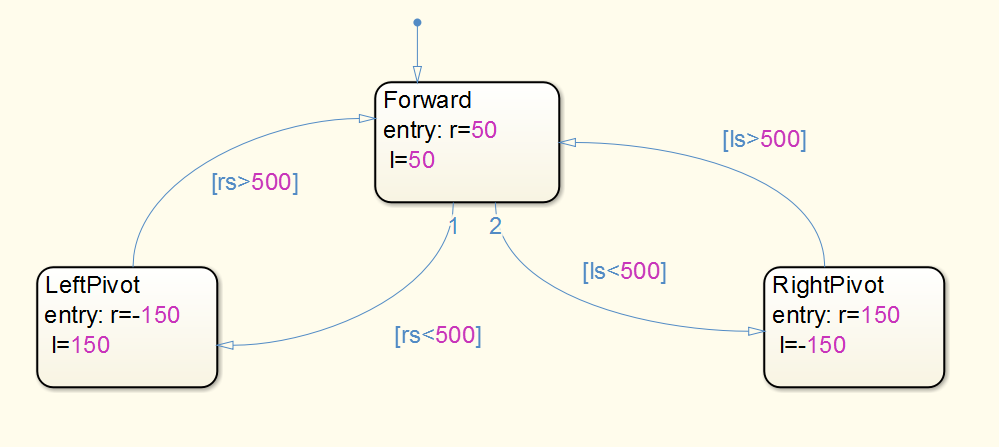
*For more information, reference the “Instructor Reference Lesson 3 Unit 4” document in the Unit 4 Instructor Reference folder*

Example Model: TwoSensorLineFollowing.slx

By using the two outermost line sensors we can create a line following behavior for our MiniQ robot. The line following is based off of an idea of keeping a line “trapped” between two outside sensors in much the same way as a train being kept to a track. Set it up as follows:



The chart for the two sensor line following is as follows. An interesting variable to experiment with is the speeds of “r” and “l” in your chart to create the speediest or smoothest form of line following:



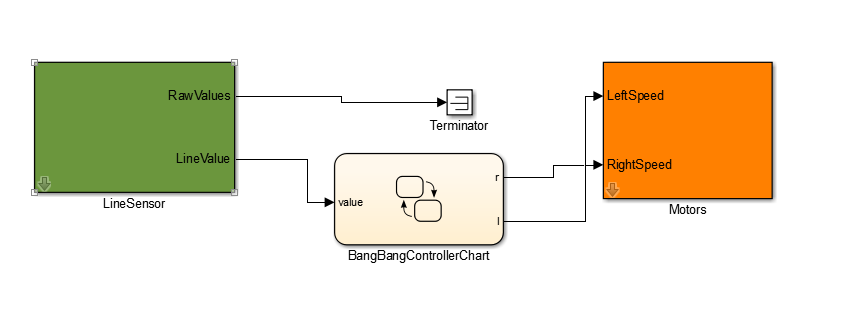
Taking it further: Experiment with different sized lines and different combinations of the inner sensors by adding those to the chart.

**BangBang Line Following**

*For more information, reference the “Instructor Reference Lesson 4 Unit 4” document in the Unit 4 Instructor Reference folder*

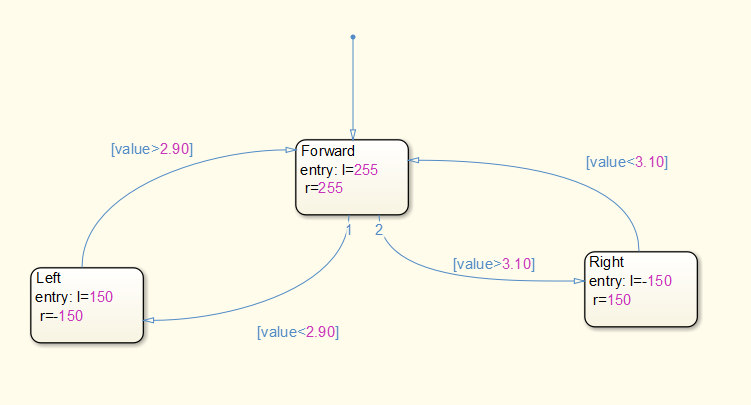
Example Model: BangBangLineFollow.slx

The difference with this form of line following is in how we are basing values of of the “Line Value” output on the Line Sensor Simulink block. This value factors in the position of a line relative to all 5 of the line sensors on the MiniQ:



The following model was created to test a “bang-bang” version of line following behavior. The name comes from how the robot dips inwards and outwards towards a line depending upon the light readings taken from the array of five sensors at the bottom of the miniQ robot.

The chart below acts as the control mechanism for deciding how much power each motor should get depending upon the position of the line. In the chart, the variable “value” indicates the position taken from the line sensor and the chart demonstrates how the model flows:



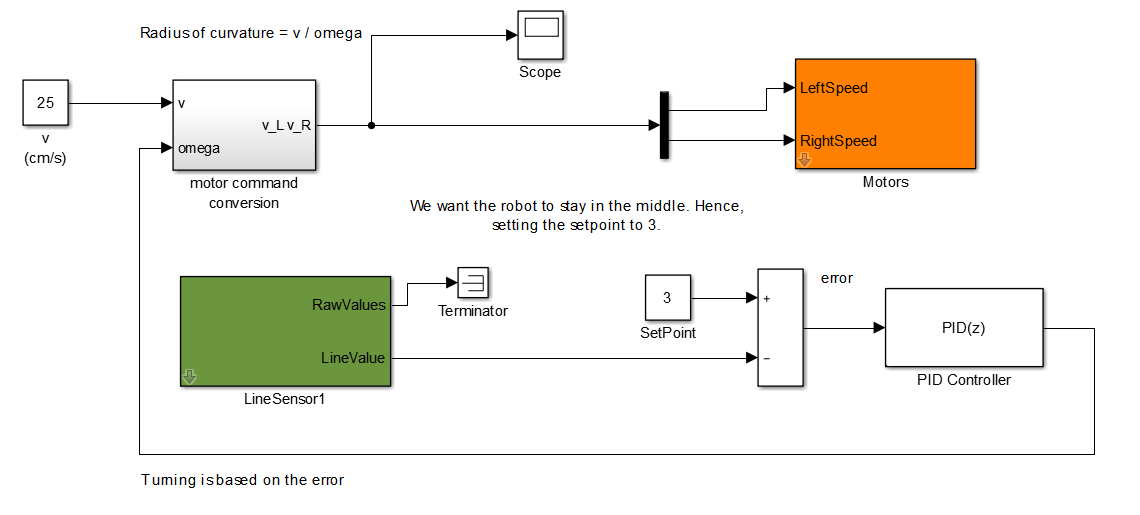
Activity to consider: Refine the model further by smoothing the line following, this can be achieved by changing some of the values in the Simulink chart. Add lights to complement the movement and help you understand the position of a line: for example, green light when the robot is right over the line and red when turning off of it.

**Taking It Further**

PID Line Following

*For more information, reference the “Instructor Reference Lesson 5 Unit 4” document in the Unit 4 Instructor Reference folder*

Example Model: PIDLineFollowing.slx

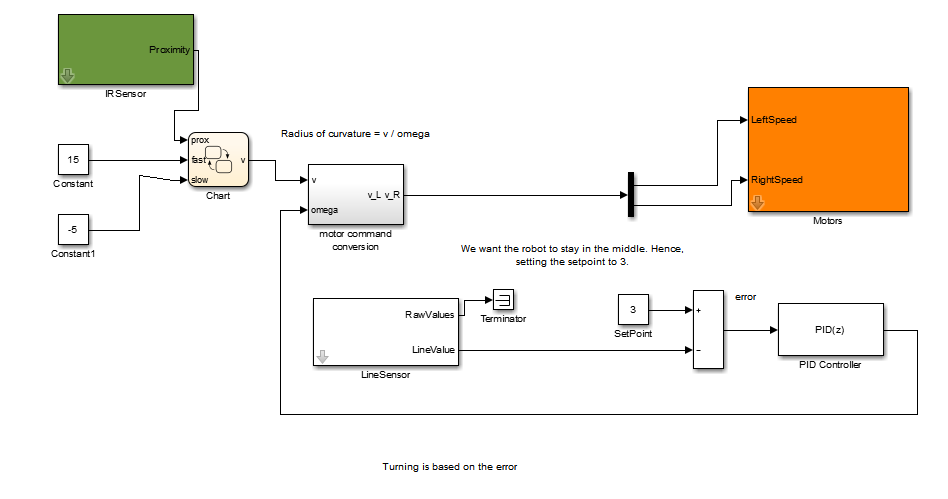


Run the model and notice how the robot runs smoother. A Proportional Integral and Derivative (PID) controller is used to adjust the speed relative to an optional position “set point” of a line being over sensor 3. This will ultimately result in a smoother line following behavior for the miniQ robot because there are less oscillations back and forth across the line.

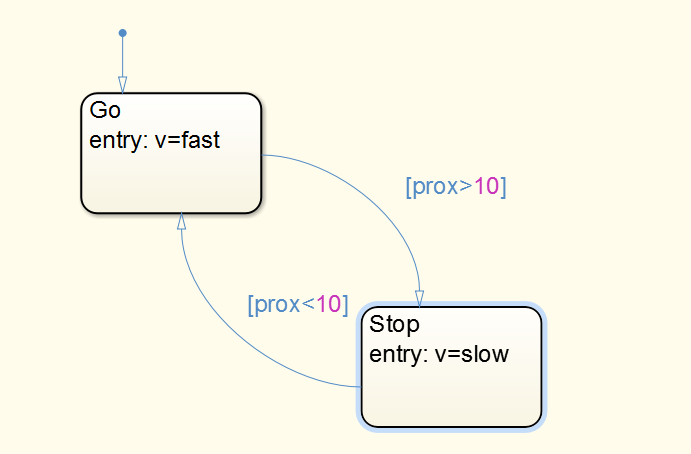
This model can be extended so the proximity sensor helps the robot figure out if an object is in front of it or not.

Line Following with Proximity Stop:

Example Model: LineFollowingWithProxCompletV1.slx



The objective in the above model is to create a line following robot which will stop when faced with an obstacle out in front of it. The chart for this model has three inputs: “prox”, “fast” and “slow”. The fast and slow inputs are attached to two constant values.

*Line Following with Proximity Chart:*

The chart shows how the output values of v, which in the Simulink model is used to control the speed of the line following changes when faced with an object. It is necessary to slow the line following rather than stop it outright because line following sensor readings need to be uninterrupted.

Activities

1. Adjust some of the values to improve the proximity line following robot
2. Program the robot to pause at a broken line then cross the gap to continue line following.
3. Light following robot which can lock onto a line and follow it. And disconnect from the end of the line when a perpendicular portion of tape marks the exit point.

**Study 6**

*Note: Below is a copy of Study 6. For print-outs, the original document can be found in the Unit 4 folder*

Standards Covered: (a), (b), (c), (d), (e)

Sequence:

1. Watch this video: Tug Hospital Robot <https://www.youtube.com/watch?v=rRRS815C3Hc>
2. Discuss the following prompts as a group: *(30 min)*
3. Can you conceptualize how this robot could incorporate line following into its function?
4. What are the similarities and differences between the Tug Hospital Robot and the Atlas Robot?
5. What motivates one to develop one type of robot over the other (militaristic vs. altruistic)?
6. Are there any ethical considerations to be considered?
7. Taking it Further (High School): *(50 min)*
8. Read: <http://ijarcet.org/wp-content/uploads/IJARCET-VOL-2-ISSUE-8-2446-2450.pdf>
9. Describe the structure of the writing and summarize the paper.
10. What are some key points the authors outline around the development of their robot?
11. Discuss what ideas for line following robots this article brings up with you.

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