

Robotics 204: Introduction to Human-Robot Systems

Winter 2025

Lab Title: Mental Models and Hierarchical Control Levels

Submission Type: [Individual Submission](#)

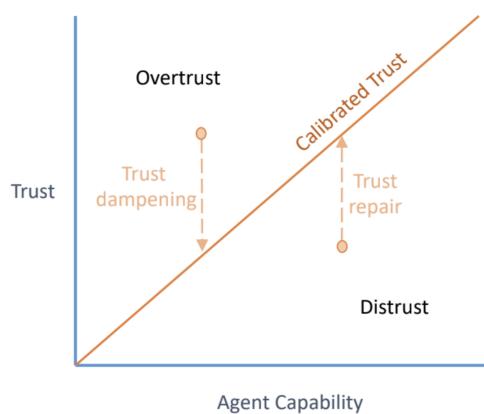
Necessary Materials: Astro Lab Kit, including iPad

Learning Objectives:

1. Develop a mental model of a robotic system and evaluate it.
2. Understand the importance of calibrated trust in automated systems.
3. Compare and contrast operating a robot at different levels of control.
4. Evaluate when certain levels of control are more appropriate than others.

Introduction:

You have been learning in class about both mental models and hierarchical controls and how they relate to trust in automated systems. Mental models are influenced by your environment and your goals. Your mental model of an automated system can change when you receive training or interact with the system.

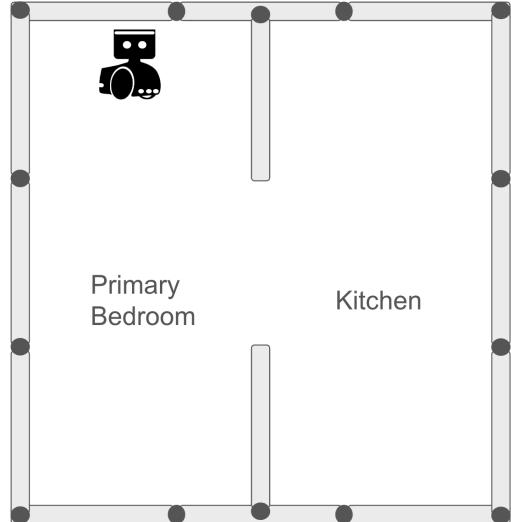


Calibrated trust is when the trust you have in a system is aligned with the capability of that system. Your trust in a system and the capability of the system can both be separately influenced by the environment and the task being performed. For example, you may trust a self-driving car to automatically avoid pedestrians during the day, but not at night. In Week 1 of this lab, your group will use the Amazon Astro system as a test case for how mental models are developed.

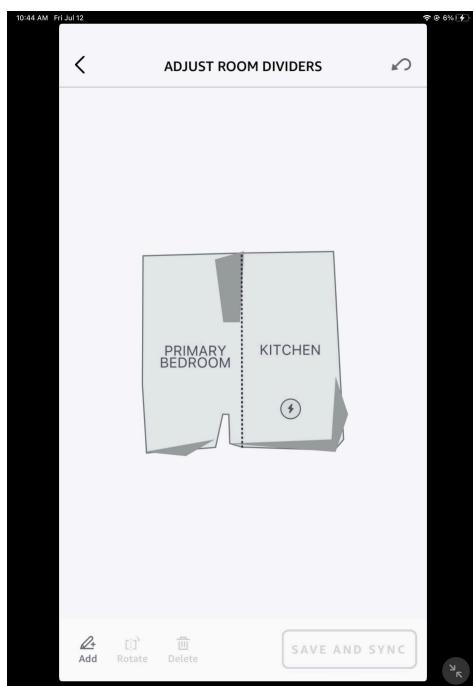
In Week 2 of this lab, we will focus on hierarchical control in a robot, which is a way to define control algorithms at different levels of a task (e.g., goal level, motion trajectory level, motor command level). People can interact with robots at different levels in the hierarchy, influencing what they need to specify and the needed system capabilities. At higher levels of control a person may specify a behavior or goal, while the robot defines the motion trajectory (mid-level) and determines the motor commands necessary (low-level). A person can also interact with a robot at a mid-level, where they directly control the robot trajectory, while the robot control determines the motor commands needed (low-level) to achieve the input motion. A person may also directly specify the low-level motor commands. Depending on the device and the task, interacting with the robot at a different level of the hierarchy may make more sense than the others. In Week 2, you will perform several tasks using the Amazon Astro system at different levels of control. You will then reflect on what tasks each level of control may be appropriate for and how human interaction with a robot in context with the hierarchy of controls should be considered when designing a robot.

Week 1

Part 1: Setup



1. Ensure your maze is set up like the pictures above, and your robot is in the correct location.
2. Each group's Astro will have a specific wake word label. Please be sure to use your robot's wake word to prevent interfering with other groups! For example, your group will say "[wake word], follow me" rather than "Astro, follow me". Wherever you see "[your robot]" in the instructions, use your robot's wake word name. For example, to lower your robot's volume, the instructions will note as "[your robot], lower volume." Please try not to say Astro as much as possible.
3. Open the "Amazon Astro" app on the iPad provided to your team.
4. In the Astro app, click on the "**Settings**" tab, click on "**Map**", then click "**Delete Map**", and click "Delete Map" on the warning that pops up to reset your robot's map.



5. Once the map is deleted, say "[your robot], start exploring". At this point, the robot should practice docking with the charger. Once the docking process finishes, say "[your robot], start exploring" again.

6. After the robot is finished exploring, it will display the message "Area explored is too small". This behavior is expected; press "**continue**".

7. **View the map in "Edit map" and show this to your GSI/IA before you continue on with the lab.**

8. The robot should then prompt you to begin a home tour. Say, "[your robot], start home tour" (have only one person in the maze conducting the tour). Your robot will then explain how to give a home tour. When conducting the home tour, name the rooms according to the diagram above. If the robot says "You already

named this room" during the tour, continue and label the room regardless. Make sure to end the home tour once you've labeled all the rooms.

9. Open the Amazon Astro app on the iPad, and on the bottom click Settings -> Map -> Edit Map-> Room Dividers. You should see 2 rooms (primary bedroom and kitchen with a divider line splitting the map in 2 separate areas). If there is not a line already there, you can add one using the "Add" tool at the bottom left of the screen (see reference below).
10. Swipe down from the top of your robot's display, click settings -> profiles -> add profile, select two people in your group to go through the process of making a profile and setting up a visual ID. **DO NOT SET UP A VOICE ID.**

Deliverable: Take a picture of your group's created map

Part 2: Exploration Phase

You have already seen some of what Astro can do during the setup process. To further build your mental model of Astro, watch the following video, which advertises some of Astro's features. As you watch the video, think about what environments Astro is navigating and what tasks it is doing. Also, consider what subtasks these tasks could be broken into.

- <https://youtu.be/sj1t3msy8dc>

Deliverable: Write 3 tasks that you perceive Astro can do

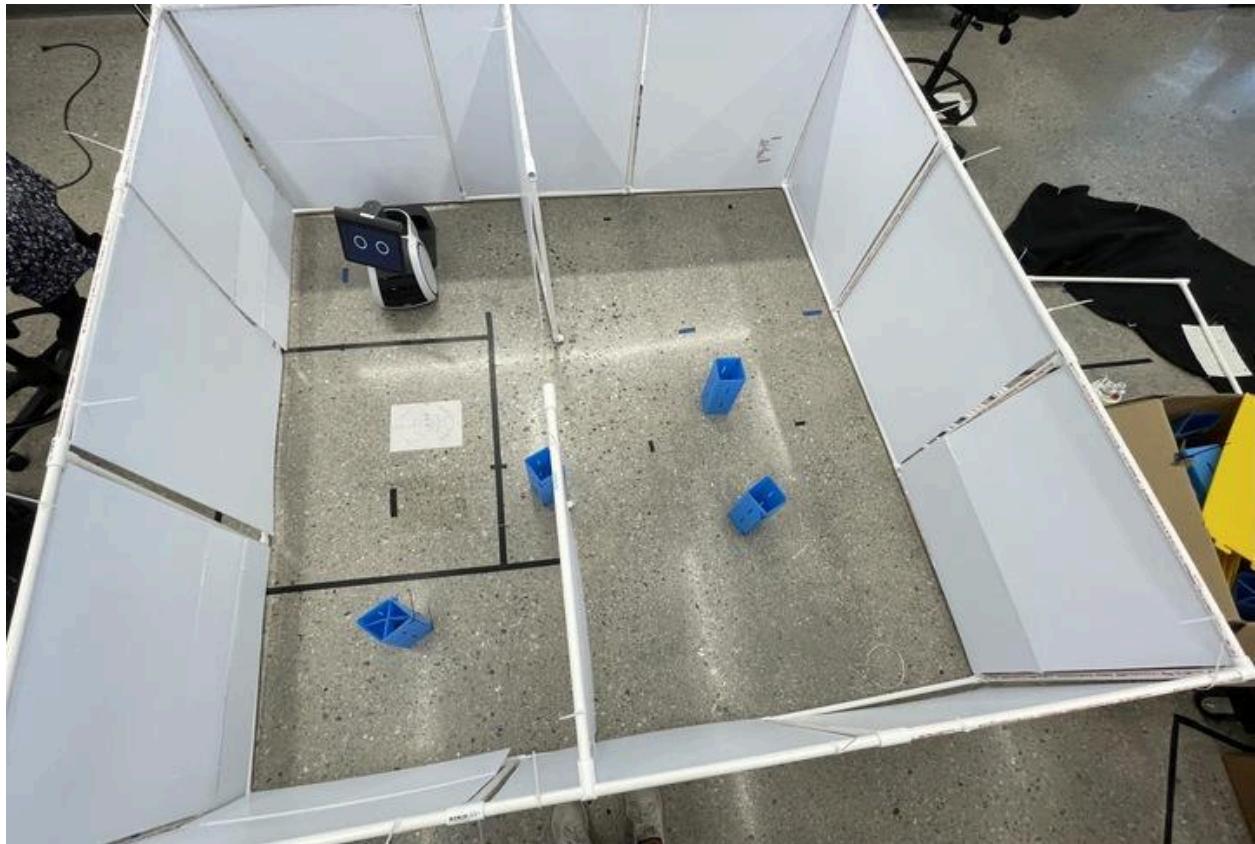
Part 3: Evaluate your trust

To evaluate your trust in Astro to complete tasks, you will rate how much you would trust it to complete tasks from a list in the submission template linked on canvas. **Each individual in your group should record their trust separately**—draw your own conclusions about this! You may compare afterwards, but assess these values on your own first.

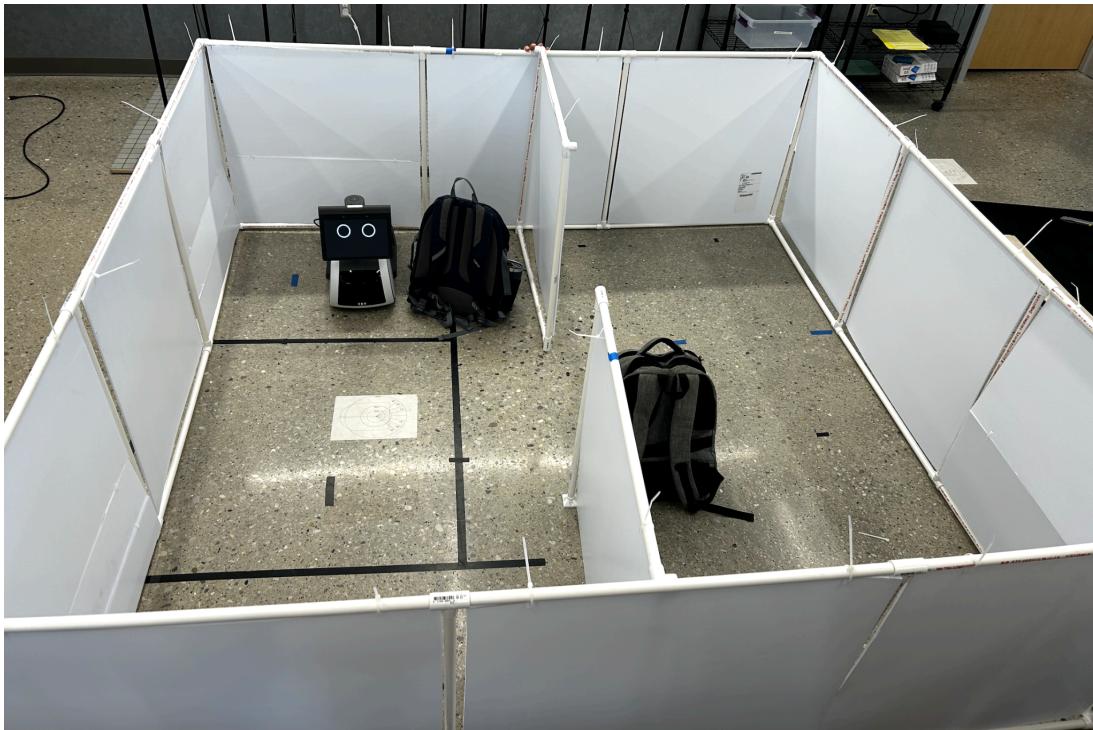
Use the following scale to rate the tasks on the table provided in the submission template. *Rate your trust individually; do not discuss your ratings with your group. Do not have your robot actually perform these tasks yet.*

1 completely distrust	2 somewhat distrust	3 neutral	4 somewhat trust	5 completely trust
-----------------------------	---------------------------	--------------	------------------------	--------------------------

1. Fill out Column 1 of the table with **your predictions** for how well your robot will perform the tasks with no obstacles in its pen.
2. Fill out Column 3 of the table with your predictions for how well your robot will perform the tasks with obstacles added to its pen, as shown in the image below. Do not have your robot perform this task, but consider that you will not remap the environment after the obstacles are added.



3. Fill out Column 5 of the table with your predictions for how well your robot will perform the tasks with a different set of obstacles in its pen, as shown in the image below. Do not have your robot perform this task, but consider that you will not remap the environment after the obstacles are added.



Deliverable: Trust table with performance prediction columns filled out (columns 1,3,5)

Part 4: Evaluate Astro's performance

Now that you have recorded your trust in your robot to perform these different tasks with multiple environmental changes, you will instruct your robot to complete the tasks. After observing the robot's behavior, use the same scale to rate how much you would trust it to complete these tasks now.

<u>1</u> completely distrust	<u>2</u> somewhat distrust	<u>3</u> neutral	<u>4</u> somewhat trust	<u>5</u> completely trust
------------------------------------	----------------------------------	---------------------	-------------------------------	---------------------------------

1. First, complete Column 2 of your table by having your robot complete all of the listed activities with no obstacles in the pen.
2. Second, complete Column 4 of your table by having your robot complete each task, with obstacles added to the pen, as shown in the image in Part 3.2.
3. Finally, complete Column 6 of your table by having your robot complete each task, with the different obstacles added to the pen, as shown in the image in Part 3.3.

Once you've completed the lab, reflect on your robot's performance across each observed task. Based

on the behavior you have observed during the lab, how do you predict Astro would perform in a typical home setting? What features would be the most useful? You may discuss with your group but any typed responses should be from your own perspective.

Deliverable: Trust table with actual performance columns filled out (columns 2,4,6) and brief reflection.

Part 5: Data Analysis

1. Use your individual data to create a table that clearly shows the *average trust* (across all tasks) and *standard deviation* for each of the following **six conditions**:
 - a) No obstacles - prediction
 - b) No obstacles - actual
 - c) Obstacles 1 - prediction
 - d) Obstacles 1 - actual
 - e) Obstacles 2 - prediction
 - f) Obstacles 2 - actual

Add a thorough caption. Discussion 6 will guide you through refining the design of this table, but for now, just focus on filling in the content.

2. Create a bar chart of your average trust in each treatment (no obstacles, obstacle setup 1, obstacle setup 2). For each treatment, you should have two bars: one bar should represent your average trust before Astro performed the tasks, and the other should represent your average trust afterward. Include error bars representing the standard deviation for each condition. As with the table, Discussion 6 will guide you through further refining this chart.

Deliverable: After refining your table and chart in Discussion 6, insert data table and bar chart into the submission template

Part 6: Reflection Questions

You may discuss these questions with your group but each member must submit their own responses. Somewhere in your responses, you should include at least one in-text reference each to your table and chart from Part 5, properly formatted according to Discussion 6 instructions.

1. Compare your initial trust in Astro to its performance in the tasks. Did Astro perform well in the tasks you thought it would? Highlight 2 tasks where Astro performed how you expected and 2 where it did not. Why do you think it may have had trouble with those tasks?
2. Think about the concept of mental models. Recall that your mental model of Astro includes information about its purpose, form, function, and behavior. Think specifically about your model of Astro's behaviors. Was this model accurate? How did you use your initial model to predict how Astro would perform in the tasks? How did your model change after you observed Astro perform the tasks?
3. Reflect on the bar chart you created. What would a bar chart for this experiment look like for a user that had calibrated trust in Astro? Does your bar chart indicate that your trust was

calibrated after your initial interaction and watching the advertisement? Why or why not? Refer to specific data from the chart to support your response.

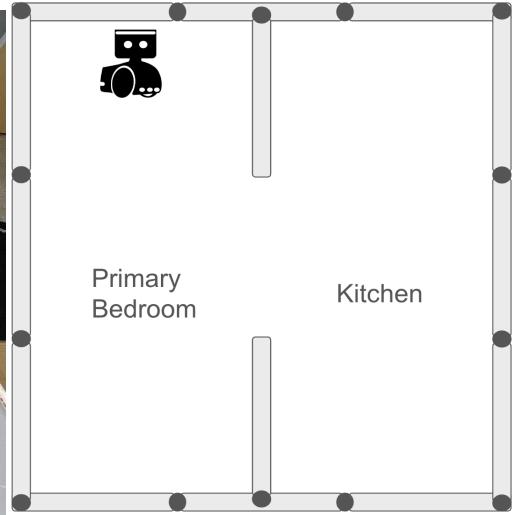
4. In lecture, we discussed how each dimension of trust can support a user's situational awareness at every level. Think about how Astro could better support users' expectations of its behavior. Give 2 improvements that you would make. For each improvement, discuss what level of situational awareness (perception, comprehension, projection) and what dimension of trust (purpose, process, performance) it would support.
5. Consider the concept of calibrated trust. Why is it important for users to have properly calibrated trust in automated systems? Give two examples using robotic systems other than Astro that illustrate your reasoning.

Deliverable: Answer the above questions on the submission template

Week 2

If you are continuing on to this section in the same day, you do not need to redo your mapping with Astro.

Part 7: Setup



1. Ensure your maze is set up like the pictures above, and your robot is in the correct location.
2. Each group's Astro will have a specific wake word label. Please be sure to use your robot's wake word to prevent interfering with other groups! For example, your group will say "[wake word], follow me" rather than "Astro, follow me". Wherever you see "[your robot]" in the instructions, use your robot's wake word name. For example, to lower your robot's volume, the instructions will note as "[your robot], lower volume."
3. Open the "Amazon Astro" app on the iPad provided to your team.
4. In the Astro app, click on the "Settings" tab, click on "Map", then click "Delete Map", and click "Delete Map" on the warning that pops up to reset your robot's map.
5. Once the map is deleted, say "[your robot], start exploring". At this point, the robot should practice docking with the charger. Once the docking process finishes, say "[your robot], start exploring" again.
6. After the robot is finished exploring, it will display the message "Area explored is too small". This behavior is expected; press "continue"
7. **View the map in "Edit map" and show this to your GSI/IA before you continue on with the lab.**
8. The robot should then prompt you to begin a home tour. Say, "[your robot], start home tour" (have only one person in the maze conducting the tour). Your robot will then explain how to give a home tour. When conducting the home tour, name the rooms according to the diagram above. If the robot says "You already named this room" during the tour, continue and label the room regardless.
9. Open the Amazon Astro app on the iPad, and on the bottom click Settings -> Map -> Edit Map-> Room Dividers. You should see 2 rooms (primary bedroom and kitchen with a divider line

splitting the map in 2 separate areas). If there is not a line already there, you can add one using the “Add” tool at the bottom left of the screen (see reference below).



10. You do not need to set up a visual id this week.

Deliverable: No deliverables

Part 8: Controlling Astro on specified tasks

You will perform multiple tasks with the robot. For each task, you will interact with your robot at different levels of control. You will start by controlling your robot using “Live View”. Click on the “Live View” tab at the bottom of the screen. Then, click “Start Live View”. See [Appendix A](#) for directions on how to control Astro at each level.

Have one person perform each task (listed below) at each level of control. For every level of control/task combination, you will rate four factors (trust, mental demand, temporal demand, frustration). Use the table provided on the submission template and the following scales to record your ratings. **Each person should record their own ratings on their individual document.** Group members who are not directly controlling the robot may base their ratings on observation or attempt the tasks themselves.

The four factors you will rate each task on are the following:

- **Trust:** How much did you trust Astro during the task
- **Mental Demand:** How mentally demanding was the task?
- **Temporal Demand:** How hurried or rushed was the pace of the task?
- **Frustration:** How insecure, discouraged, irritated, stressed, and annoyed were you?

You will rate each factor with a number between 1 and 5 corresponding to this scale:

1 2 3 4 5

Very Low	Moderately Low	Neither Low nor High	Moderately High	Very High
----------	----------------	----------------------	-----------------	-----------

Task 1: Following a person

1. Low: Use swiping to command the Astro to move with the forward/backward buttons in live view to follow you
2. Mid: Use tapping on the ground in live view to create waypoints of the path to follow you
3. High: Use the “[your robot], follow me” command
4. **Discuss:**
 - a. Why did you select the ratings you did for each level of control?
 - b. Which level of control did you prefer to use for this task?
 - c. Why did you prefer the selected level of control? Consider the four rated factors in your discussion.

Task 2: Go to room

1. Low: Use swiping to command the Astro to move with the forward/backward buttons in live view to navigate to the room
2. Mid: Use tapping on the ground in live view to create waypoints of the path to follow
3. High: Use the “[your robot], go to [room]” command
4. **Discuss:**
 - a. Why did you select the ratings you did for each level of control?
 - b. Which level of control did you prefer for this task?
 - c. Why did you prefer the selected level of control? Consider the four rated factors in your discussion.

Task 3: Go to charger

*This task may not be possible with some levels of control.

5. Low: Use swiping to command the Astro to move with the forward/backward buttons in live view to navigate to the room
6. Mid: Use tapping on the ground in live view to create waypoints of the path to follow
7. High: Use the “[your robot], go to [charger]” command
8. **Discuss:**
 - a. Why did you select the ratings you did for each level of control?
 - b. Which level of control did you prefer for this task?
 - c. Why did you prefer the selected level of control? Consider the four rated factors in your discussion.

Deliverable: Trust table and discussion

Part 9: Reflection Questions

You may discuss these questions with your group but each member must submit their own responses.

1. In the second part of the lab, you had to control Astro at a low level using discrete commands to go forward, go backward, turn left, and turn right. Imagine if you had access to a joystick which could control Astro’s velocity directly. How might your “frustration” and “mental demand” ratings change if low level continuous control was implemented instead of discrete control?

Would you recommend designers to use continuous or discrete control for tasks 1, 2 and 3?

Why? Think about the pros and cons you developed during the UI Lab earlier in the semester.

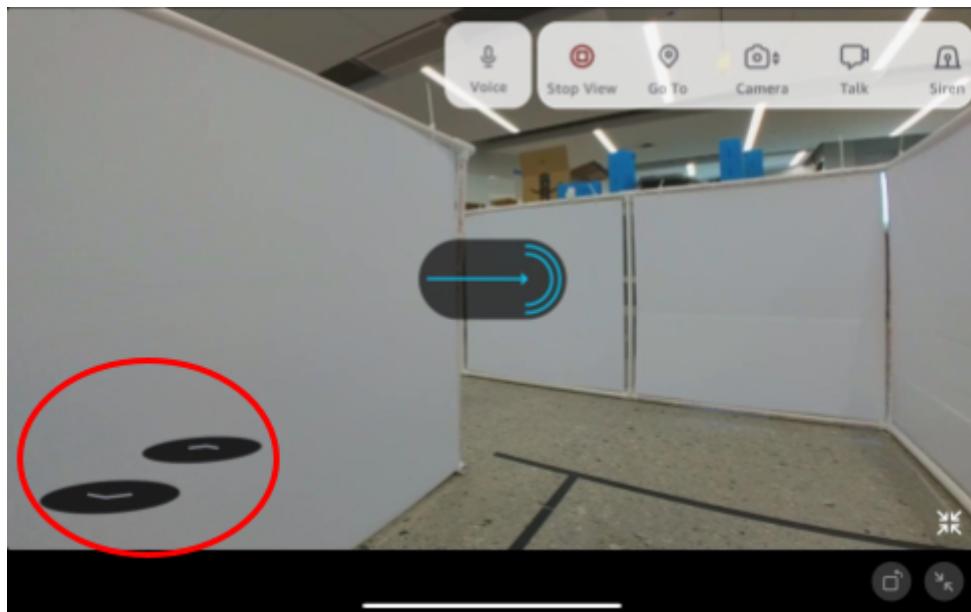
2. Think again about the low level control of Astro with discrete commands. How much movement did each command produce? Did Astro move too much or too little? What would happen to the speed and distance if the gain on the velocity were increased? What if the gain was decreased? What are the challenges if the gain for this system is set too high? Too low?
3. Reflect on each task you performed and the level of control you preferred for each task. List the level of control you preferred and why. Describe your reasons for choosing that level of control.
4. Picture Astro being used in a home environment, as if its users were the main target consumers intended by Amazon. Describe three hypothetical scenarios where each level of control would be useful to the user. Be creative in your descriptions!
5. Using your answers to questions 2 and 3, think about how levels of control are related to a robotic system's understanding of its environment. What assumptions are required for high level control to be effective? What circumstances make lower levels of control more effective? Give examples using Astro or other robotic systems.
6. Looking back to Lab 3/4 (gaze tracking), what principles from Lab 3/4 does Astro use to enhance its user experience? Which techniques work well for Astro? How could Astro improve its user experience using principles from Lab 3/4?

Deliverable: Answer the above questions in the submission template

Appendix A

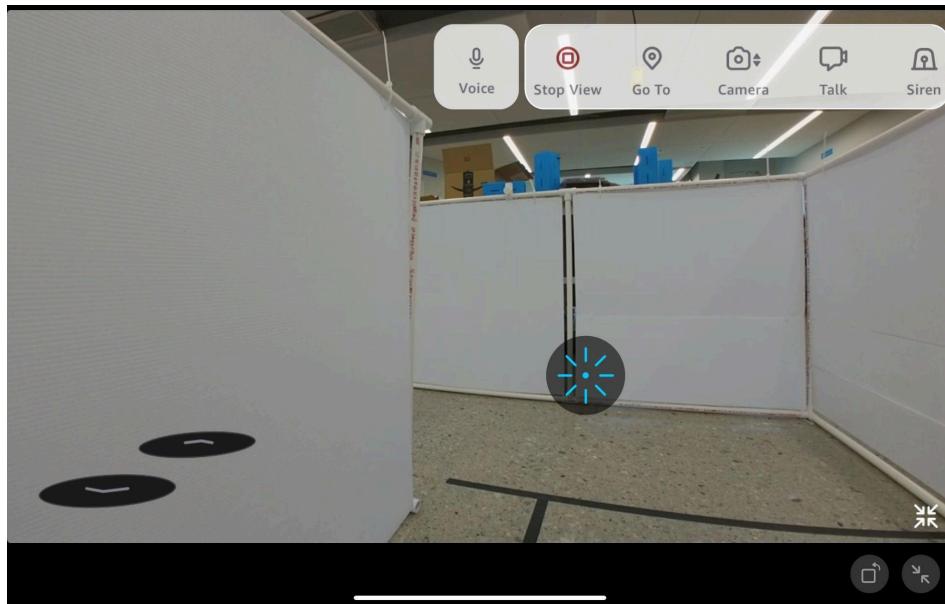
As discussed in lecture, we can operationalize how a person interacts with a system at different levels of control by considering high level control as defining the goal, mid-level control as defining the trajectory, and low-level control as defining the motion commands. For interaction with the Astro at each level, we define the interactions as follows.

Low Level of Control - The user provides the motor commands for Astro directly.



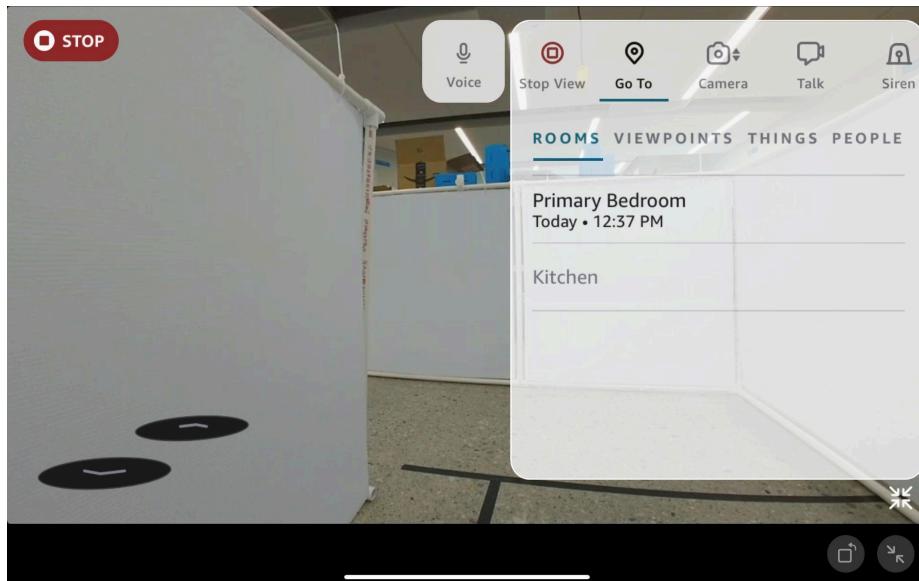
To control Astro at a low level, swipe left and right on the Live View to rotate Astro left or right, and use the forward and backward arrows (circled in red) to move Astro forward or backward. Be sure to enter full screen (button on the bottom right) to be able to use the arrows.

Mid Level of Control - The user provides the trajectory by defining way points along the path.



To control Astro at the mid level, click on the ground where you want Astro to go, and Astro will go there.

High Level of Control - The user specifies the goal location or task using verbal commands with the goal



To control Astro at a high level, use the Astro command that corresponds to the task you are doing. For the “Go to room” task, open the “Go To” menu and select the room that you are sending Astro to. For the “Following a person” task, have the person Astro is supposed to follow say “[wake word], follow me”.

[Astro Voice Commands](#)