Robotics 204: Introduction to Human-Robot Systems
Winter 2025

Lab Title: User Interface Design for a Robotic Arm

Submission Type: Individual submission

Necessary Materials: UI Lab Kit, Laptop to run Arduino and web software

Learning Objectives:

1. Design and evaluate a user interface to support a robotic task.
2. Implement different types of direct input controls for robotic systems.
3. Investigate the role of perception in interface design.

Introduction:

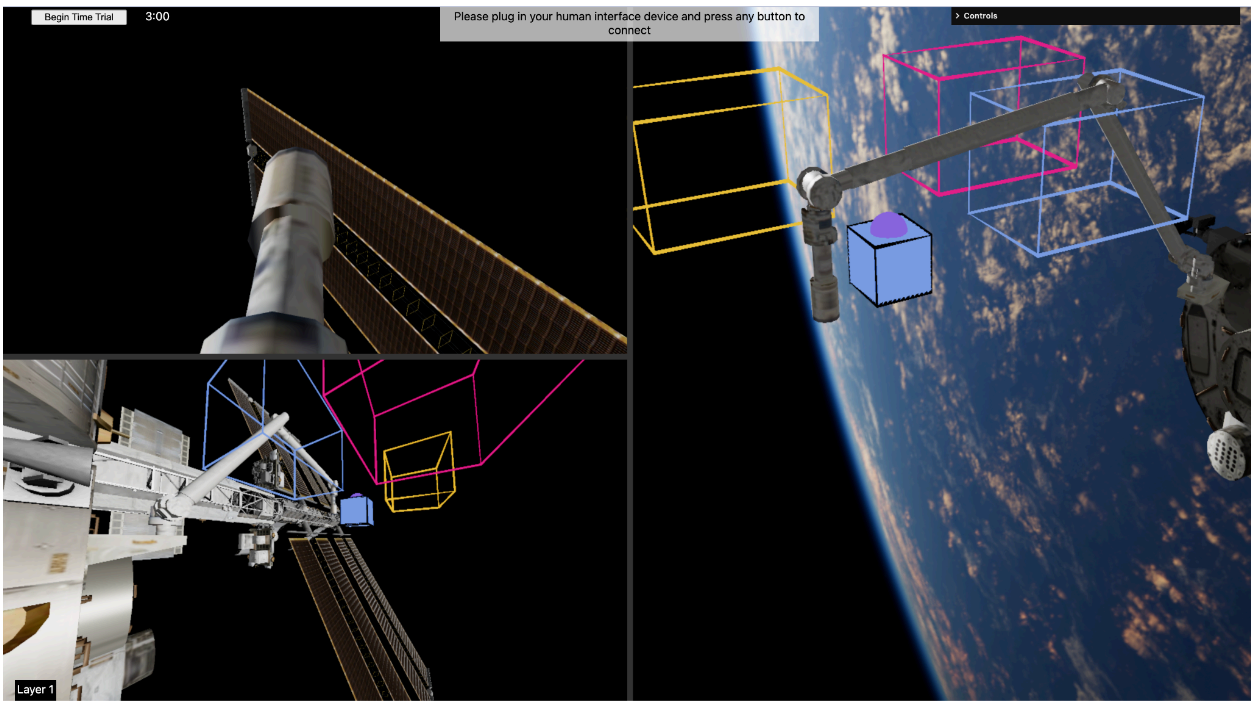
In lecture, you learned about the principles of good user interface (UI) design and how human perception and mental models can influence these designs. Gestalt principles describe how the visual characteristics of a user interface can affect how people perceive and interact with the interface. Natural mapping describes how well the design of the interface aligns with its purpose. In this lab, you will be tasked with designing a user interface to control a simulated robotic arm. The simulator is based on the Japanese Experiment Module Remote Manipulator System on the International Space Station. You will use the arm to retrieve objects at a precise orientation and then place them into designated areas. This task will be timed, so it is important that your user interface allows for efficient control. The placement of the objects is also defined, so your user interface needs to support a level of precision in object placement as well.

In the first week of this lab, you will design the user interface (Parts 1 through 3). In the second week of this lab (Parts 4 through 6), your user interface will be tested by other groups, so make sure that your interface is easily learnable.

Week 1

Part 1: Setup & Exploration (15 minutes)

1. This lab will use a simulator hosted at this link: https://websites.umich.edu/~rob204labs/. Only one member of the group needs to open the simulator.
2. Your group will be provided with a kit that includes several input devices. These peripheral components will be plugged into a board that is connected to the computer running the simulator. **Please do not unplug the components from the board.** When you open the webpage, the simulator will display a message asking you to "Please plug in your human interface device," which is the board to which you will connect the peripherals. Once you plug in the device, press any of the buttons attached to it to connect it to the simulator. You should see a message saying your arduino board is connected.
3. **IMPORTANT: Before connecting the arduino board to the computer, put the potentiometers at the zero/middle position. Also note that these components are *very* sensitive.**



4. The simulator has three camera perspectives of the robotic arm. The upper-left camera view is attached to the robot's end effector and moves when you move the robot. The bottom-left camera view is a stationary view. The view on the right half of the screen can be controlled using the "Pan Camera" control.
5. You can use the drop down menu labeled "Controls" in the top right corner of the screen to select what peripherals are bound to each action. Each peripheral is numbered and corresponds to the names in the drop-downs of the "Controls" menu. For example, the button labeled with a "0" will show up as "Button 0". You can bind each peripheral to as many actions as you want. Joint control and end effector control can be used at the same time, but this may lead to some unexpected behavior (see Appendix C for more details).

6. **Read over Appendix A to get a sense for the capabilities and limitations of each input device.** Experiment with each of the components within the simulation and fill out the table on the submission template in Part 1 to demonstrate your understanding of each control method.

Deliverable: Filled out table

Part 2: Design your UI (80 minutes)

1. You will be designing a UI to help you complete a timed task with the robotic arm. See Appendix B for the rules of the task. You will lay out the input devices on the provided board and assign them as inputs to the robotic arm in the "Controls" menu in the simulator. **You are not required to use every peripheral, or every binding.**
2. The controls menu provides two layers of control that can be defined, which can be edited by selecting a layer using the "Edit Layer" dropdown. Each layer has the exact same actions, but you can have different bindings on each layer. For example, you use layer one to focus on one mode of control, and layer two to focus on another mode of control. In the bottom left corner of the screen, there is a display which shows which layer you are currently using. You can assign the "Layer Toggle" control to switch between layers. This allows you to switch between two different control bindings while you complete the timed task. If you want to copy all of the controls from one layer to the other, use the "Copy Controls From Layer" button. **You do not need to use two layers in your solution, it is just included as an option for testing different controls.**
3. Once you have selected which peripherals you are using, attach them on the board and create labels for your controls with the provided sticky notes.
4. Take turns testing out the system and iterating on your design. When your group is happy, **take a picture of the UI layout and export the controls config file using the "Download Controls Config" button. Make sure at least one member of your group keeps track of this config file.** *(This file will be imported for next week's lab).*

Deliverable: Labeled figure of your UI design

Part 3: Design Reflection

Reflect on the following questions and respond to them in the submission template . ***These responses must be your own, although you may discuss them with your group.***

1. What control inputs did your group find the most useful? What were some of the factors that determined how you would bind the devices? Did your group only use only joint control, only end effector control, or a combination of both in your control scheme? Why did you choose the selected approach?
2. What control inputs did your group almost never use? Were there any controls that you didn't bind at all? If so, what were they, and why did your group make the decision to exclude these?
3. Consider the Gestalt and natural mapping principles. Did any of them influence the design phase for your UI? How could you use the Gestalt and natural mapping principles to improve the physical layout of your UI?

4. Consider how you used your depth perception to accurately place the boxes inside the goals. What were some visual cues that helped you place the boxes? What were some challenges you faced while trying to properly align the boxes?

Deliverable: Answer the above questions on the submission template

Week 2

Part 4: UI Testing (40 minutes)

1. Use the setup instructions in Part 1 to get your simulator ready for testing. ***MAKE SURE YOUR GROUP GRABS THE SAME KIT AS LAST WEEK.***
2. Record your team's results on the table in the submission template.
3. In the simulator, click "Begin Time Trial". This will start a 180 second countdown. This will begin the timed task. Refer to Appendix B for a summary of the rules of the task.
4. Have your group start at your station and have each member complete a trial mode run, **make sure to record the results.** Also, take a picture of each team's UI for reference later.
5. Go to the next group, and repeat the process until all students have completed a trial mode run at each group.

Deliverable: Table with the scores for each student on all group's UIs.

Part 5: Testing Data Analysis

Create a bar chart of your team's average scores at each group. Make sure to follow the best practices for creating charts. Provide your observations for any emergent trends.

Deliverable: Bar chart and written observations

Part 6: Testing Reflection

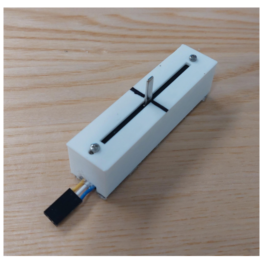
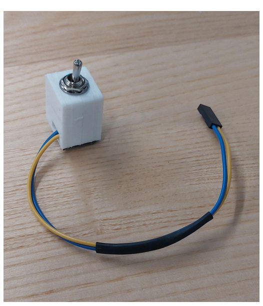
Respond to the following questions. ***These responses must be your own, although you may discuss them with your group.***

1. Reflect on the process of trying to learn each groups' control design. Were there any designs that were easier to learn? What were some challenges when trying to learn another team's interfaces? How might a UI designer make interfaces more easily learnable?
2. How did your group's design differ from other groups' designs? Did you lay out the controls in a different way? Did you have different bindings? Why do you think other groups chose to lay out their controls the way they did? Discuss at least three differences and explain the reasoning behind each difference.
3. What part of another group's design did you feel was the most intuitive? Did that part connect to Gestalt grouping principles or natural mapping principles? Reference two specific design choices in your answer.
4. Think about your mental model for controlling the robotic arm. How did the other group's design align with your mental model of the task? Did you prefer to use joint control or end effector for the same tasks as the other group did? How would the difficulty of the task change if there was a long time delay when controlling the robot arm?

5. Now that you have tested out other group's design's, is there anything that you would improve about your design? Why or why not? List at least three specific points of your design that you would keep or change, and explain your reasoning.

Deliverable: Answer the above questions on the submission template

Appendix A - Human Interface Device Peripheral Reference

Device Name	Image	Description	Usage Notes
Rotary Encoder		Rotary encoders can be incremental or absolute. The encoders used in this device are incremental, meaning that each time the shaft turns by one notch, a signal is sent to the computer.	**-** Incremental rotary encoders don't store their current position. - These rotary encoders can be turned continuously.
Linear Potentiometer		A potentiometer is a type of variable resistor. The potentiometers in this device slide in a linear fashion, as opposed to rotating.	- Potentiometers always output the same signal at a given position. - Potentiometers have a limited range of motion. -**Important: when binding end effector controls to potentiometers, you may have an invalid orientation (see Figure 1 below). Before binding, set the potentiometer to the middle "zero" position.**
Switch		The switches in this device have two states. They operate by opening or closing a circuit.	- These switches remain in the state the user leaves them in - Switches can be used to toggle between states

Button		Buttons are a type of switch which always returns to the “open” state after being pressed.	- Button always returns to the same state. - Buttons can toggle states or activate actions once.

Appendix B - Task Instructions

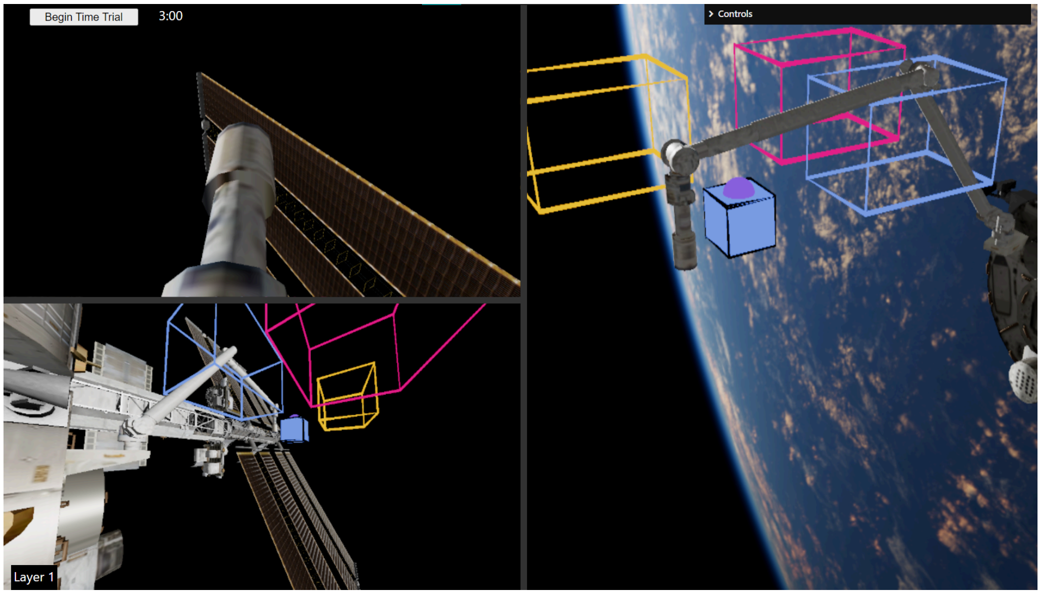


Figure 1. Screenshot of the simulator

Figure 1 depicts the screen that will show up when launching the simulator after it is done loading. The top left window is a camera view of the end effector. The bottom left window is a view from the ISS, and the right window is a view from another camera attached to the ISS, which can be controlled by assigning the "Pan Camera" control.

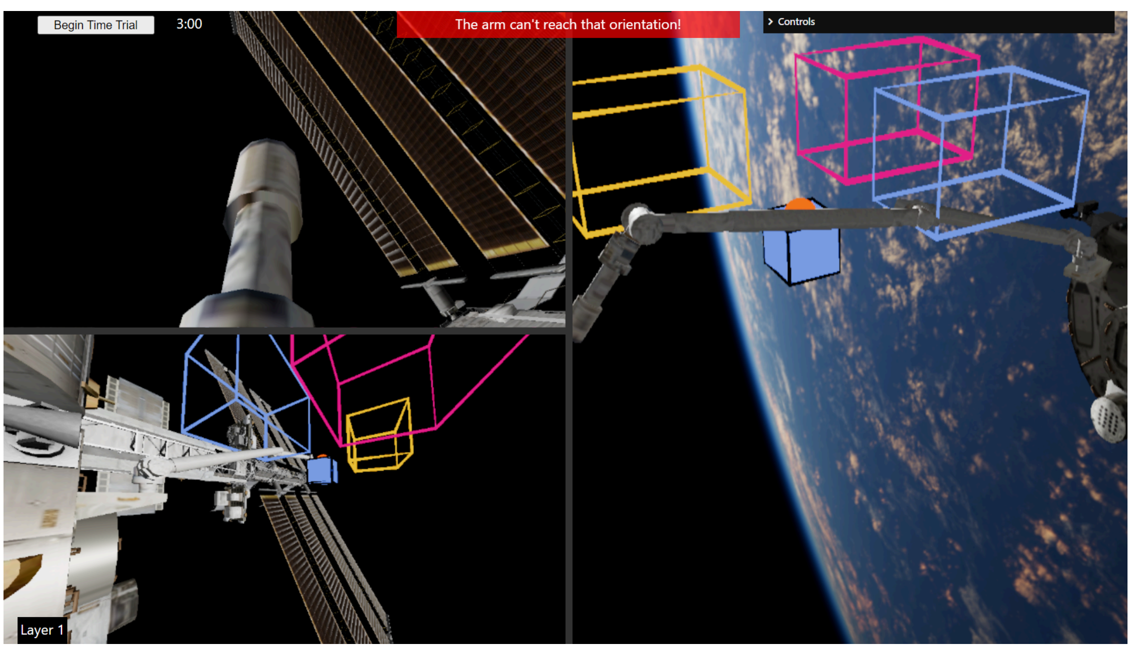


Figure 2. Screenshot of the warning that appears when the arm can't reach the orientation that the user inputs are telling it to go to.

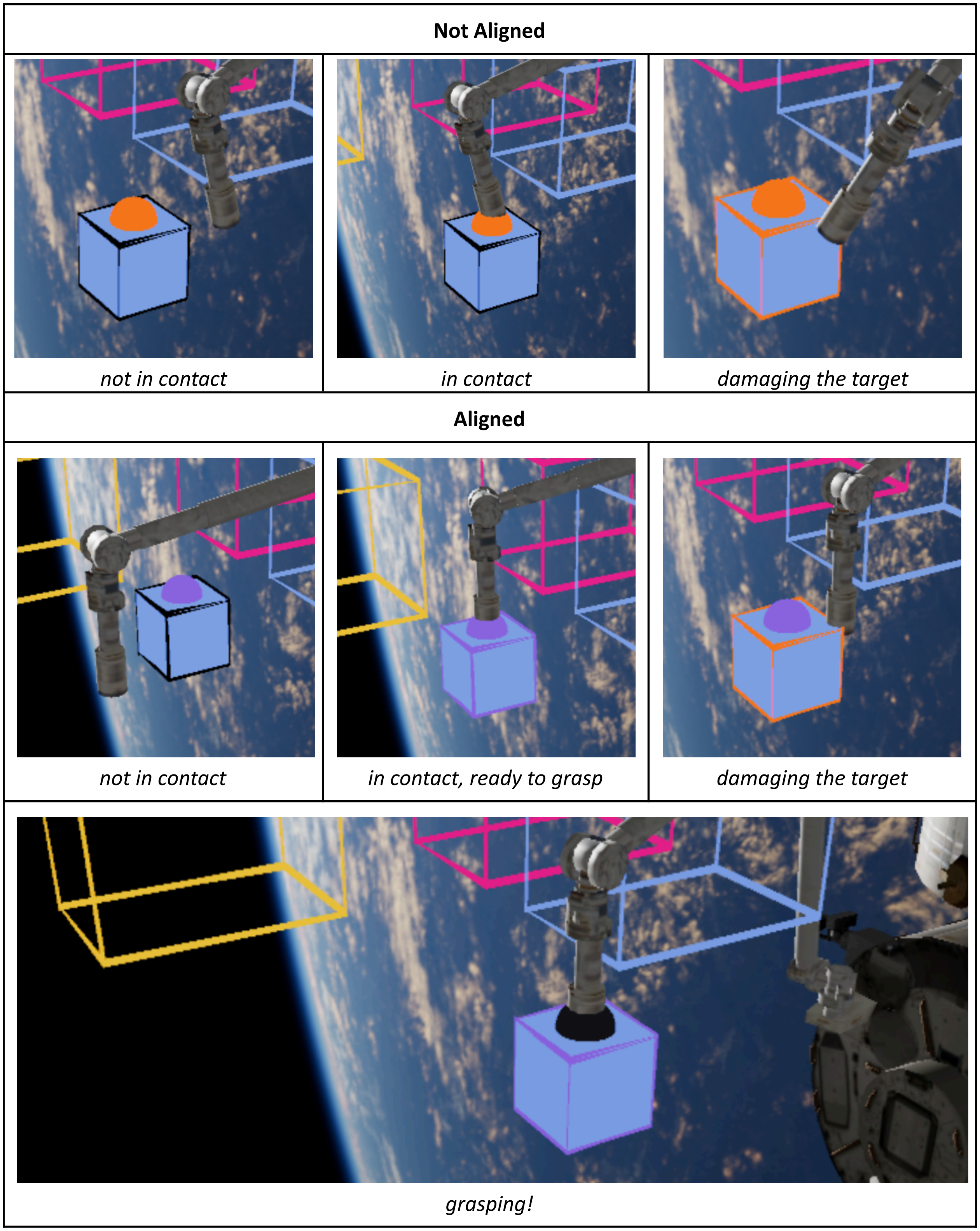


Figure 3. The different colors of the target, based on the state of the arm

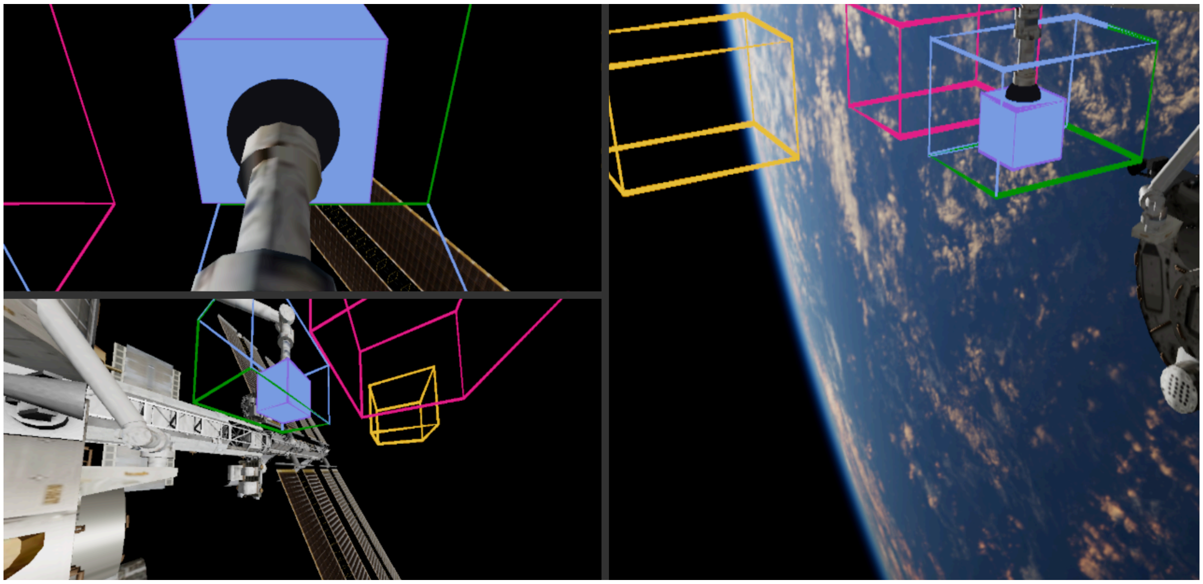
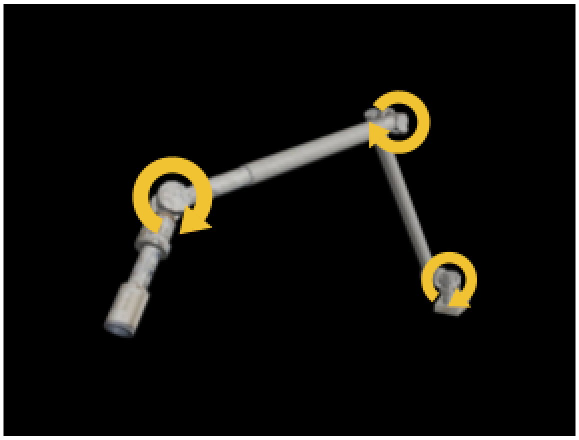


Figure 4. An image of the target aligned within the goal. The border of the goal is filled up with green to indicate how long the target must be held in the goal before releasing it.

The objective of the timed task is to receive as many points as possible by moving the cubes into the wire box of the same color. Be careful! Hitting the cube with your robotic arm will deduct 1 point per second that you touch the cube. This collision is indicated by the borders of the cube flashing magenta. In order to pick up the cube without touching it, you must move the end effector onto the attachment sphere on the box. In addition to moving the end effector on the sphere, your approach angle must be perpendicular to the face of the box that intersects the attachment sphere. When you're aligned the sphere will turn from orange to light blue. When you're aligned and your end effector is contacting the blue sphere, activate the device bound to the "Grasp" control. The sphere will turn black, and now you can move the box around and into its color matching goal. The different colors of the target based on the state of the arm are shown in Figure 3. When the box is fully within the correct goal, the border of the goal will begin to turn green, as shown in Figure 4. After two seconds, the border of the box will be fully shaded, at which point you can let go of the box and receive points. If you let go of the box too early, the border will reset. Releasing the box (by toggling to grasp control to off) after the goal border turns completely green will award you ten points and summon a new cube for you to manipulate. Try to get as many points as possible in three minutes without incurring any penalties by hitting the target!

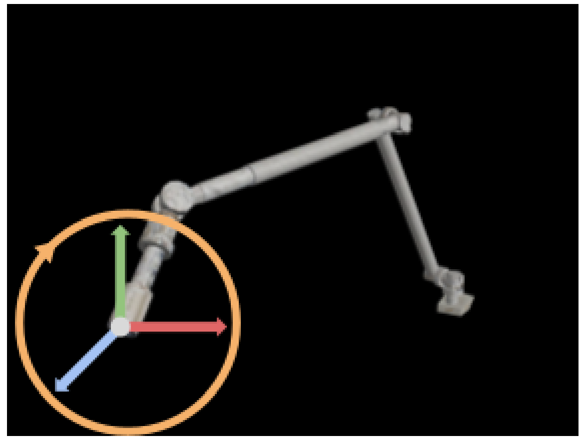
<u>Appendix C</u>

Joint Control



When using joint control, you have direct control over the angle of each joint of the arm. The arm in this simulator has six joints.

End Effector Control



When using end effector control, you set the position and rotation of the end effector. The end effector has an x, y, and z position and a rotation about the x, y, and z axes. The correct joint angles to put the end effector into this position and rotation are calculated using a process known as inverse kinematics.