Human-Robot Interface for Prosthetic Grasping in Spinal Cord Injury Subjects

Feasibility Study:

Materials

- (1) Kinova Mico robotic arm with six degrees of freedom and KG-2 Gripper
- (2) Kinect One devices positioned above the block picking area
- (1) Ultimate Switch #1671 (Adaptive switch)
- (1) sEMG Device
- (1) Amazon Echo Dot
- (1) Computer with GraspIt! Controlling software
    - Connected to the Mico, both Kinects, and all input devices (mouse/ultimate switch/sEMG device)
- (1) Foam platform, marked with (2) 11”x11” squares for block selection/placement areas
- (3) Wooden blocks, assorted sizes
    - 1x 50mm cube
    - 1x 64mm cube
    - 1x 76mm cube
- Block Placement Template
- (1) Arbitrary household objects - Gillette shaving cream can
- (1) Standard chair
- (1) Stopwatch
- Alcohol wipes
- Ten20 Conductive Paste
- Medical tape

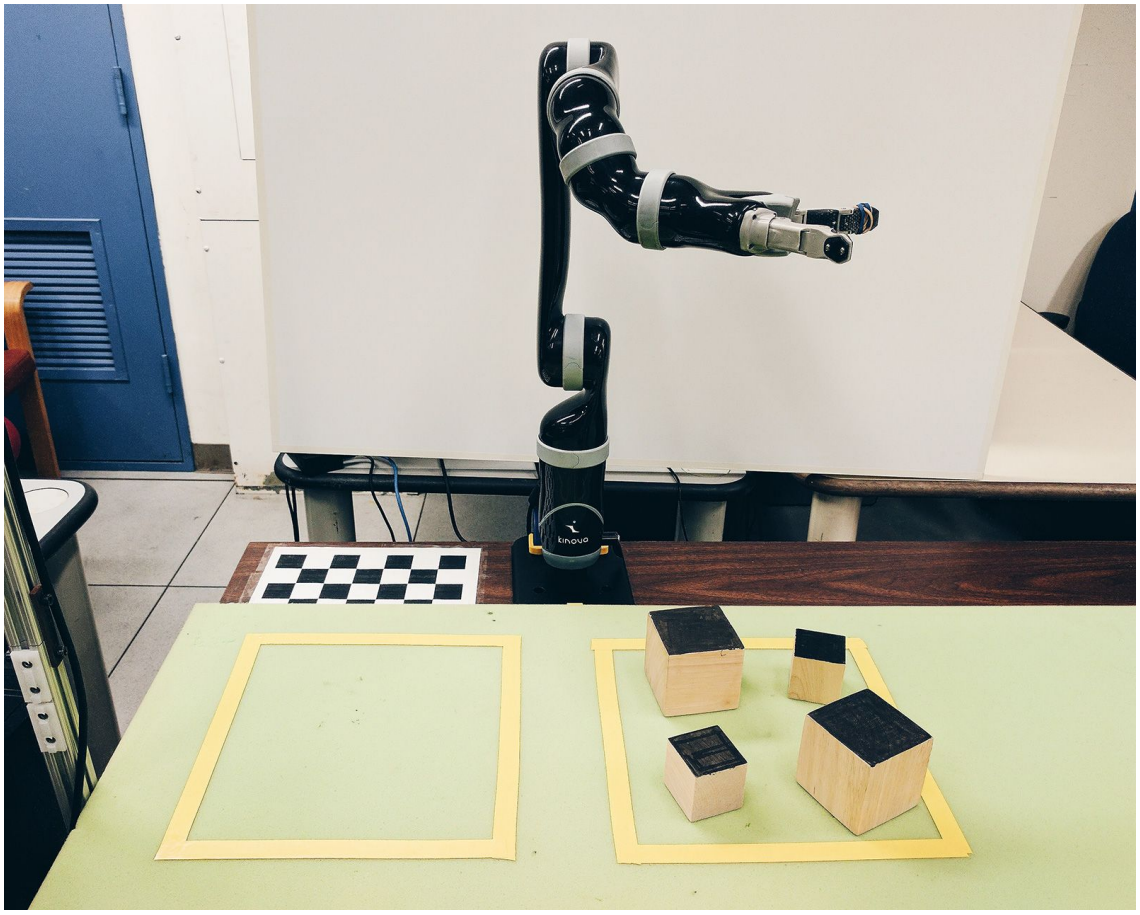
Setup

Block Experiment

- Place the 3 wooden blocks on the picking side of the foam core platform, using the block placement template to ensure consistency across experiments

Object Experiment

- Place the object in the middle of the block selection area of the foam platform



Subject Training

- Subject is provided with information on the experiment and elects to continue or terminate participation. Completes documentation as guided by IRB.
- Subject is positioned in a designated safe area away from the robotic arm, within clear view of the computer monitor/user interface and block picking area.
- Subject is trained to use GraspIt! Controlling software using standard mouse. Once patient demonstrates comprehension of software and ability to control robotic arm, continue to set-up of control mechanisms.

Control Mechanism Set-up (randomized to prevent order effect)

- Adaptive Switch Control (Ultimate Switch)
    - Subject is assessed for an appropriate point of control, which enables consistent visual regard of the computer screen and minimal effort. Switch is mounted and positioned accordingly.
    - Subject demonstrates mastery of switch activation
- sEMG Device:
    - Researcher screens subject for appropriate point of control that elicits sufficient movement to activate controller.
    - Researcher applies rubbing alcohol to selected area and thumb (for grounding)

    - Researcher applies conductive paste to 4 electrodes of controller and positions them in the aforementioned regions.
    - Researcher trains the subject to activate the device and calibrates the interface accordingly.
    - Subject demonstrates mastery of sEMG device activation
- Echo Dot and Alexa Voice Command Controller:
    - Researcher trains the subject with voice commands that activate Alexa and navigate the interface
    - Subject demonstrates mastery of Alexa voice activation

Starting the Test

- These are the series of commands required to bring up the graspit interface, the controller for the mico arm, and the controller for either the Ultimate Switch or the sEMG device

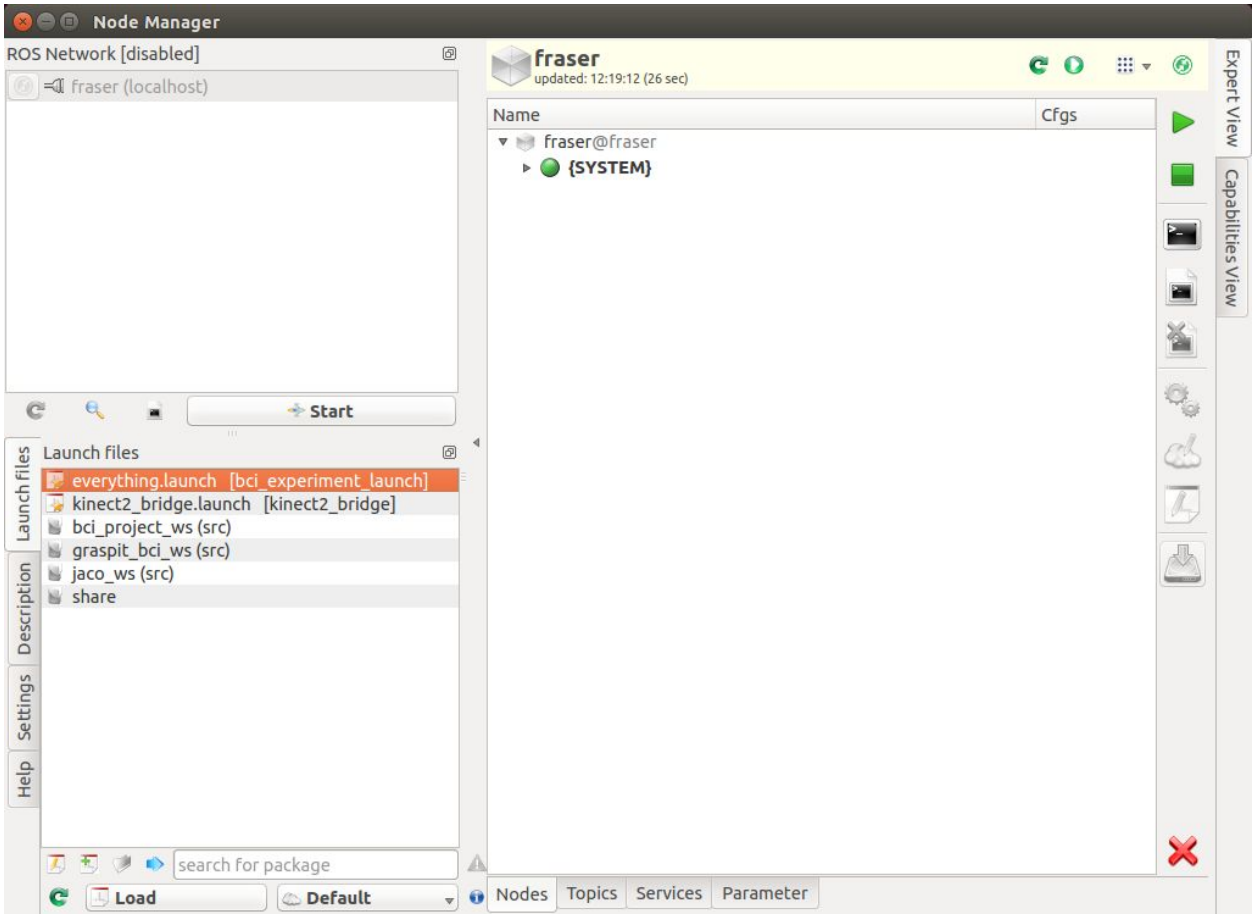
- For every terminal window you open (ctrl+alt+t):
  >cd ~/ros/bci_project
  >source setup.bash

Running these two commands ensures that you have properly configured your terminal with ROS

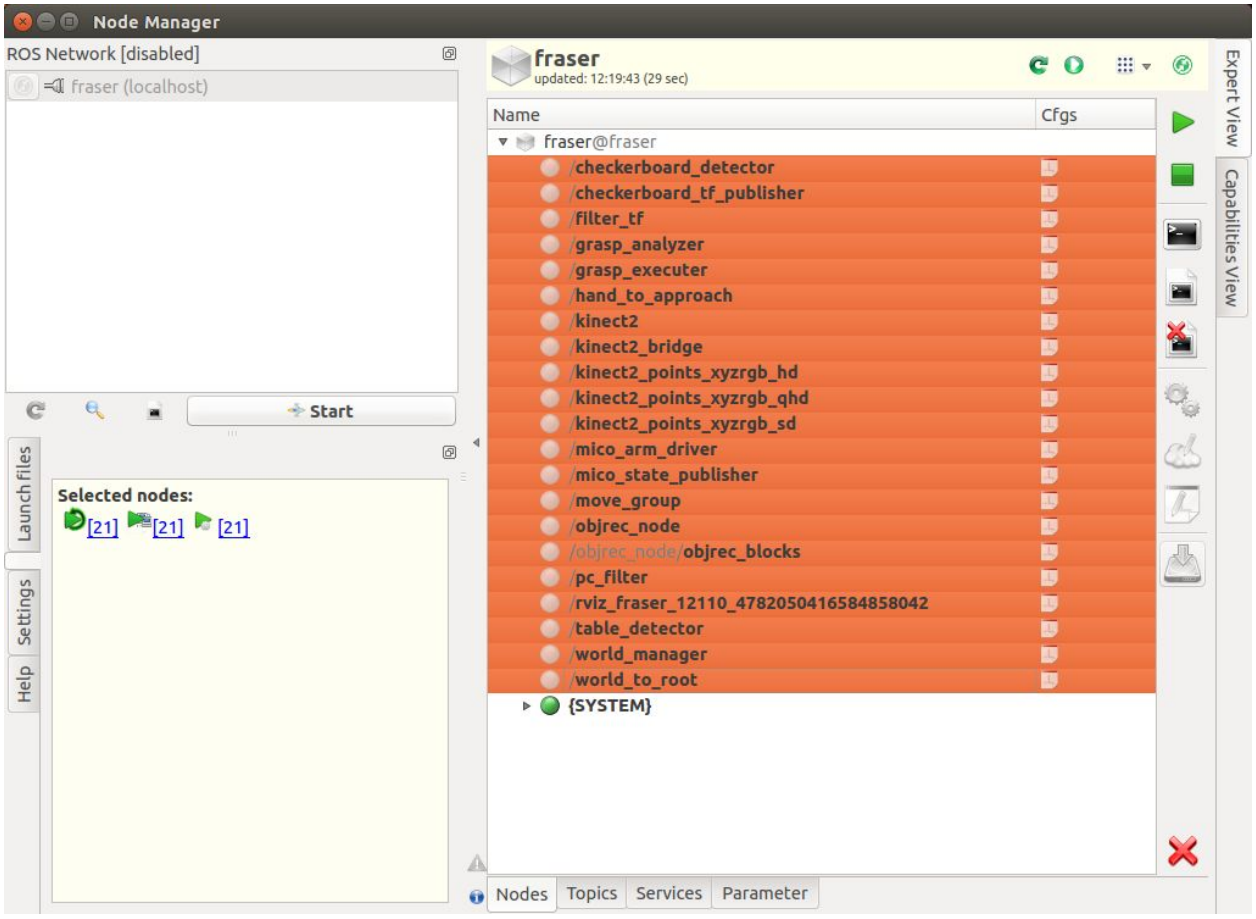
To run the mico arm controller

>nodeman

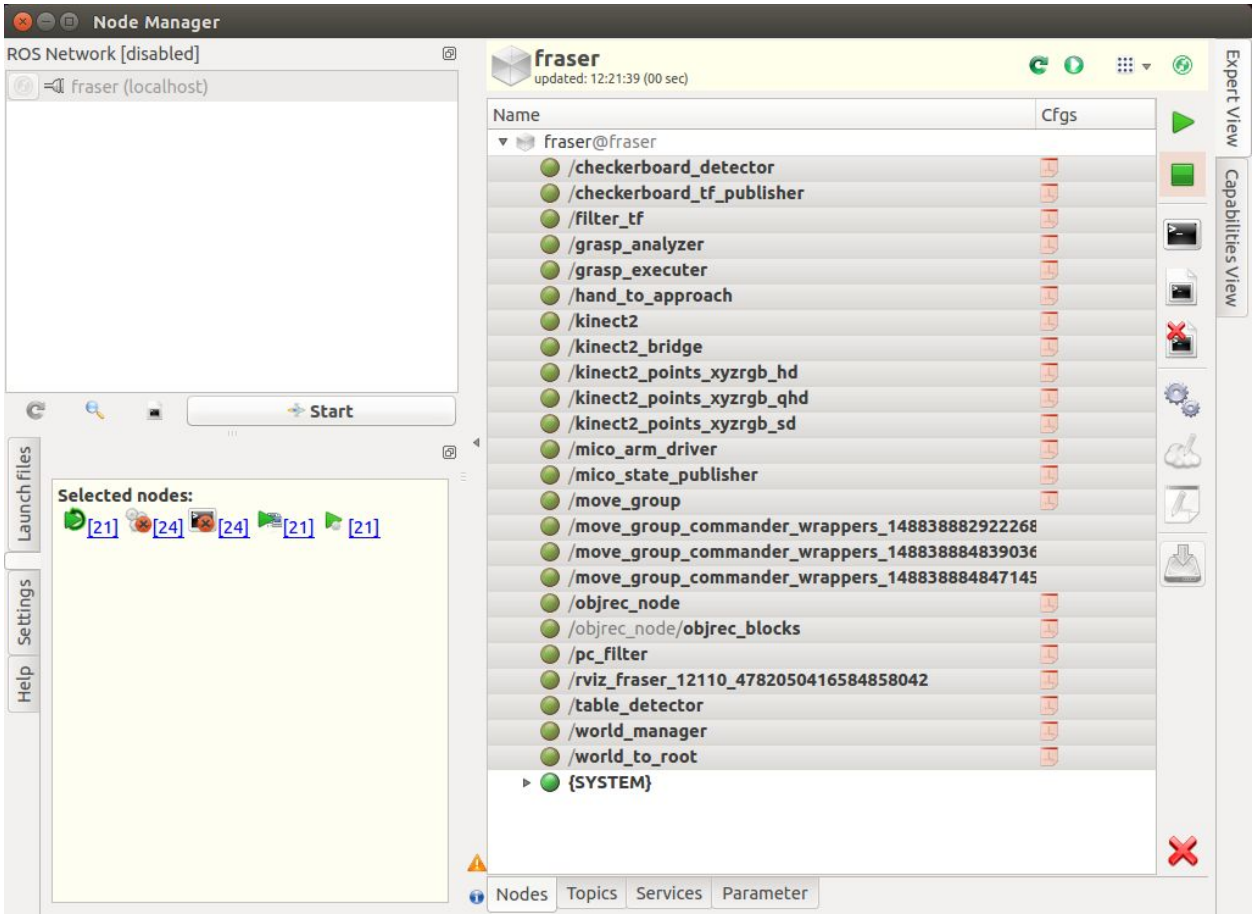
This will bring up a window that looks like the following for launching ROS nodes:



To start the controller - in the *Launch files* tab on the bottom left of the window, navigate to the file ‘bci_project_ws/bci_experiment_launch/everything.launch’ and double click. Click ‘OK’ in the popup window. Highlight all the nodes by shift-clicking the first and last node and click the green play button in the top right:



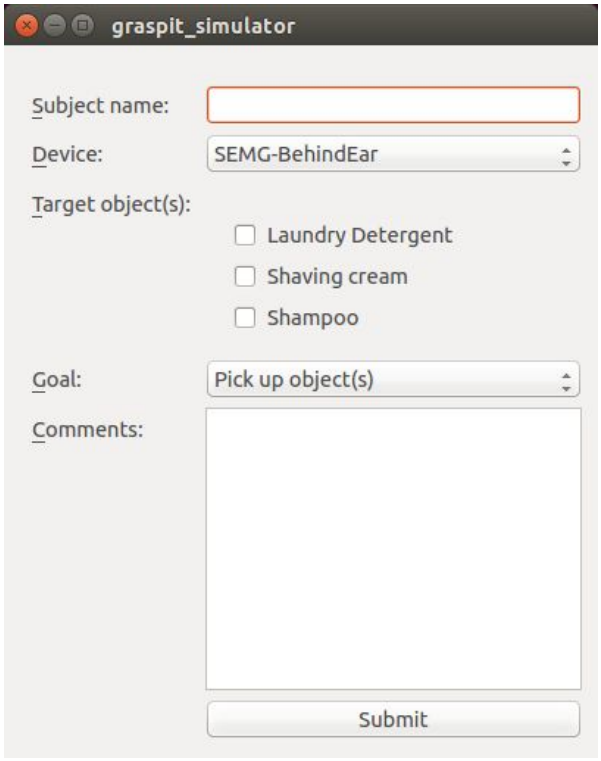
Once these nodes are all started and the dots next to their names are all green, the mico arm is ready to be used:

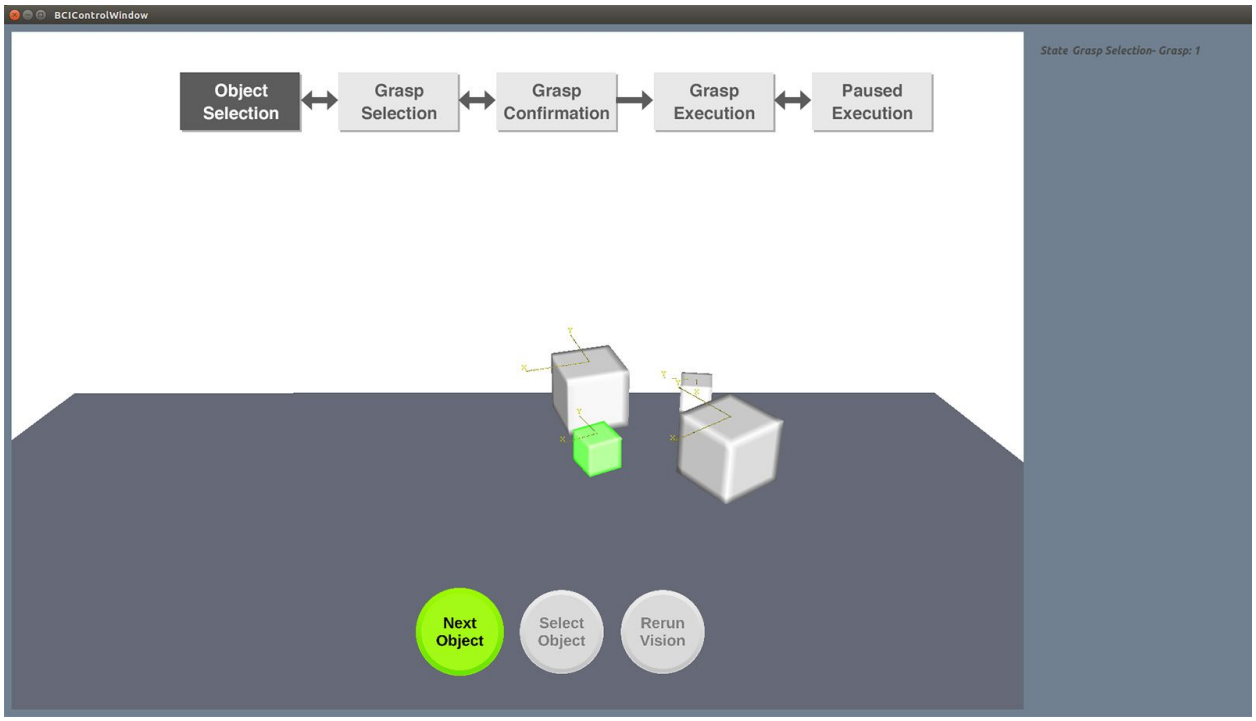


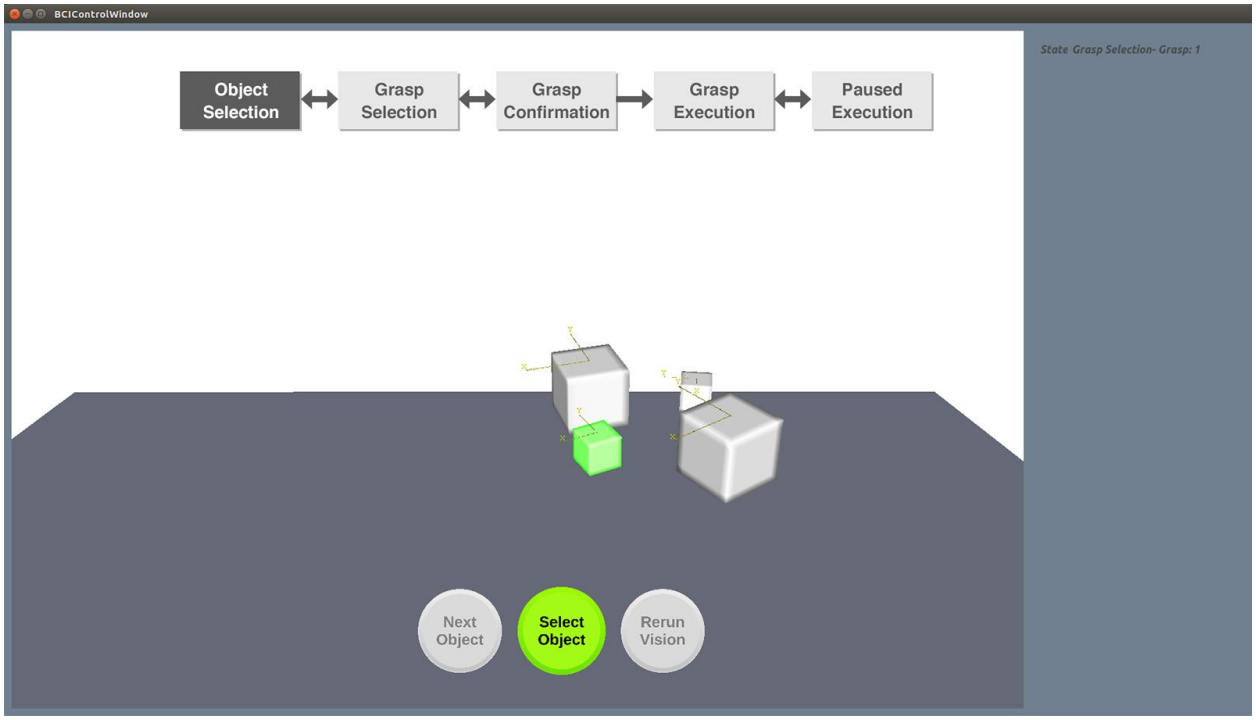
Starting the Graspit! User Interface

- Bringing up the user interface is similar, in a new terminal window run:
  >roslaunch graspit_bci_plugin ros_graspit_interface.launch

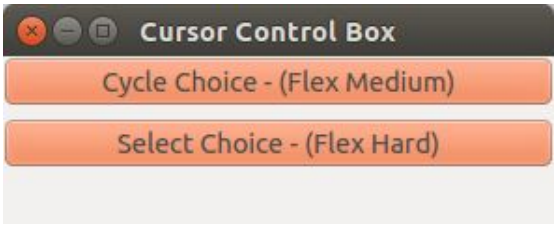
- You should now see a user interface that allows you to select blocks by moving through on screen options using one of the device controllers (see later instructions for bringing these up).

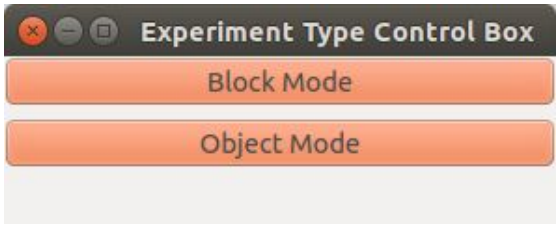

graspit_simulator
Subject name:
Device:
SEMG-BehindEar
Target object(s):
Laundry Detergent
Shaving cream
Shampoo
Goal:
Pick up object(s)
Comments:
Submit


BCIControlWindow
State Grasp Selection- Grasp: 1
Object Selection
Grasp Selection
Grasp Confirmation
Grasp Execution
Paused Execution
Next Object
Select Object
Rerun Vision

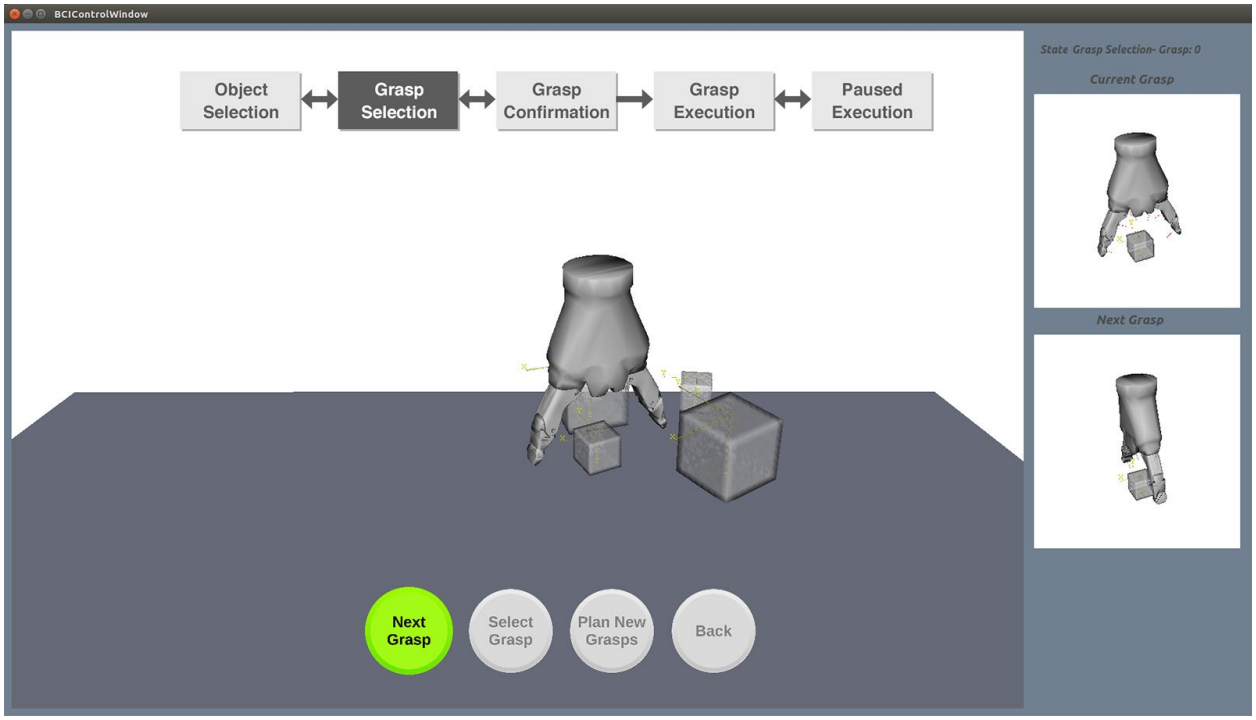


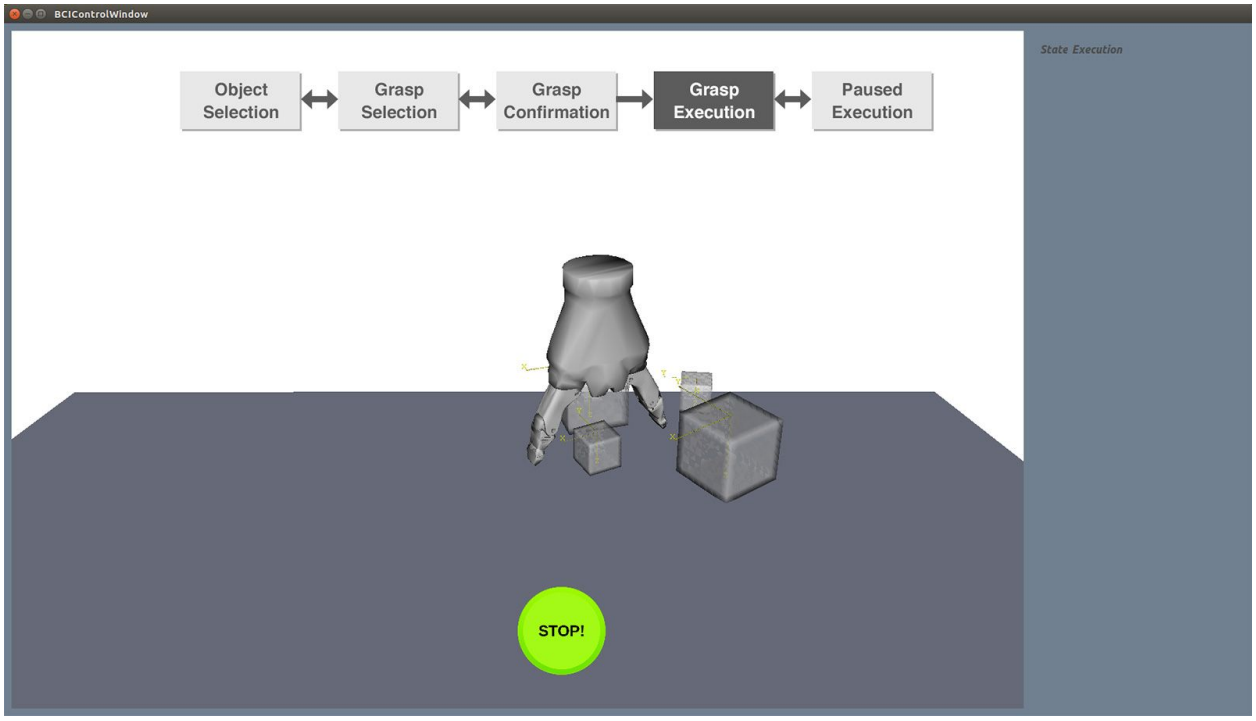
- Make sure you test the system using the debug mouse-clickable buttons that are loaded on startup (Cycle Choice and Select Choice)



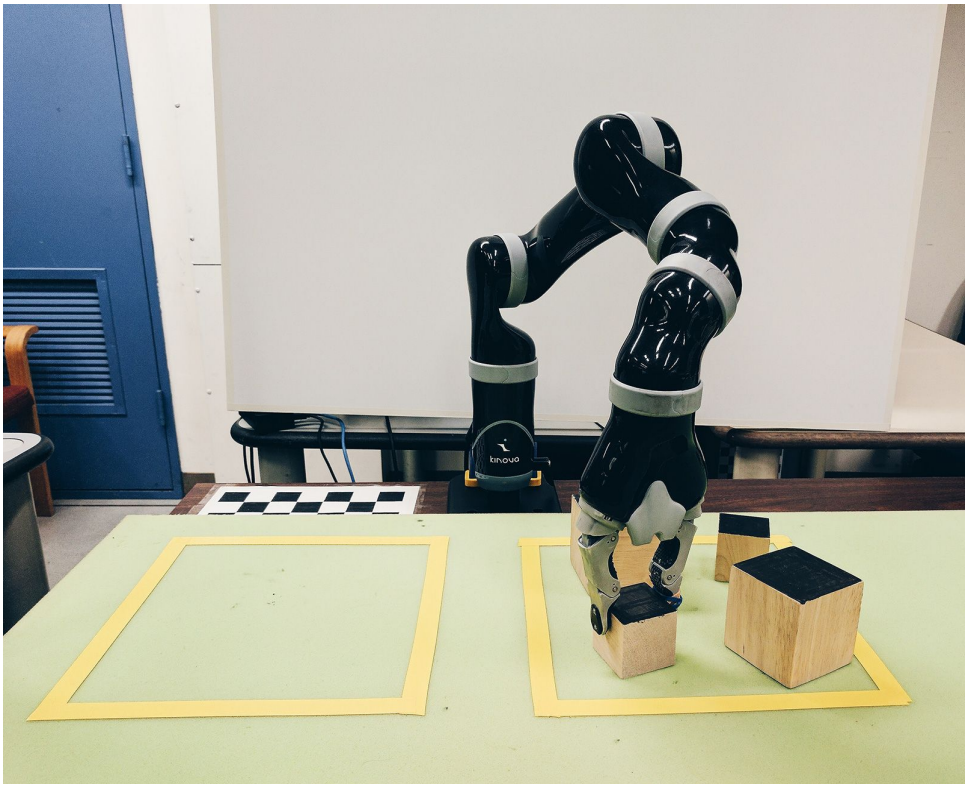


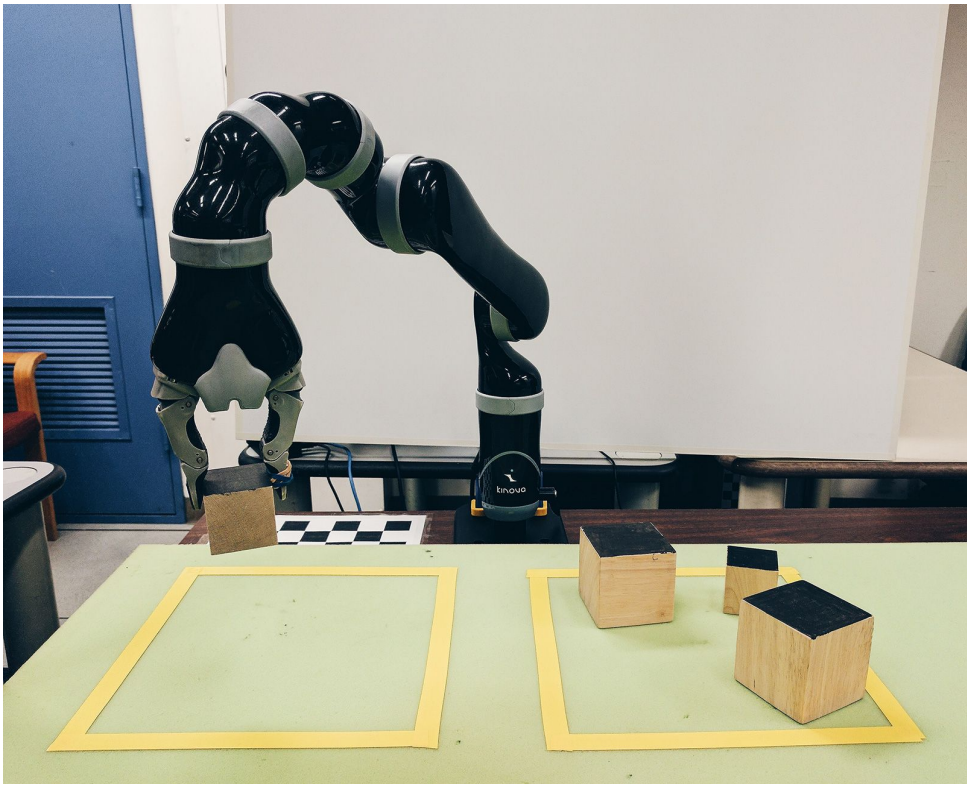
These are good for affirming the experiment works before the subject provides their own input

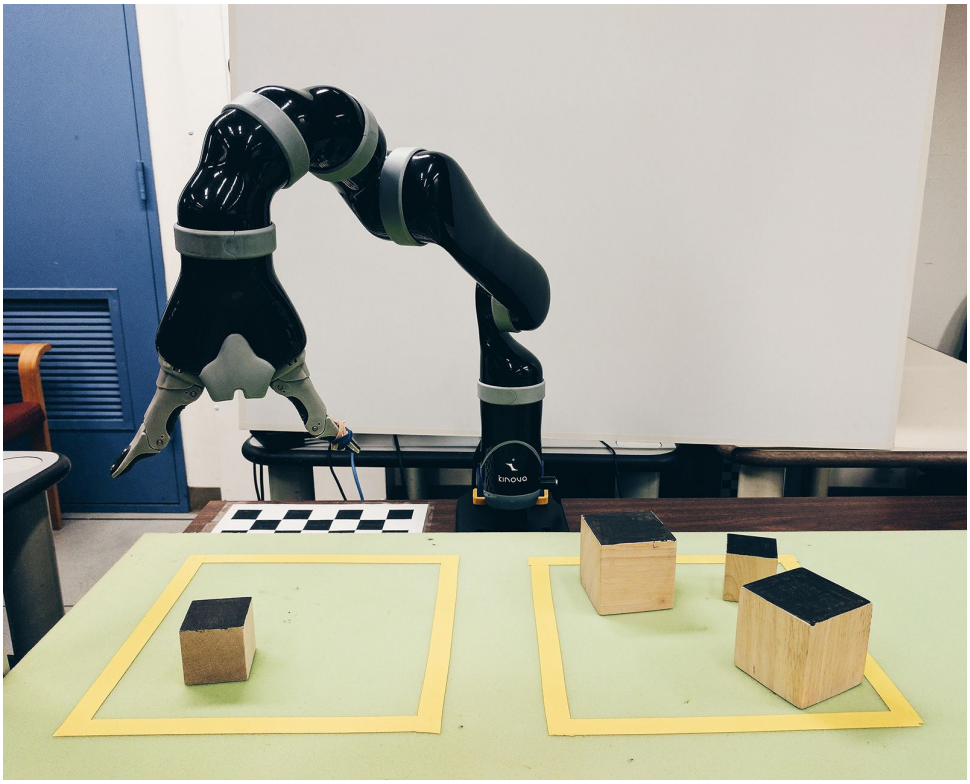




<Video of experiment working>





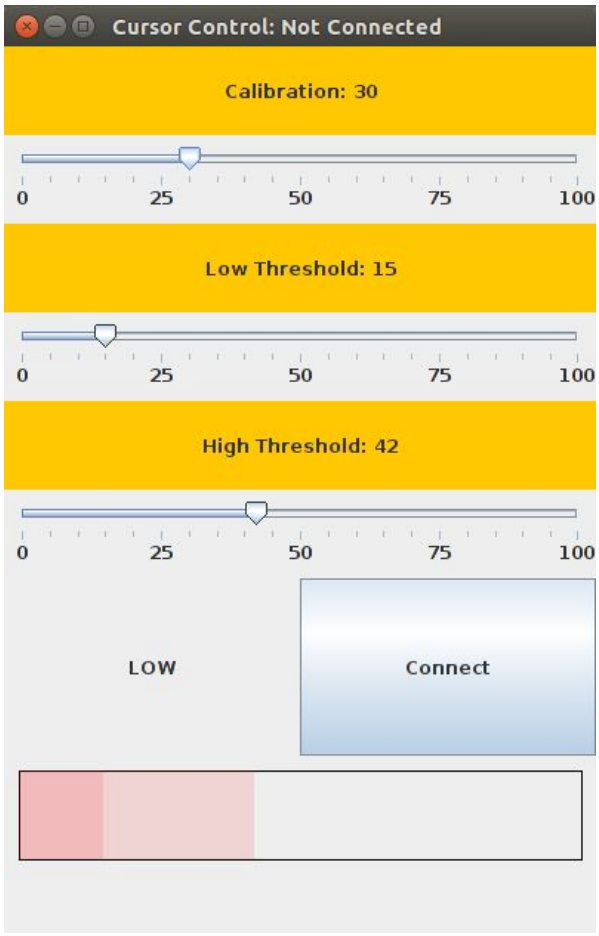


Starting and Calibrating the sEMG Device Controller

- To run the sEMG device:
  >cd ~/ros/bci_project/graspit_bci_ws/src/graspit_threshold_controller/scripts
  >./run.sh

This will bring up the controller interface. Once the sEMG device is plugged into the microphone port on the computer and the graspit! interface is running, click ‘Connect’. This will connect the sEMG controller to the graspit interface.

To calibrate the controller, find a reasonable “calibration” level or sensitivity of the device for what the subject emits by watching the animated red and white bar below and adjusting the sliders accordingly.



- **High Threshold:** Have the subject flex all the way until the read is approximately 75-80% of the bar (within the white area). This will “select” a button option in the interface.
- **Medium Threshold:** Have the subject flex partially (light red area). This will “cycle” and highlight the next button on the screen.
- **Low Threshold:** Make sure the dark red area is not exceeded while the subject is resting and idle.

Starting the Switch Controller

- To run the Ultimate Switch controller:
  >cd ~/ros/bci_project/graspit_bci_ws/src/graspit_switch_controller/scripts
  >python switch_controller.py

  This will start the following interface:
  <Python interface>
- Make sure that a single, held press is registered properly as “Next”, followed by “Select”, followed by “Waiting for input”.
  - “Next”: press the switch and release within a 0.1 - 1 second window
  - “Select”: press the switch, hold, and then release after at least 1 second but no more than 3 seconds has passed.

    - While holding, if 3 seconds pass and the state becomes “Waiting for input”, release the switch at any time to try again.
- Note: for the Ultimate Switch, a press is designated by any initial motion that causes the switch to make an audible clicking sound. Releasing the switch will also make a clicking sound.

Starting the Echo Dot and Alexa Controller

Procedure

- Follow the setup for the user interface as indicated above and the input control setup for the mouse, Ultimate switch, sEMG device, or Alexa.
- Subject begins by viewing the Graspit! Interface on a monitor positioned in front of them.
- When testing begins, the subject should select one object at a time, waiting for the robot to finish placing each object in the designated area before selecting the next.
- For each input device, testing is complete after all 3 blocks and 1 arbitrary object have been placed (or attempted).
- In the event of a system malfunction or crash, the system can be restarted, and testing continues from the point at which the last object was successfully placed.

Test Sequence

1. Mouse as input device
    a. Test trial with Graspit! Interface to cycle and select buttons
    b. Timed 3 block trial and 1 object
2. Randomize order in which the Ultimate Switch and Alexa are used for Control #2 and #3
3. Control #2 as input device
    a. Test trial with Graspit! Interface to cycle and select buttons
    b. Timed 3 block trial and 1 object
4. Control #3 as input device
    a. Test trial with Graspit! Interface to cycle and select buttons
    b. Timed 3 block trial and 1 object
5. sEMG Device as input device
    a. Test trial with Graspit! Interface to cycle and select buttons
    b. Timed 3 block trial and 1 object
6. Survey of which was preferred

Subject Instructions

“I want to see how quickly you can pick up and move blocks from one box to the other using the interface to control the robotic arm.”

Test with the Mouse first, then randomize order of the Ultimate Switch and Alexa, and lastly test with the sEMG device. For each of the 4 input devices, follow steps 1-3 below.

1. Subject Training

a. Mouse Controller

“For this trial, you will use the mouse to tell the computer what to do. There are two buttons that you can click to “Cycle” or “Select” a button in the interface.”

b. sEMG Device

“*We are now going to proceed with the part of the experiment that uses the sEMG device to control the robot. Which ear would you like to use?”*

After the subject has indicated which ear they would like to use, request that they flex that region of their head until they can feel movement of some kind. If the subject cannot flex their ears, use their forearm instead and follow the rest of the prompts accordingly.

“Place your fingers behind that ear and check to see if you can feel movement - it helps if you can wiggle your ears. Once you have found this active region, I will need you to take this alcohol wipe and wipe off both that region behind your ear and around the thumb of your non-dominant hand.”

Once they have determined the location behind their ear that gives the most feedback - hand them an alcohol wipe so they can wipe down both behind their ear and their thumb.

“I will now take this controller and apply conductive paste to the electrodes. These two electrodes will be placed behind your ear to receive input from your muscle movement. This other electrode will be clamped onto your thumb to ground the controller. Are you ready to continue?”

[Wait for yes]

Take the sEMG device and apply the conductive paste as described above. Place the two main electrodes on the region they indicated earlier behind their ear - about an inch apart from each other - it should stick with the conductive paste. If needed, use tape to secure. Clip the grounding wire on their thumb, also securing with tape. Once they have been equipped with the sEMG device, follow the instructions above for calibrating the device to their skin.

“I will now begin the calibration process. I will need you to flex that region behind your ear as much as you can.”

[Take measurement of high]

“Now I need you to rest the region.”

[Take calibration of low]

“Now I need you to flex halfway between no effort and maximum effort.”

[Take calibration of medium].
*Note: it may help if the subject can see the calibration tool while flexing. If using the forearm, some subjects have an easier time if holding an object e.g. a bottle.

c. Ultimate Switch Controller

“For this trial, you will use the Ultimate Switch to tell the computer what to do. The switch can be pressed in any direction. When you press on the switch and then release it, that will be registered as an input. There are two types of input in this experiment. When you press the switch and release within a 0.1 to 1 second window, that will cycle and highlight the next button to the right on the screen. When you press the switch and release after 1 second has passed, but before 3 seconds have passed, that will select and execute the currently highlighted button. If more than 3 seconds have passed, no input will be registered and you can release the switch to restart. Releasing too quickly will also be ignored.”

d. Alexa Controller

“For this trial, you will give voice commands to Alexa and the Echo Dot to tell the computer what to do. To initiate a command, say the wake word ‘Echo’. Then say ‘tell the robot’ and the label of the button on the screen that you would like to execute. You don’t need to cycle buttons here.”

“Echo, tell the robot Next Grasp.”

“Echo, tell the robot Select Grasp.”

2. Trial Period (same for all devices)

“Before we begin, can you show me how to move between buttons on the screen?”

[Subject demonstrates toggle]

If patient is able to demonstrate toggle, continue with protocol. If not, re-train on use of device until competent and re-test.

“Can you show me how to make a selection?”

[Subject demonstrates ability to make selection]

If patient is able to demonstrate selection, continue to test. If not, re-train on use of device until competent and re-test.

3. Test Procedure (same for all devices)

“*Now we are ready to begin the actual test. Remember, we want to see how quickly you can move all three blocks from one area to the other. When it is time to start, I will say ready and then go. If the robotic arm or system malfunctions, we will restart the system and continue from the last successful block. If, for any reason, you feel uncomfortable or wish to terminate the experiment, please let me know and we will stop the experiment. Do you have any questions?”*

[Answer questions]

“Work as quickly as you can. Ready? Go.”

For each object, measure the time the subject interacts with the interface, and the time the robot takes to execute block placement. More specifically, use the lap function and click lap once object detection is complete, as soon as the subject is allowed to interact with the interface. Click lap again as soon as the subject selects “Confirm Grasp”. Click lap after the robot completes its task and object detection is complete, as soon as the subject is allowed to interact. Continue for all objects.

[Switch the experiment to Object Mode, remove the block template, and place the arbitrary object - a bottle - in the center of the picking area]

“Now try to pick up this bottle. Ready? Go.”

Take the same measurements as the blocks.

[Return the transported blocks to their original position]

4. End of Experiment Survey

After completing steps 1-3 for all 4 input devices, have the subject fill out the survey rating their experience.

Scoring

The score is recorded as the amount of time it takes to transport each individual block. Record the amount of time between when the system recognizes blocks and when the user confirms a grasp and executes. Record the time it takes the robot arm to pick up and place each block. Record the total time to complete the entire 3 block task.