VCU Software Engineering

Duplo: Proctor's Guide

Robots

In this experiment, we use the two-armed collaborative robot ABB IRB 14000 (also known as YuMi), mounted to a base station. YuMi has two arms with 7 degrees-of-freedom each, both including smart grippers to pick up objects. 3D printed bases for both pickup and drop locations rest on the table. These bases will be starting and finishing points for objects to be transferred.

Figure 1. The robot executes a pickup and place movement on its station.

The electric components of IRB 14000 can be located on the base of the robot behind the station, including connections to the teaching pendant and controller along with IRB 14000's main power switch and power supply.

Tasks

In this experiment, participants will be presented with three similar but separate tasks. These tasks involve the picking and placement of three 3D printed objects. Each task should be completed using one or both of the robot arms.

The tasks should be completed in the order given by this documentation.

- **Task 1 (Spacer):** Participants will be asked to move the 3D printed spacer from its starting position (Figure 2) to its final resting position (Figure 3) using the two-armed robot. To perform this task, the participants will need to program the IRB 14000 movement positions using one of two programming interfaces.

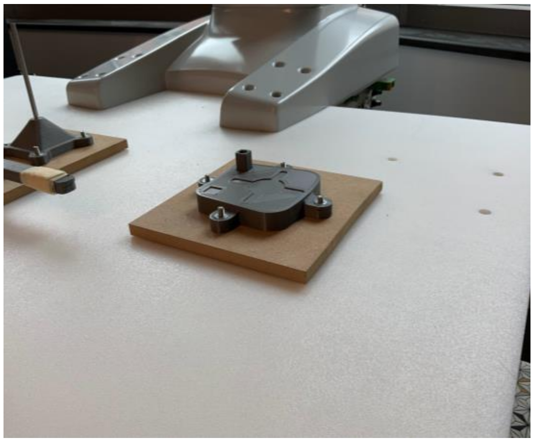

Figure 2. Starting position of the spacer on its 3D printed base plate.

The spacer has a fixed home position where it should be placed before the start of the experiment. Participants are not allowed to change the starting or ending positions of any objects in this experiment.

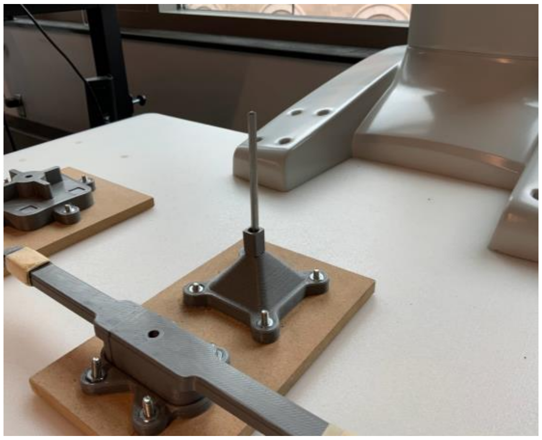

Figure 3. Final solution with the spacer successfully placed at the end position.

- **Task 2 (Gear):** Participants will be asked to move the 3D printed gear from its starting position (Figure 4) to its final position (Figure 5) using the robot. To perform this task, the participants will need to program the IRB 14000 movement positions using one of two programming interfaces.

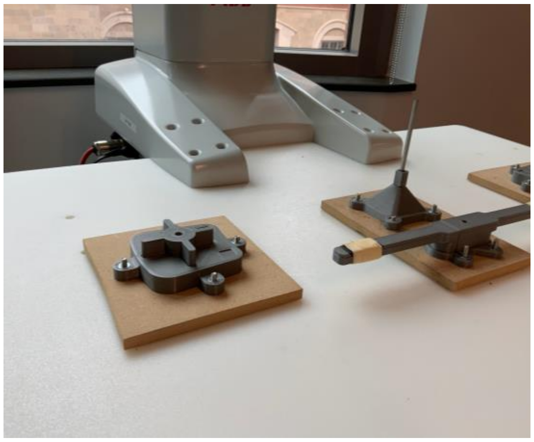

Figure 4. Starting position of the gear on its home 3D printed base plate.

The gear has a fixed starting position where it should be placed before the start of the experiment.

Figure 5. Final solution with the gear successfully placed at the end position.

- **Task 3 (Propeller):** Participants will be asked to move the 3D printed propeller from its starting position (Figure 6) to its final position (Figure 7) using the IRB 14000. To perform this task, the participants will need to program the robot movement positions using one of two programming interfaces. Pick and placement of the propeller are supposed to be completed using both robot arms working together simultaneously.

Figure 6. Starting position of the propeller on its home 3D printed base plate.

The propeller has a fixed starting position where it should be placed before the start of the experiment.

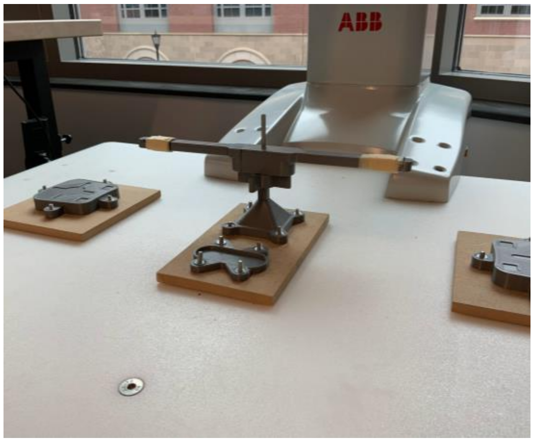

Figure 7. Final solution with the propeller successfully placed at the end position.

Watch a tutorial about the tasks at: https://shorturl.at/fEO89 and https://shorturl.at/gqswP

Programming language

In this experiment, our goal is to compare two alternatives to program collaborative robots. To do so, we have implemented a block-based programming system called Duplo and used the manufacturer's published alternative called RobotStudio Online Yumi for comparison. Our language was specifically designed to make programming industrialized robots easier for end-users. Keep in mind however that Duplo is a prototype programming language and bugs may occur (and should be reported).

- **The Duplo Programming System:** Duplo was created to make programming of collaborative robots easier for end-users. The system has a single interface where all the programming work is done (See Figure 8). On this interface, we have implemented multiple movement types, gripper controls, speed settings, and buttons to execute the program and manipulate the robots. The interface has two canvases where users can implement robot actions by attaching blocks in desired orientations.

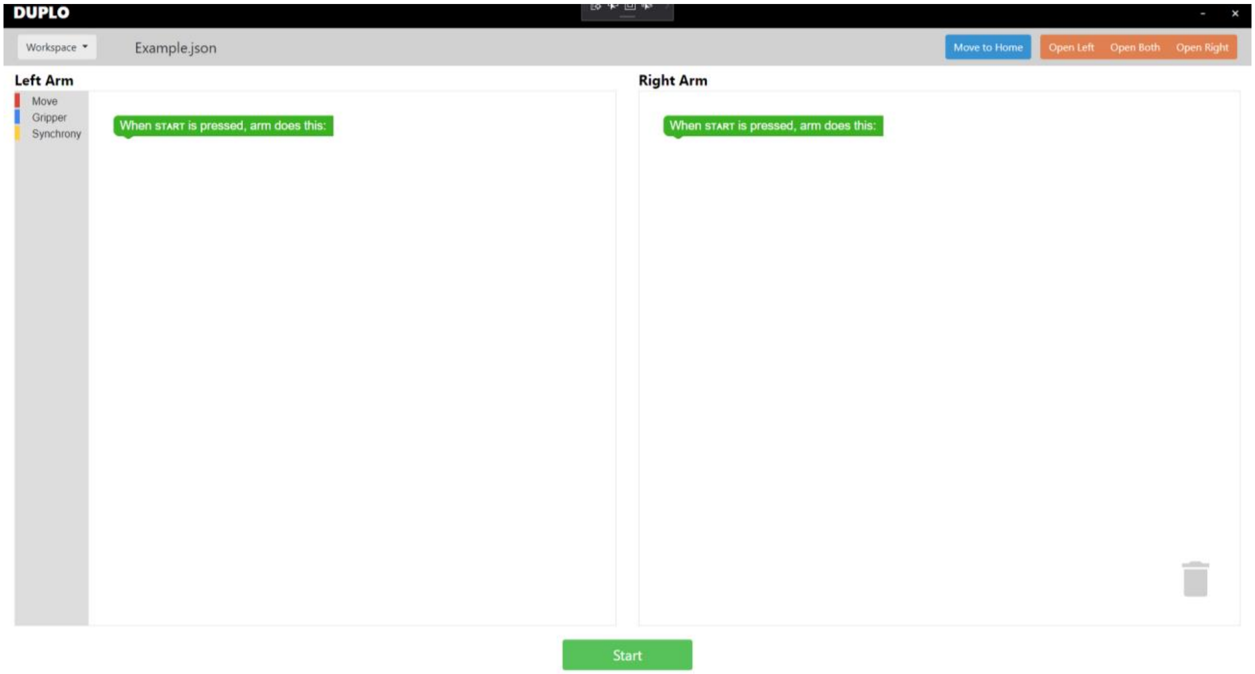

Figure 8. Duplo's main interface, two canvases one for each robot arm.

- **RobotStudio Online Yumi (RSOY):** RobotStudio Online Yumi was created by ABB as a prototype programming alternative for YuMi. The prototype has multiple interfaces for users to program in. In the main interface (Figure 8), users can perform the majority of the functionalities that come with RobotStudio Online Yumi, including teaching positions and opening grippers. There are also separate interfaces to setup the code for each arm, and another interface to execute the code.

Figure 9. RSOY's main interface, two canvases one for each robot arm.

Watch a tutorial about Duplo prototype language at: https://shorturl.at/cmxzU
Watch a tutorial about RobotStudio Online Yumi language at: https://shorturl.at/nozAI

Workflow

As a proctor, your duty will be to guide the participants through the whole experiment. Your work is divided into three phases: before, during, and after the experiment. Each step is explained in detail below:

Before the experiment

Before receiving a new participant, you must guarantee that the workspace is ready. This task includes inspecting if the station and objects are in their initial layout, turning on the robot, turning on the computer, and opening the language in the correct programming interface.

The initial position for the objects

Ensure that all objects are in their initial position. First, the spacer should be placed below the robot's left arm in the position closest to the robot (See Figure 2). Second, the gear should be placed below the robot's right arm in the available position (See Figure 4). Finally, the propeller should be placed in between both robot arms in the position available (See Figure 6).

Turning on the robot

Follow the steps below to turn on the robot:

1. **Ensure the controller and robot are both turned on:** Both the controller and YuMi should be left on, if not make sure to turn on both. Please note that if YuMi is turned off for a long time, you may need to reset the system and set up the grippers (See Step 4).

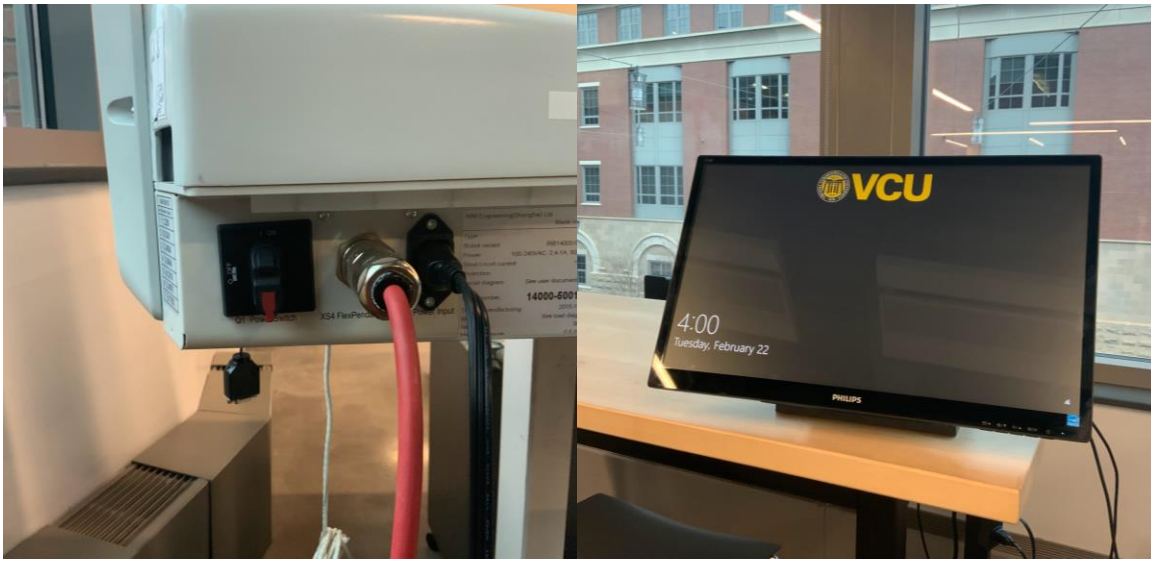

Figure 10. On/Off switch for the IRB-14000(left), Controller, computer, screen(right).

2. **Set up the teach pendant:** The teach pendant is a tool for the proctors use only, participants will not need to interact with the teach pendant at any point during the experiment. If you don't know how to use it, please ask a supervisor to give you the basic training. Before the experiment proctors should ensure the IRB 14000 is in the correct modes through the teach pendant. The teach pendant should be found to the right of the YuMi station.

Figure 11. Location of plex pendant.

a. By pressing the two gears located at the bottom right of the teach pendant's screen you can open the main mode selector menus. The first mode you want to set is the robot movement speed percentage, this should always be set to 50%.

Figure 12. Flex pendant display, speed mode selector menu.

b. Next, ensure the run mode is correctly set to the "Single Cycle" setting.

Figure 13. Flex pendant display, run mode selector menu.

c. Next, ensure that the motors are turned "On" and that the operator mode is set to "Auto".

Figure 14. Flex pendant display, operator panel and operator mode menus.

3. **Open the following menus inside the teach pendant:** To use the teach pendant, proctors will need to learn how to use the screens below. All of the following menus can be assessed through the button with three equal length bars at the top left of the teach pendant screen.

a. *System Info - Controller properties - Network connections - Service port:* will be used to find the IP address of YuMi to input into the controllers' interface if ever prompted. Using this screen is not necessary unless requested by a superior.

b. *Input and Outputs - View menu - I/O Devices:* Where Hand_L and Hand_R should display as running. If Hand_L displays as deactivated it can be activated by clicking on Hand_L and pressing "Activate" in the bottom left. Repeat for Hand_R if needed. This is only necessary if the robot was off for a long time.

c. *Smart Gripper - Configuration:* Where both grippers can be turned on or off. If the "power switch" menu displays a green light next to both right and left flange then the gripper motors are on. If the light is red you will need to turn on the gripper motors, however to do so you will need to return to the operator mode menu and turn it to "Manual" mode (See Figure 14). After that you will be able to activate the gripper motors and return the operator mode to "Auto".

d. *Jogging:* Make sure on the bottom left it says "Disable Lead-through". If instead it says "Enable Lead-through" you will need to click on "Enable Lead-through" to turn on the collaborative programming mode.

Only complete step 4 if the robot was reset/off when you found it. You can also reset to troubleshoot problems, but remember if you reset the systems you need to repeat steps 1 through 3.

4. **Reset the systems:** In the same menu that you used for all of Step 3, you will find a "Restart" option on the bottom right. If you click this button it will take you to a reset screen. Then you will hit "Advanced…" on the bottom left and restart the following systems in the following order: ***Restart - Restart system - Restart RAPID***.

Preparing the computer

Now that you have the robot ready for use, it is time to prepare the computer for the experiment. The desktop that you will use is located on top of the table next to the YuMi robot.

1. **Log into the system and load up the correct programming interface:** Log into Windows using your VCU account. Note: the proctors will log into their VCU account for each experiment they conduct, the participants VCU account should never be used.

Figure 15. Desktop Controller

Opening the programming language

After using your VCU credentials to log in to the computer; it is time to open the correct programming language interface.

If you don't have a copy of the interfaces under your user, you can create one by following the steps below:

1. Connect to the VCU SafeNet Wireless WiFi;
2. Open the File Explorer;
3. Click on "T7(D:)";
4. Copy the "Duplo" folder to your Desktop.
5. Open the "ABB-OnlineMangage" folder.
6. Locate the file called "RightClickAndClickRunWithPowerShell" and right click on it and select run with PowerShell.
7. Follow the prompts given in PowerShell.

You now have Duplo and RobotStudio Online YuMi on your computer. Before opening the programming language, always connect to the VCU Safenet Wireless WiFi network (Login/Password: Your VCU credentials).

Duplo

Inside the "Duplo" folder, you will find a folder called "app". Inside this folder there will be a Visual Studio file called VCUProject.sln. Open this file inside the Visual Studio and press run to open the Duplo programming prototype. Click on the connect button to start the program. The IP address should be automatically filled in. In case you are using a different IP address, you can find it using Step 3a of the above section.

RobotStudio Online YuMi

After running the file with PowerShell, you can find a copy of RobotStudio Online YuMi by searching in the taskbar. You will open the program and press "Create new Program" to start a new program. The IP address should be automatically filled in, but if you don't know the IP address you can find it using Step 3a of the above section.

During the experiment

The experiment will last exactly 1 hour and 45 minutes, it will be your job to keep track of time and make sure the participant doesn't have more time than allowed. During the experiment your job will be to examine the experience the participants have attempting to program the IRB-14000 robot. It is important to take down every data point without bias and with 100% accuracy. Therefore, try to keep any distractions away while proctoring experiments. To take down data points you will fill out the Google Drive sheet corresponding to the programming interface being used. No other sheet will be edited, each corresponding sheet is automatically calculated based on the data you entered on the "Duplo" or "ORS" spreadsheet. The data gathered will be split into three categories "During the experiment", "After the experiment", and "Questionnaire Data".

During the experiment

During the experiment it will be your responsibility to enter time stamps corresponding to the spreadsheet. Each timestamp should be entered at the **FIRST** observed successful occurrence. Furthermore, it will be your responsibility to enter count occurrences for the following data; *#Program Runs*, *# Objects Dropped*, *# Controller Errors: Motion Supervision,* and *# Controller Errors Predicted Collisions*. Each of these categories you will add to as they occur during the experiment. Lastly, if you notice anything interesting during the experiment you can enter thoughts into the *Details* category at the end of the spreadsheet.

After the experiment

After the experiment it will be your responsibility to evaluate success rates of the participants. To do this there will be two sections that you will enter either a “y” or “n” in. The first of which being the *Evaluate Success (Potential)* category. In this category you will enter a “y” if the participant ever successfully completed the corresponding task. Next, the *Evaluate Success (Overall)* category. In this category you will enter a “y” if at the **END** of their experiment the program they are left with will complete the corresponding task. Lastly, you will take down more count occurrences regarding their programs. Enter the number of times each of the corresponding data sections occur throughout the participants program.

Questionnaire Data

Questionnaire data also will be gathered from the participants while you are gathering the “After the experiment data” and doing your closing duties. The first page of the questionnaire data is to be filled out by the proctor and contain the *Participant Number, Proctors Initials,* and *Programming Prototype used*. The next two pages of the questionnaire are to be filled out **ONLY** by the participant. After the participant has finished filling out the questionnaire you can submit it and start/finish entering data and/or your closing duties.

Click the following link to view the current questionnaire data: shorturl.at/ouNW1
Click the following link to view the current data spreadsheet: shorturl.at/dlzZ1

After the experiment

Once a participant finishes its attempt, it is time to clear the environment and prepare it for the next experiment. This step involves saving the previous participants' program, taking final data points, logging off the computer, and cleaning the environment.

Turning off the computer

Once the experiment is completed and the final data values have been entered. Save the participant's workspace from Duplo or RobotStudio Online YuMi to the corresponding folders inside the“T7(D:)” drive.

To do so in Duplo, click on the “Workspace” dropdown menu on Duplo, and click on the “Save current workspace” button to select the destination folder. Find the T7(D:) drive on “My Computer,” and open the “Duplo Files” folder. Click on the “Save” button to store the participant’s data. **Saving the workspace is crucial for our future analysis, so please always confirm if the participant's workspace was saved correctly.**

To do so in RobotStudio Online Yumi, click on the three lined dropdown menus on top left, and click on the "Save a Yumi Program" button to select the destination folder. Find the T7(D:) drive on "My Computer," and open the "ORS Files" folder. Click on the "Save" button to store the participant's data. **Saving the workspace is crucial for our future analysis, so please always confirm if the participant's workspace was saved correctly.**

Now you can turn off the computer after verifying that all data points have been entered into the google spreadsheet and that the participants programming file has been saved into the T7(D:) drive.

Cleaning the environment

Return the pieces to their initial positions and ensure that everything is in order for the next participant. Contact a superior immediately if something compromises the following experiment (e.g., grippers or pieces are broken or missing), and feel free to leave once you are done with this task.

Common issues

Not able to log into your credentials on the controller.
If you are not able to log into your credentials at the controller please make sure you are connected to the VCU Safenet Wireless network. If you are not connected to the VCU Safenet Wireless network then your domain is not available for connection.

The robot arms are not moving.
This error might happen before or during the experiment, check to make sure that the IRB-14000 has "Lead through mode" enabled. See step 3d from the "Turning on the Robot" section of this guide. Also ensure that the emergency stop on the flex pendant is not engaged.

If there are any issues that you do not understand, stop immediately and contact your superior to assist you.