ECSE211 Lab 2 – Inputs, Outputs, Testing

Report Due: February 8^{th} 2023, 11:59PM

Objectives

By now, you should have finished Lab 1 and have selected an idea for your mini project. With the system level design from the previous lab, you should also have a clear idea of the inputs (sensors/motors) and outputs (sound) involved in your design. The objectives of this lab are to:

- Give you a hands-on experience in working with the DPM kit, your main design material.
- Help you understand the characteristics of the different sensors you have available as input devices.
- Help you understand how to design and conduct tests.

You can compare this lab to the Research & Development phase of an engineering project; after generating requirements and preliminary designs, tests must be conducted to evaluate the feasibility of the design.

Grade Breakdown

- Demonstration to the TA: 40%
- Code quality and functionality: 10%
- Lab Report: 50%

Resources

You will need the following items from each DPM kit:

- The BrickPi
- A touch sensor
- An ultrasonic sensor
- A color sensor
- Sensor cables
- Speaker or headphones with an AUX jack cable

A set of colored foam cubes should have been distributed to you by a TA. If you do not have a set of foam cubes, ask a TA during one of your lab slots.

You will also need a computer for the programming component of the lab. Alternatively, you may use the monitors available in the DPM lab and write your code directly on the BrickPi.

Group Work

You will need both DPM kits for this lab. Divide your team into two sub-groups of 3 members (teams of 5 may divide into 2 and 3 members), with each sub-group taking charge of one DPM kit. Each subgroup should complete the lab to test all three types of sensors as instructed below, such that you can compare the results and performance of the same sensors in the two different DPM kits afterwards. Each member should do some testing, and everyone should understand the Lab.

1. Contextualizing the Lab
    a. Identify the inputs and outputs of your selected design from Lab 1.
    b. Agree on how you will work together as a team to complete this lab (feel free to refer to your team expectations contract from Lab 1 if you've discussed this issue in the contract already).
    c. Decide on how you will differentiate/refer to the same sensors from two different kits.
    d. While you work on the rest of this lab, document how long it takes for you to complete each task involved. Some tasks will be done together as a group (e.g., group meeting), while other tasks may be done in parallel by different members of the group (e.g., writing the report). Therefore, **each member should keep track of their own task completion time**.

2. Implementation and Testing

In this lab, you will test each of the following set of sensors: button, ultrasonic sensor, and color sensor. Considering how they might be used for the mini project; you will design tests that will help you identify the capabilities and limitations of each sensor. Below are pre-designed procedures to test the capabilities and limitations of the touch sensor, the ultrasonic sensor, and the color sensor. Some of the test Python code is missing. Complete the design of the test code, then conduct the tests as per the procedures.

Starter Code

Starter code will be provided on myCourses. Within this starter code, there are detailed technical instructions on how to use it. These instructions are stored in the **README.md** and **flexible-setup.md** files. The starter code is located in the **project/** folder of the provided .zip file.

For this lab, you will need the 3 following files:

- **speaker_button.py**
- **collect_us_sensor_data.py**
- **collect_color_sensor_data.py**

Some of them will require modifications.

You are allowed to add your own modules, classes, and functions, but you cannot change the submission structure (i.e., you must keep the original structure of the code). You are also free to use anything in the standard library, any library provided in the BrickPi or in the starter code.

If you wish to use an additional external library, you must obtain permission from a TA and indicate that this permission was granted in the code.

Sensor Testing

A. Touch Sensor Sampling

<u>TEST 0: EQUIPMENT TESTING</u>

Connect the speaker's 3.5mm AUX jack to the audio port of the BrickPi. Run the **speaker_button.py** script (from the starter code) and confirm that a beeping sound can be heard. Keep the speaker connected to the BrickPi for the remainder of the lab.

<u>TEST 1: SPEAKER BUTTON TEST</u>

Implement a function that plays a sound when the button (touch sensor) is pressed. In the file **speaker_button.py**, implement the function **play_sound_on_button_press()** that will sample the touch sensor and play a sound when it is pressed.

The code should contain:

1- A *while* loop that continuously samples the touch sensor.
2- An *if* statement that checks for the touch sensor status.
   Hint: *You can get the status of the touch sensor by calling "**TOUCH_SENSOR.is_pressed()**", which should return a boolean.*
3- A call to **play_sound()** if conditions are met.

You will demonstrate the functionality of the **speaker_button.py** program during your demo with a TA.

B. Ultrasonic Sensor Sampling

This section provides guidelines to test the accuracy of the ultrasonic sensor when sampling at a fixed rate.

For this test, we will move the robot along a parallel surface and observe the data collected by the US sensor. Keep in mind that, assuming you are moving the robot at a perfectly constant distance from the surface, the value measured should be constant (this probably won't happen… think about why).

TEST 2: ULTRASONIC SENSOR SAMPLING

Follow these steps to conduct the test:

1. Connect the Touch Sensor to port S1 and the Ultrasonic Sensor to port S2
   a. Ensure the Ultrasonic Sensor is firmly attached to the robot.
   b. The Touch Sensor may be held freely in one hand while you perform this test
   c. You may use either battery or wired connection to power the robot
2. Run the function **collect_continuous_us_data()** on the robot (**project/collect_us_sensor_data.py**)
   a. Place the robot along a surface that is parallel to another e.g., in a hallway or a box.
   b. Press the attached Touch Sensor once, then slide the robot along the surface while trying to keep the distance to the surface constant.
   c. Keep sliding the robot for a distance of at least 60cm. Then, press the touch sensor again to stop saving data to the file (see figure 1; the blue line should be at least 60cm long).

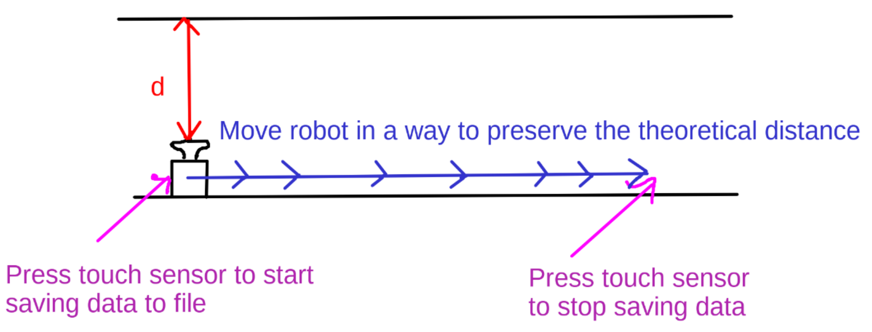

Figure 1: Bird's eye view of the robot's trajectory for the US sampling test

3. The data will be saved automatically in the **lab2/data_analysis/us_sensor.csv** file in your project.
4. Generate the graph resulting from the .csv file using the guidelines provided in Appendix I.

You will need the .csv file and the generated graphs for the report – keep them handy!

C. Color Sensor Sampling

In this part, you will implement a discrete color sampler using the touch sensor. In the **collect_color_sensor_data.py** file, complete the **collect_color_sensor_data()** function such that when the touch sensor is pressed *once*, the program reads and prints the RGB values from the color sensor *once*, then writes the values to a file. <u>The number of measurements should be equal to the number of touch sensor presses.</u>

The code should contain:

1- A statement to open the output file (refer to **collect_us_sensor_data.py** for an example).
2- A *while* loop that continuously samples the color sensor.
3- An *if* statement that checks for the touch sensor status.
4- An action to write the color sensor reading to the output file when conditions are met.

You will use this function to collect data from the color sensor and generate the RGB Gaussian Distributions of three different colored foam cubes.

<u>TEST 3: COLOR SENSOR SAMPLING</u>

1. Pick a colored foam cube and position it very close to the color sensor input (about 5mm from it).
2. Run the script **collect_color_sensor_data.py**
3. Press the touch sensor and make sure that it collects only one RGB Data point.
4. Use the touch sensor to collect at least 10 data points from the colored cube.
5. The data should be saved automatically in the **lab2/data_analysis/color_sensor.csv** file in your project. Verify that this is the case.
6. Generate the graph resulting from the .csv file using the guidelines provided in Appendix I. You should obtain 1 graph for each cube sampled, and each graph should contain 3 bell curves.
7. Repeat steps 1-6 with 2 other foam cubes of different colors.

The distribution generated by the graphing tool represents the profile of a real-world color. There are 3 Gaussian Bell Curves, one for each color Red, Green, and Blue. If an RGB value collected from the color sensor has its R value, G value, and B value fit underneath or on each of these 3 bell curves, then the collected RGB value matches this color.

Note: At the end of this section, you will know the "standard" RGB values of 3 different colored cubes. When you sample the RGB values of a cube of unknown color, you can try to match the sample values with the colors you know the values for. Then, if you find a color whose set of values is close enough to your unknown color, you can assume that the block is of that color.

Part 3: Design Iteration

1. Revisit the design idea your group selected in Lab 1 and its system specifications. Discuss the feasibility of the idea based on the results of your tests (tests reveal any new constraints, such as sensor noise).
2. Come up with at least one new idea for your system to address the design problem. You are welcome to come up with more. You will be asked to write those ideas in your report.

Submission and Evaluation

Demonstration to the TA (30 points)

You will need to demonstrate your work to a TA during one of your team member's lab slots. Teams of 6 should have 5+ students present, while teams of 5 should have 4+ students present.

The demonstration must be completed by Friday, February 10th, to accommodate for your team's schedules. However, the lab code and repost must be submitted by the deadline, regardless of your demo date.

During the demo, your TA will ask you questions about your testing procedures and group work together. And each sub-group needs to demonstrate the followings:

1. Demonstrate that the speaker plays a sound when you press the attached touch sensor. (5 points)
2. Demonstrate your testing procedure for collecting Ultrasonic Sensor data. (5 points)
3. Demonstrate your testing procedure for collecting Color Sensor data. (5 points)
4. Show your TA the data that you have collected and answer questions on what it means. (15 points)

Code Submission (7 points)

You should submit the entire source code folder in a .zip file on myCourses. You will be evaluated on code functionality, style, and documentation.

Lab Report (63 points)

Section 0: Group Identification (3 points)

- Identify the division of the team into sub-groups (list the names of its members) and which kit was assigned to each sub-group.
- Describe the nomenclature used to identify the same sensors from the two different DPM kits. (e.g., TS-05 refers to touch sensor in DPM kit 05, TS-11 refers to the touch sensor in DPM kit 11).

Section 1: Test Data (20 points)

In this section, you will run tests and report test results for the sensors explored above **for Each Sub-Group**.

A. **Touch Sensor (TEST 1)**

   To include in the report:

   a. **Sub-group 1:** Report qualitative results on the efficiency of the touch sensor based on the results of Test 1.

   b. **Sub-group 2:** Report qualitative results on the efficiency of the touch sensor based on the results of Test 1.

   c. Highlight any differences observed between the performance of the two different touch sensors.

   d. Which sensor will you use (between the two sub-group sensors) for the remainder of the projects?

B. Ultrasonic Sensor (TEST 2)

Perform the test procedure described in the Group Work – Ultrasonic Sensor section of this handout **for distances of 10cm, 20cm and 30cm** and present a table containing the following data:

- Minimum value recorded by the US Sensor
- Maximum value recorded by the US sensor
- Mean of the recorded values
- Standard deviation of the recorded values

In addition, provide the graphs generated by the graphing tool.

Your table should contain three rows of data and you will have three graphs to present from each sub-group.

To include in the report:

a. **Sub-group 1:** Provide a table as described above to report quantitative results on the efficiency of the ultrasonic sensor based on the results of Test 2.

b. **Sub-group 2:** Provide a table as described above to report quantitative results on the efficiency of the ultrasonic sensor based on the results of Test 2.

c. Highlight any differences observed between the performance of the two different ultrasonic sensors.

d. Which sensor will you use (between the two sub-group sensors) for the remainder of the projects?

C. Color Sensor (TEST 3)

Perform the test procedure described in the Group Work – Color Sensor section of this handout **for three different colors (including at least a red cube)** and present a table containing the following data:

- Mean and standard deviation of the R values recorded by the sensor
- Mean and standard deviation of the G values recorded by the sensor
- Mean and standard deviation of the B values recorded by the sensor

In addition, provide the graphs generated by the graphing tool for each sub-group.

Your table should contain three rows of data and you will have three graphs to present.

To include in the report:

a. **Sub-group 1:** Provide a table as described above to report quantitative results on the efficiency of the color sensor based on the results of Test 3.

b. **Sub-group 2:** Provide a table as described above to report quantitative results on the efficiency of the color sensor based on the results of Test 3.

c. Highlight any differences observed between the test procedures used by the two sub-groups and any performance differences between the two color sensors.

d. Which sensor will you use (between the two sub-group sensors) for the remainder of the projects?

e. **Write up a full test procedure for the color sensor test** by filling out the Test Procedure Template (attached to this assignment, with a pre-filled example). **(5 points from the Test Data section)**

*Note: for **task c**. of each section (comparison), the description should include your thoughts about the discrepancies, why they might have occurred, and what are you planning to do about it.*

During this process, you should identify the components that you are going to use for your project and mark them. Do not use any permanent ink on the components, rather put crafting tape on the components and write using a pencil or a marker on the tape.

Section 2: Discussion (25 points)

*Answer the following questions in separate paragraphs. Include the questions in your report. **This section should be maximum 3 pages long, excluding figures**.*

*This section should be completed **only once** by the whole group.*

A. Touch Sensor

- What are the capabilities and limitations of the touch sensor in the DPM kit?

B. Ultrasonic Sensor

- What is the sampling frequency of the US sensor used in this lab?
- From the graphs generated in the Test Data, how would you describe the accuracy of the sensor? Clearly explain what makes you draw this conclusion.
- Does the amount of noise change as the distance to the wall changes? If so, explain how.
- Can a noisy sensor impact the performance of a design? Why or why not?
- Can there be any extreme situation where the sensor data might get interrupted? Think of an example and discuss how you would handle the situation.

C. Color Sensor

C1. Questions

- Look at the graphs generated by the graphing tool. What does the position of the Gaussian curves represent for the RGB value? Explain why the graph generated with a red cube has curves so far from each other.
- From the graphs generated in the Test Data, how would you describe the accuracy of the sensor? Clearly explain what makes you draw this conclusion.
- Are there colors for which the sensor was particularly accurate? State which ones and formulate a hypothesis as to why.
- Are there colors for which the sensor was not accurate at all? State which ones and formulate a hypothesis as to why.

C2. Color Detection Algorithm

Using the results obtained from the color sensor testing, **design a color classification algorithm** to determine the color of a cube based on its RGB values. In other words, give a detailed description of how you would detect and differentiate colors using the color sensor.

Your answer to this question should be **a list of steps** your algorithm would have. You do not have to write the Python code for the function; simply tell us how you would approach the problem.

Section 3: Design Iteration (7 points)

For each question in this section, provide answers in the form of a paragraph (no bullet-point lists).
***This section should be maximum 1 page long, excluding figures*.**

1. Initial Design Description:
   - Briefly describe the system you had selected in Lab 1.
   - Now that you have more concrete ideas (e.g., quantitative measurements) about the capabilities and limitations of the input devices, re-write the specifications for each component of your system.
2. Feasibility: Referring to the results of the tests you've conducted, and the specifications you've outlined, describe whether your initial idea is feasible as it was originally envisioned in Lab 1.
3. Design Selection:
   - Has your decision changed to modify your initial idea, or to follow the new design idea?
   - How did the tests help make the decision for your group?
   - Provide a conclusion on which idea you will pursue to implement in the next two weeks.

Section 4: Team Reflection (8 points)

1. Timesheet: Provide a summary of how long it took each member of the group to do different tasks involved in this lab. This can be presented as a table or a figure.
2. Time Management: Describe whether members of the group are satisfied with the time it took for each type of task to be completed by the group. If not, outline how the team will do things differently in the subsequent labs. Did one sub-group finish the same task faster/slower than the other sub-group? What made the difference?
3. Challenges: List technical, organizational or interpersonal challenges you faced while completing the lab (e.g., scheduling, setting up the Brick, etc.)

Appendix I: Creating Graphs for your Project Report

This guide will help you generate the graphs required for your lab reports.

1. **Create the CSV files**

   You create the csv files as part of your lab when you run your experiment. Running the experiment should create the csv files: `color_sensor.csv` and `us_sensor.csv` on your robot.

2. **Copy data to computer**

   You must first copy the `color_sensor.csv` and `us_sensor.csv` from the `data_analysis/` folder on your robot to the same folder, `data_analysis/` on your computer.

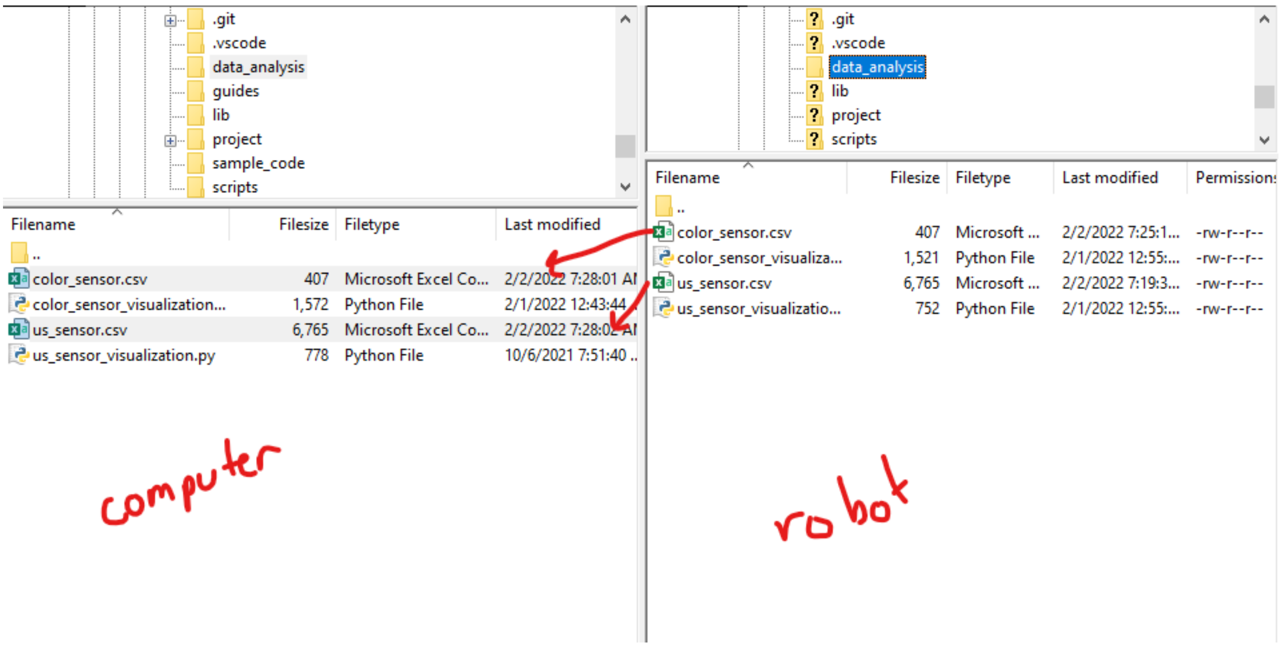

Figure 1: transferring the files using FileZilla

3. **Start Graphing Program**

   Inside the `data_analysis/` folder are two Python scripts:
   - `color_sensor_visualization.py`
   - `us_sensor_visualizaiton.py`

   Make sure matplotlib is installed on your computer by typing the following command in a terminal (command prompt):

   - `python3 -m pip install matplotlib`

Then, run these 2 Python scripts (only one at a time):

```
-   python3 color_sensor_visualization.py
-   python3 us_sensor_visualizaiton.py
```

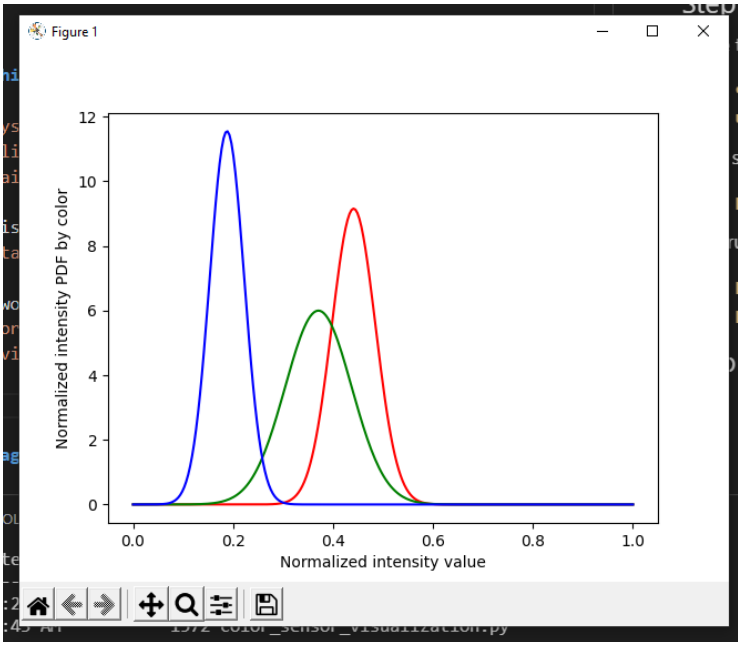

Figure 2: image of the graphing program

4. Save the graph as an image

With the graphing program open, press the "save" button circled in the image below. ***Do not take a screenshot of the image!***

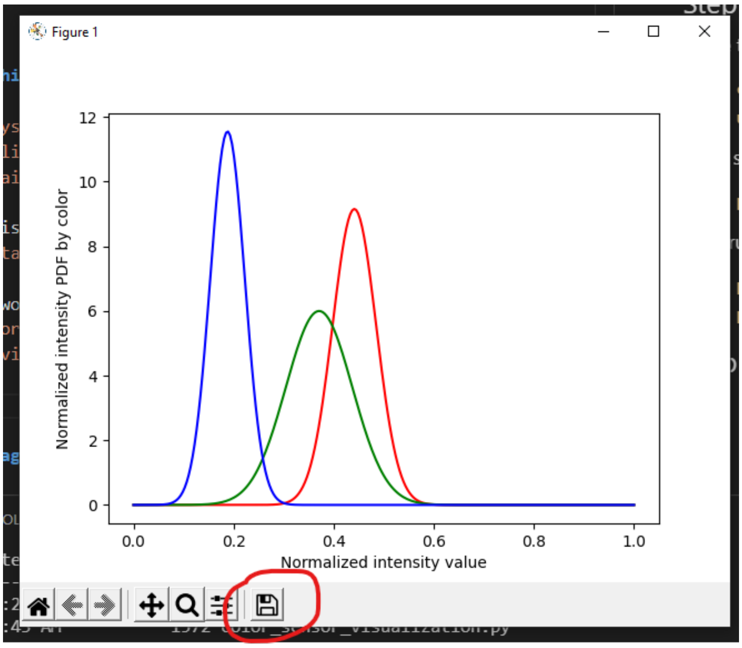

Figure 3: click the save image button circled in red

The resulting saved image should be as follows:

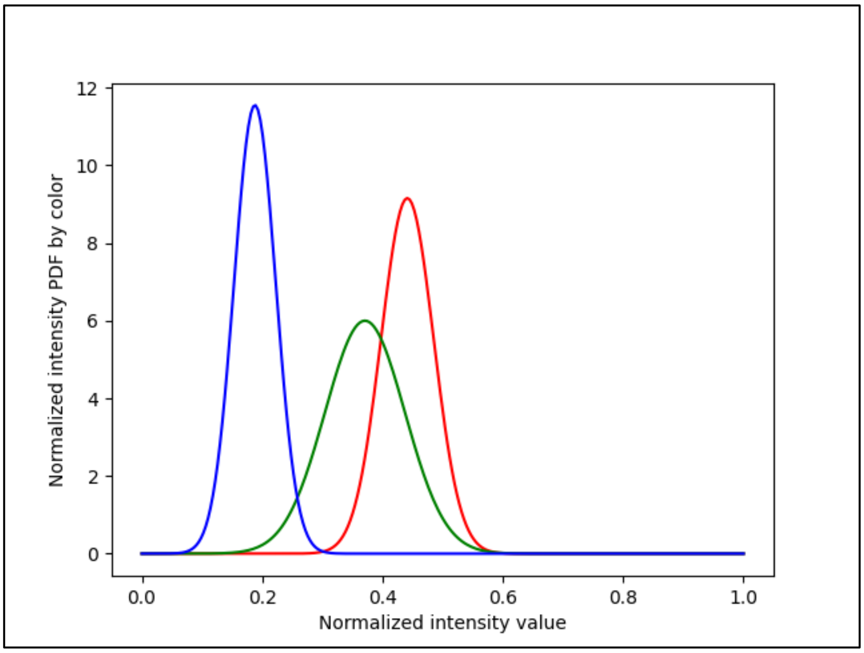

Figure 4: saved image from graphing window

5. Do not submit blurry graphs