# Lab 04 Behavior-Based and Hybrid Control Worksheet

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## Part I – Photoresistor test

Complete the following photoresistor data tables.

Table 1: Environment Data

|  |  |  |
| --- | --- | --- |
| Conditions | Left Photoresistor (V) | Right Photoresistor (V) |
| Ambient light on the table | 960 | 960 |
| Ambient light under the table | 730 | 716 |
| Sensor covered | 159 | 95 |
| In front of a flashlight or cell phone light | 1020 | 1021 |

Table 2: Distance and Angle of Incidence Data

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Left Photoresistor (V) | | | Right Photoresistor (V) | | |
| Environment | Distance  (in) | Angle of Incidence  -45° | Angle of Incidence  0° | Angle of Incidence  45° | Angle of Incidence  -45° | Angle of Incidence  0° | Angle of Incidence  45° |
| On the table | 6 | 950 | 962 | 980 | 968 | 968 | 960 |
| On the table | 12 | 954 | 960 | 964 | 964 | 964 | 960 |
| On the table | 18 | 952 | 966 | 954 | 960 | 962 | 960 |
| On the table | 24 | 952 | 964 | 953 | 954 | 962 | 952 |
| On the table | 30 | 952 | 960 | 952 | 953 | 960 | 953 |
| Under the table | 6 | 856 | 948 | 960 | 954 | 888 | 838 |
| Under the table | 12 | 848 | 964 | 854 | 928 | 940 | 840 |
| Under the table | 18 | 832 | 932 | 838 | 845 | 910 | 838 |
| Under the table | 24 | 836 | 912 | 825 | 832 | 910 | 832 |
| Under the table | 30 | 816 | 884 | 820 | 816 | 888 | 822 |

1. How reliable was the photoresistor at detecting the light in different environments, various distances, and angles of incidence (head on, slightly left, slight right)?

The light was not very effective at detecting the light in bright environments, and when the light source was far away. The angle of incidence also affected the sensor readings, with the angle predictably changing the sensor readings to be greater on the side which the light source was on.

1. How significant was the difference in photoresistor voltages for the left and right sides? How did you use this difference to extract directional information to move the robot toward the beacon?

The difference between the photoresistor voltages depends on the proximity to the light source, and the angle of the light source. This difference was used to extract directional information by having the voltage difference determine the turn direction. Whatever side the voltage from the sensor is lower, should turn faster to move towards the light.

1. How reliable was the photoresistor at detecting the light at various angles and distances? Compare and contrast sensor data.

The photoresistor was very reliable at detecting light at various angles and distances, especially when in a dark environment. This can be seen by the large variance of voltage values when data was taken underneath the table.

1. How significant was the difference in sensor data based upon distance from the source? How did you use this difference to extract distance information to move the robot toward the beacon?

There was about a 100 difference in the analog read values between 6in to 30in away. This was used to move the robot towards the beacon by having the robot move faster the farther away the light source was.

## Part II - Reactive Control

### Excitatory Behavior & Cross Excitatory Behavior

How does the robot behave when (a) the light source is directly in front of the robot, (b) the light source is to one side of the robot? Is there anything about the robot’s behavior that surprises you? ***Answer this question in the lab worksheet.***

***a) If it's Fear, the robot goes faster, but turns away from the light source. If it’s love, the robot goes faster towards the light.***

***b) If it’s Fear the motor closest to the light increases in speed to quickly turn away from the light. If it’s love, the motor opposite to the light increases in speed to quickly turn towards the light.***

### Inhibitory Behavior & Cross Inhibitory Behavior

How does the robot behave when (a) the light source is directly in front of the robot, (b) the light source is to one side of the robot? Is there anything about the robot’s behavior that surprises you? ***Answer this question in the lab worksheet.***

1. ***If it’s Explorer, the robot slows the motor furthest from the light source and the robot turns away from the light. If it’s Aggressive, the robot slows down the motor closest to the light source so the robot turns and slowly approaches the light.***
2. ***If it’s Explorer, the robot will turn directly away from the light source by slowing the opposite motor. If it’s Aggressive, it will turn towards the source by slowing the closest motor.***

### Light Sensing Behaviors

Match the four light sensing behaviors with inhibitory, excitatory, cross inhibitory, cross excitatory.

Fear Excitatory

Aggression Inhibitory

Love Cross Excitatory

Explorer Cross Inhibitory

### Photoresistor Mounting Position

How did you decide on the position of the photoresistors? Were there certain lighting conditions that were more difficult or easier for the robot to sense?

Since we drive the robot backwards, we put them on the back of the robot. The robot performed much better in a dark environment than a light one.

## Part III - Obstacle Avoidance

Describe how you implemented obstacle avoidance with light tracking.

Obstacle avoidance with light tracking was implemented by utilizing the love behavior to track the light, and having the robot entire avoid behavior when the lidar sensors detect and object too close to the robot.

How did you integrate the light sensors into the obstacle avoidance behavior?

We used subsumption architecture and used the light sensing excitatory/inhibitory behaviors as a final layer on top of the wall following / state machine layer. This means both behaviors are always active simultaneously.

## Part IV – Homing or Docking

Nothing to report here.

## Part V – Docking the Robot and Return to the Wall

1. What does the hybrid control architecture for your design look like? What was on the planning layer? Middle layer? Reactive layer?

The planning layer contained flags keeping track of what step it was in the docking processes. The Reactive Layer contained the “Love” behavior, where it drove towards and stopped at the light, and the middle layer was a state machine that moved between different wall following and movement states.

1. What was your general strategy for planning the path back to the wall from the beacon?

Turn around and go until we reach the wall, then turn to be parallel with the wall and continue wall following.

1. How did the architecture respond to differences in robot start position or beacon location?

Assuming the beacon is close enough to the robot to detect it, it accounts for regular positional changes. It also keeps track of which wall it was initially following, so it can be run starting from either direction.

1. How did the robot’s hybrid controller respond to dynamic changes in the environment (i.e., other robots and people) and compare this to purely deliberative control?

Deliberative control cannot react to changes in the environment. Our hybrid controller is constantly polling the sensors, so that despite not having a world model, it can still complete tasks with

1. Were there any challenges in implementing the homing routine?

Finding the right sensor threshold for the ambient light in the room was the most difficult part. Each time we changed the value we’d have to wait multiple minutes for compilation.

1. What could you do to improve the robot homing?

Turn off the lights and increase sensor sensitivity. This would allow the robot to home at further destinations and identify them earlier.

1. How did docking the robot modify the control architecture or algorithm?

We had to create a planning state which controlled returning to the wall after it homed as well as preventing it from getting distracted by the homing block when it drove past it later. Aside from the inhibitory layer, the middle layer also had extra states for docking and homing.

## Conclusions

Respond to the following questions.

1. How reliable was the photoresistor at detecting the light in different environments, various distances, and angles of incidence (head on, slightly left, slight right)?

The photoresistor was not reliable at detecting light in bright environments but was reliable in dark environments. The photoresistor could effective detect different distance that the light was from the sensor, as well as detecting angle of incidences.

1. How significant was the difference in photoresistor voltages for the left and right sides? How did you use this difference to extract directional information to move the robot toward the beacon?

The difference was significant depending on how far it was turned away from the light. Using the basic love behavior, the robot reactively turned in proportion to the difference between the left and right sensors.

1. How did you integrate the light sensors into the obstacle avoidance behavior?

The light sensors were utilized as beacon tracking for obstacle avoidance behavior. These sensors are what drove the robot to the light source. A state machine was utilized to determine if the robot would light follow or avoid.

1. How reliable was the photoresistor at detecting the light at various angles and distances? Compare and contrast sensor data.

The photoresistor was very reliable at detecting light at various angles and distances, especially when in a dark environment. This can be seen by the large variance of voltage values when data was taken underneath the table.

1. How significant was the difference in sensor data based upon distance from the source? How did you use this difference to extract distance information to move the robot toward the beacon?

The light values quickly trailed off with distance (which makes sense due to the inverse square law), which meant our beacon had to be close to the robot for it to be seen, especially with the ambient light in the room.

1. What does the hybrid control architecture for your design look like? What was on the planning layer? Middle layer? Reactive layer?

Planning layer -> flags for making sure that once the robot homes, it docks, and stays on the wall after.

Middle layer -> contains the main state machine of what “task” it is currently on. (Wall following, homing, docking, etc.)

Reactive layer -> contains the basic light seeking behavior “love”. It’s turned on/off by the middle and planning layer.

1. What was your general strategy for planning the path back to the wall from the beacon?

Once we home, we turn 180 degrees and drive straight back to the wall.

1. How did the architecture respond to differences in robot start position or beacon location?
2. How did the robot’s hybrid controller respond to dynamic changes in the environment (i.e., other robots and people) and compare this to purely deliberative control?
3. Were there any challenges in implementing the homing routine?
4. What could you do to improve the robot homing?
5. How did docking the robot modify the control architecture or algorithm?
6. What did you learn? What did you observe? What could you improve?

I learned that light sensors require a dark environment to operate effectively and each trial there are different light levels that could effect operation. I observed that I needed to set a proper light level that would trigger the love behavior when doing the homing and docking behaviors. This could be improved by, instead of setting a light level, running a light calibration before each trial.

## Appendix

Attach properly commented, modular, cleaned up code here.