Sea Slug Simulator
Design Document

ECE 445 Project #55

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1. Introduction

1.1 Objective

Our interdisciplinary group of engineering and biology researchers would like to have a prototype controller with the ability to collect and process sensor inputs and generate control outputs for a robot platform that can run a simulated nervous system simulation[1]. The long-term goal is to create a physical model of sea slug and simulate its motivations from perception and interaction with its environment, predators and prey.

In order to develop such a platform, we would utilize an iRobot Create (Roomba robot) as the mobile robot platform to simulate the Sea Slug, a Microcontroller(Arduino) as interfaces to sensors for exploring an environment and controlling the robot, a sensor circuit for mimicking the functioning of the sea slug olfactory sensor, and we also need to setup an environment for testing and presenting the robot. In order to simulate the health state of the sea slug, we use 4 LED bar graphs connected together to represent the HP (health points) of the robot. In addition to health points, the robot uses another group of 4 LED bar graphs to represent the satiety level in order to indicate the level of satiety of the simulated sea slug. The internal algorithm of the robot will simulate the behavior and decision of an actual sea slug under complex natural environments based on both HP points and the satiety level.

1.2 Background

Oceanographers have been interested in various creatures in the ocean and have conducted research on the behaviors of these creatures. The study results of the natural behaviour and habitat of oceanic creatures such as the sea slug will provide invaluable information for study in water pollution, environmental protection and animal protection. Monitoring the behaviour of real sea slugs electronically using robots will provide precious opportunities for researchers to observe and study the sea slugs while not having to capture real sea slugs in the wild and potentially destroy their natural habitats. Besides research potentials, the robotic sea slug can also serve as an educational tool to show the general public how amazing, alert and fantastic a sea slug is, and raise people’s awareness about environmental and animal protection. Moreover, we hope to use the sea slug simulator as a predecessor to use robots to simulate the behaviour of either domestic or wild animals.

1.3 Visual Aid

1.4 High-level requirements

- The robot must change its directions before hitting the wall of the testing environment
- The robot must have the correct health percentage(HP) and satiation percentage(SP) display.
- The robot must avoid the zone of predator through the radio communication module.

2. Design

The entire system consists of 5 sub-systems: Robot Chassis, Power supply, Microcontroller, Sensors, and Testing Environment.

We use iRobot Create robot as our chassis and platform. The iRobot is powered by its own rechargeable battery. The rest of the system is powered by a 12 V battery, which will be adjusted to fit the requirements of each circuit components by utilizing voltage regulators. Each "predator" circuit is powered by an external 9V battery.

The Microcontroller will receive data collected by ultrasonic and color sensors, as well as the radio signal from the sea slug's "predator". It then runs the algorithm that processes the incoming data to guide the movement and behavior of the robot. The ultrasonic sensor will detect the obstacles ahead, and based on the distance to the obstacle, the speed of the two wheels of the robot will be adjusted to avoid hitting them. The RF receiver on the robot will pick up the RF signal emitted by predators who are equipped with a RF transmitter. The color sensor is used to differentiate the type of the food, and whether the robot is close with the predators.

The robot also equips two LED bar graph sets to indicate the current HP and satiety level of the robot. The testing environment is a physical playground we would setup to test and demonstrate the robot. We would use different objects and colors to represent food and predators in the testing field.

2.1 Block Diagram

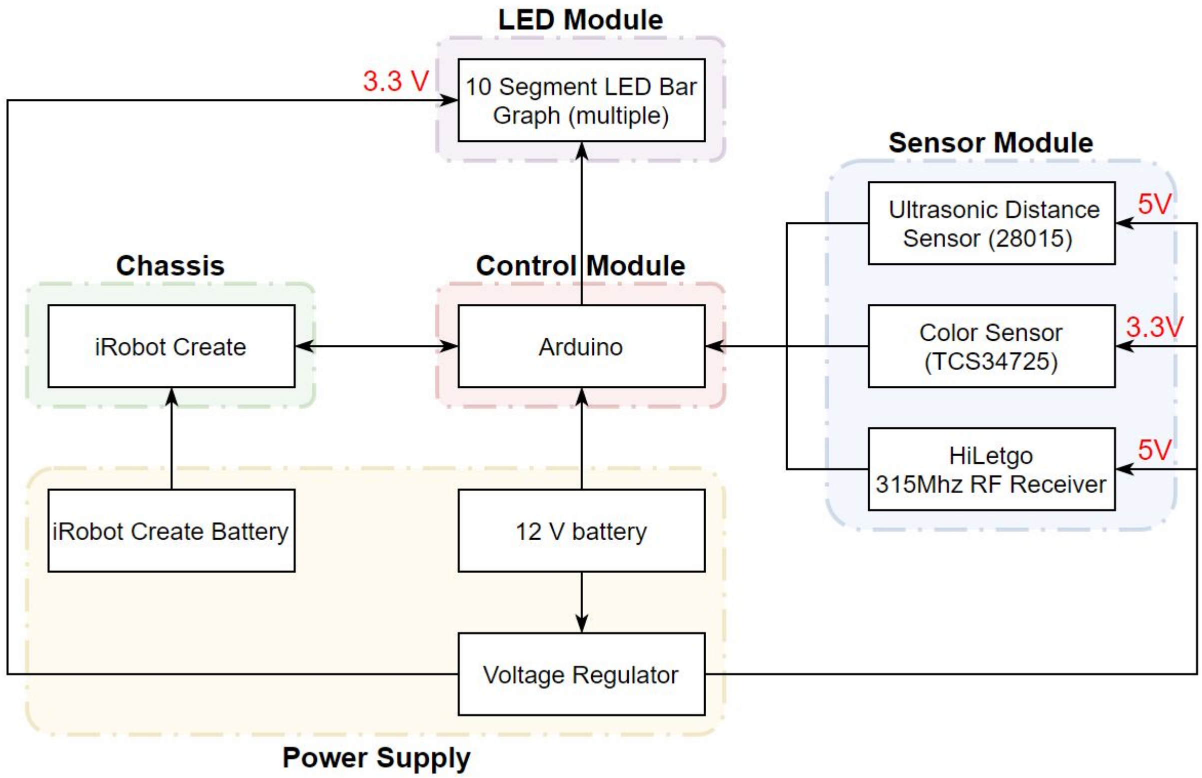


Fig.1 Block Diagram of robot system

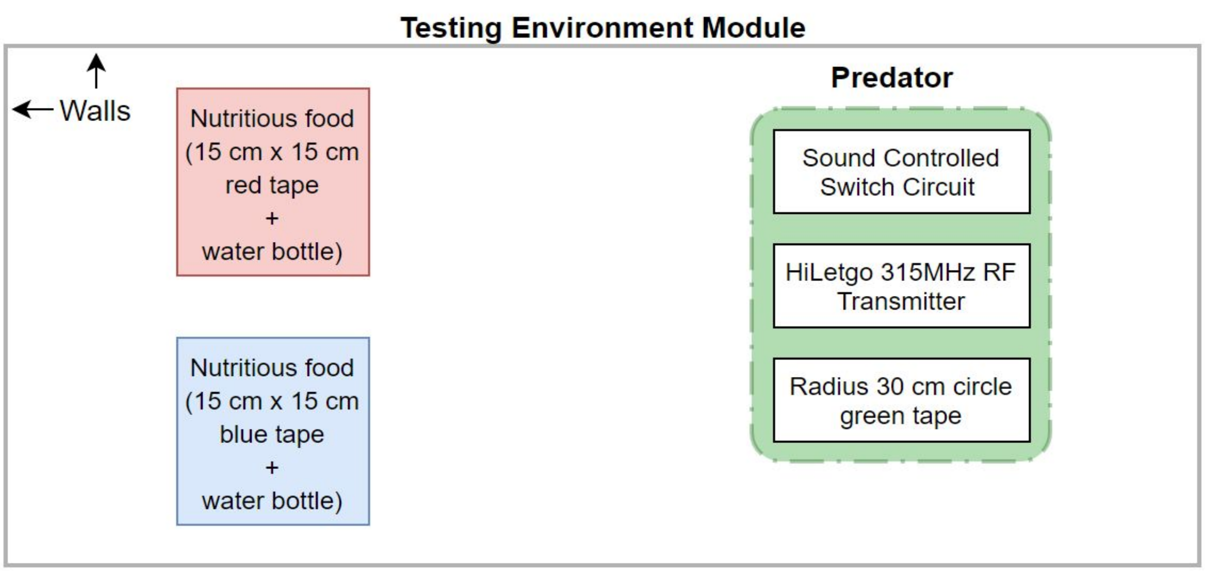


Fig.2 Block Diagram of the testing environment

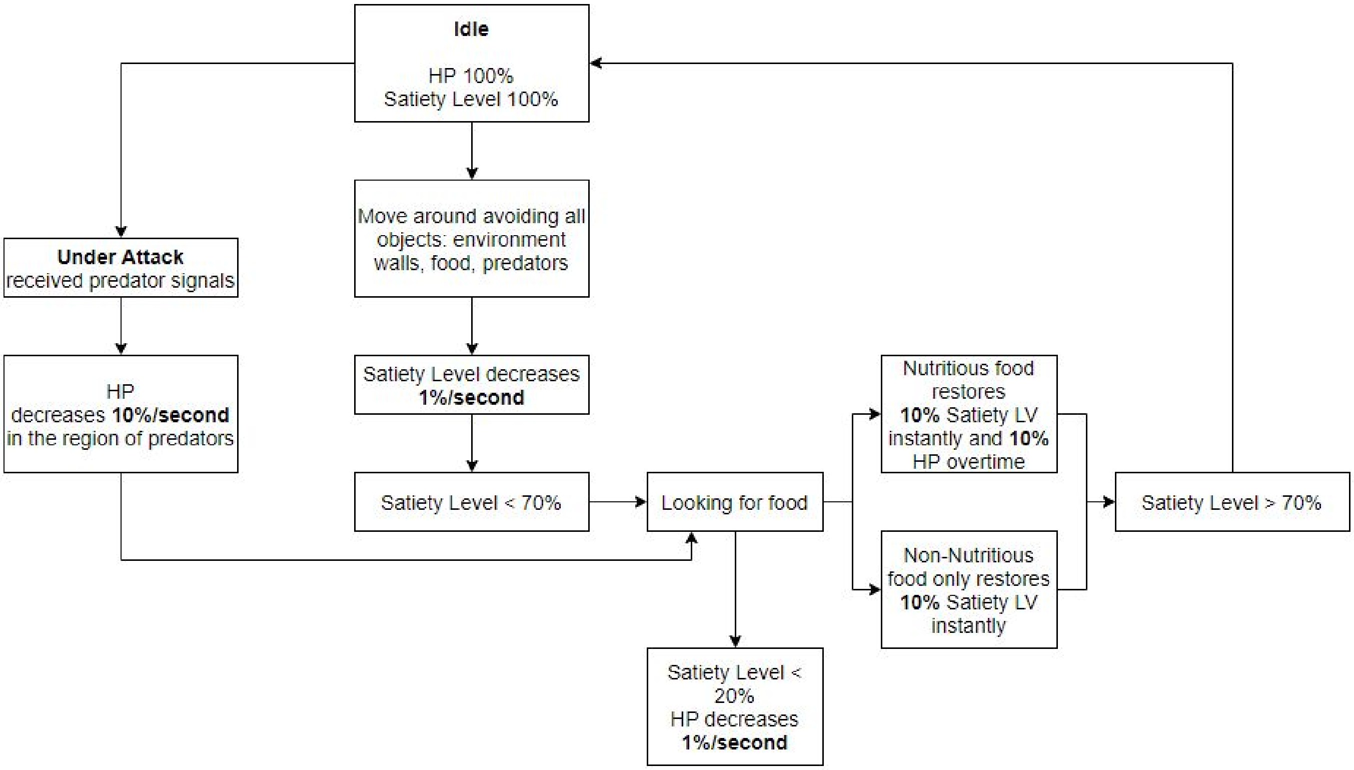
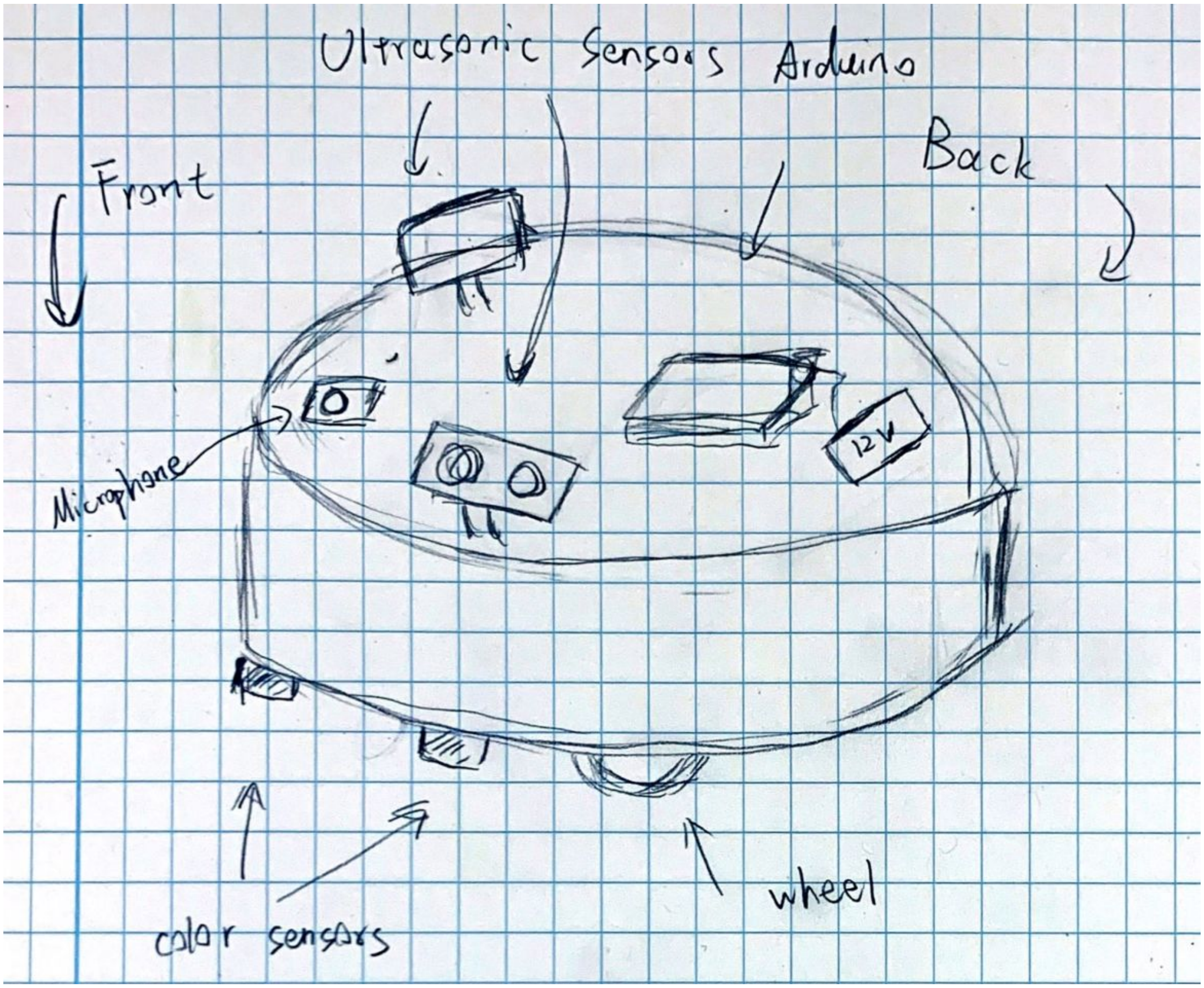


Fig.3 Entire System flow chart

2.2 Physical Design



2.3 Control Module

2.3.1 Microcontroller

Arduino is used as the microcontroller of the system. It calculates the HP and satiety level of the robot based on its interaction with the environment and makes necessary actions to stay alive when needed.

The robot ’s satiety level drops at a steady rate when there is no food intake. When the robot consumes food, its satiety level value increases by a fixed amount. If its satiety level is lower than a certain threshold value, its HP would also start to decrease due to hunger. Also, its HP drops by a large amount when it comes in contact with predators. Eating food will increase the satiety level, and if satiety level is above the threshold value, HP will be restored.

The robot has random movement as its default state of motion, provided that its satiety level and HP are above a threshold value. By moving randomly, the robot will avoid all kinds of objects including its food and predators.

When the satiety level of the robot falls below the threshold value, it prioritizes finding food. After investigating the food, the robot will depart in the opposite direction so that it will not be picking up the same food in a short period of time. Finally, when it is in close proximity with its predators, it prioritizes escaping over everything else.

The controller module makes decisions based on input data from sensors that are used to detect distance, the presence of food and predators. From the data collected by ultrasonic sensor, the microcontroller determines when to slow down and when to turn to avoid obstacles in the environment. The most critical part of the microcontroller is to connect to the iRobot Create chassis, it will determine when to slow down the speed of one wheel to turn, and when to slow down to pass some narrow path. It also determines whether the object is a food, which kind of food based on the data from color sensor. The audio data collected from the microphone will let the microcontroller determine if there are predators nearby, and if there are, which direction to escape. The microcontroller is also connected to the two LED bar graph sets that act as a display of HP and satiety level.

Requirements	Verification
1. Able to connect to and control the iRobot Create Chassis 2. Able to obtain reliable data from ultrasonic distance sensor 3. Able to obtain reliable data from color sensor 4. Able to obtain reliable data from microphone 5. Able to send correct signals out based on the data collected from sensors	1. Write a sample testing program to see if the microcontroller can make the iRobot do some simple movements like moving straight. Make sure the microcontroller can communicate with the iRobot before we attach any sensors to the chassis. 2. Connect the microcontroller to LEDs and write a testing program to show the the data from ultrasonic distance sensor through LEDs. 3. Connect the microcontroller to LEDs and write a testing program to show the the color data from color sensor through LEDs. 4. Connect the microcontroller to LEDs and write a testing program to show the the audio data from microphone. 5. Connect the microcontroller to LEDs and write a testing program to see if the microcontroller and produce correct output signals to different LEDs. For example, if the microcontroller thinks there's an obstacle in front, the red LED will be lit.

2.4 Sensor Module

2.4.1 Ultrasonic Distance Sensor

The Ultrasonic Distance sensor(28015) is used to detect the distance between the robot and the wall that marks the boundary of the environment as well as other obstacles in its way.

The 28015 sensor transmits an ultrasonic burst and provides an output pulse corresponding to the time required for the burst echo to return to the sensor. The distance to target can be calculated from the time difference.

We plan to use two ultrasonic distance sensors placed on the front of the robot. Two sensors are approximately 120° apart so they can assure the robot can detect obstacles on both its left and right.

Requirements	Verification
1. Able to detect obstacles in range 2 cm to 3m as the datasheet specifies 2. Able to output useful information 3. Able to operate under 5V supply voltage	1. Connect the sensor to Arduino and use the Arduino IDE to print out the readouts of the sensor. Put an obstacle in front of the sensor, and move it back and forth in the range of 2cm to 3m to see if the readouts get updated. 2. Verify the output by converting it to distance and check if the number matches the actual distance. 3. Test if the sensor works by connecting to a function generator outputting 5V in ECE 445 Lab.

2.4.2 Color Sensor

The color sensor (TCS34725) will be used to detect objects that represent edible substances to the sea slug. In the testing environment, food is marked with colored tapes on the floor. There are two types of food, nutritious food is represented with red tapes and a water bottle sitting at center, while non-nutritious food is represented with blue tapes and a water bottle sitting at center.

There will be three color sensors placed at the front of the robot along the bumper, and the color sensors will be facing down to detect color patterns on the floor. This will enable the robot to detect food when moving forward.

Requirements	Verification
1. Able to digitally connect with Arduino and establish data transfer 2. Able to provide very different readings from red and blue colored patches on the ground, 2 cm from the sensor itself.	1. Provide the color sensor with 3.3V power supply, and connect its I/O pins to Arduino. Check if the sensor reading keeps updating itself. 2. Place sensor 2 cm above red and blue patches in a lighted room. Check if the R and B readings from the sensor have at least 100% increase or 50% decrease.

2.4.3 RF Receiver

An HiLetgo 315Mhz RF Receiver will be used to detect the RF signal from the transmitter on the predator module. The receiver is powered by 5V DC and its data output is directly connected to Arduino. Since the only information the robot has to know is whether there is a predator nearby, this 1-bit data is sufficiently represented by the presence and absence of RF power received by the arduino.

Requirements	Verification
1. Detects the presence of RF power when the transmitter is turned on. 2. Accurate detection within a range of 4m.	1. a. Connect the receiver to Arduino and use the Arduino IDE to print out the readouts of the sensor. Record the average level of noise. b. Turn on the transmitter. c. Test if the SNR is larger than 20dB. 2. Repeat step 1 while keeping the distance from the receiver to the transmitter at 4m.

2.4.4 RF Transmitter

An HiLetgo 315Mhz RF Receiver will be used to transmit RF signals representing the presence of a predator nearby. The transmitter is powered by a 9V battery, and the circuit is closed by a sound controlled switch that detects the approaching robot. The DATA pin is connected to VCC directly as the information to be sent will only be 1 bit(whether there is a predator nearby).

Requirements	Verification
1. Transmit RF power when powered by a 9-V battery. 2. Able to communicate within a range of 4m.	1. Power the transmitter with a 9-V battery. 2. Use the network analyzer to measure the output power of the transmitter up to the distance of 4m and record.

2.4.5 Sound Controlled Switch

A sound controlled switch circuit is used to turn on the RF transmitter. It consists of an electret microphone, a semiconductor relay(LH1540), transistors and passive components such as resistors and capacitors. When the robot approaches the microphone, the microphone will detect increasing amplitude of its motor sound. When the amplitude exceeds a certain threshold, the relay will be turned on, thus transmitting RF signal that signifies the presence of a predator nearby.

Requirements	Verification
1. Relay changes position only when the robot is within 1m of the switch.	1. a. Power the switch circuit with a 9V battery, and connect the relay to a simple LED circuit. b. Program the robot to approach the switch, check if the LED lights up only when the robot is within 1m of the switch.

2.5 LED Module

We use two sets of 10 Segment LED Bar Graphs to represent the HP and level of satiety of the robot. Each set will consist of 4 bar graphs. If the robot has full health, all LEDs will be lit. Each LED indicates 2.5% of its maximum HP.

Requirements	Verification
1. The switch or lighting of the bar graphs can be controlled by the microcontroller. 2. The lighting segment of the two sets of the bar graphs can be dropped or raised by the microcontroller in both directions. 3. Can be operated under 3.3V voltage.	1. Provide the LED with 3.3V supply, and see if all segments of the LED Bar Graphs can be lit. 2. Connect the LED to the Ardinuo and see if the Ardinuo can receive the signals of the LED. 3. Assign variables to control the signals from the LED Bar Graph on Arduino, and see if the segments on the LED Bar Graph can be controlled by the variables from the Ardinuo.

2.6 Power Supply

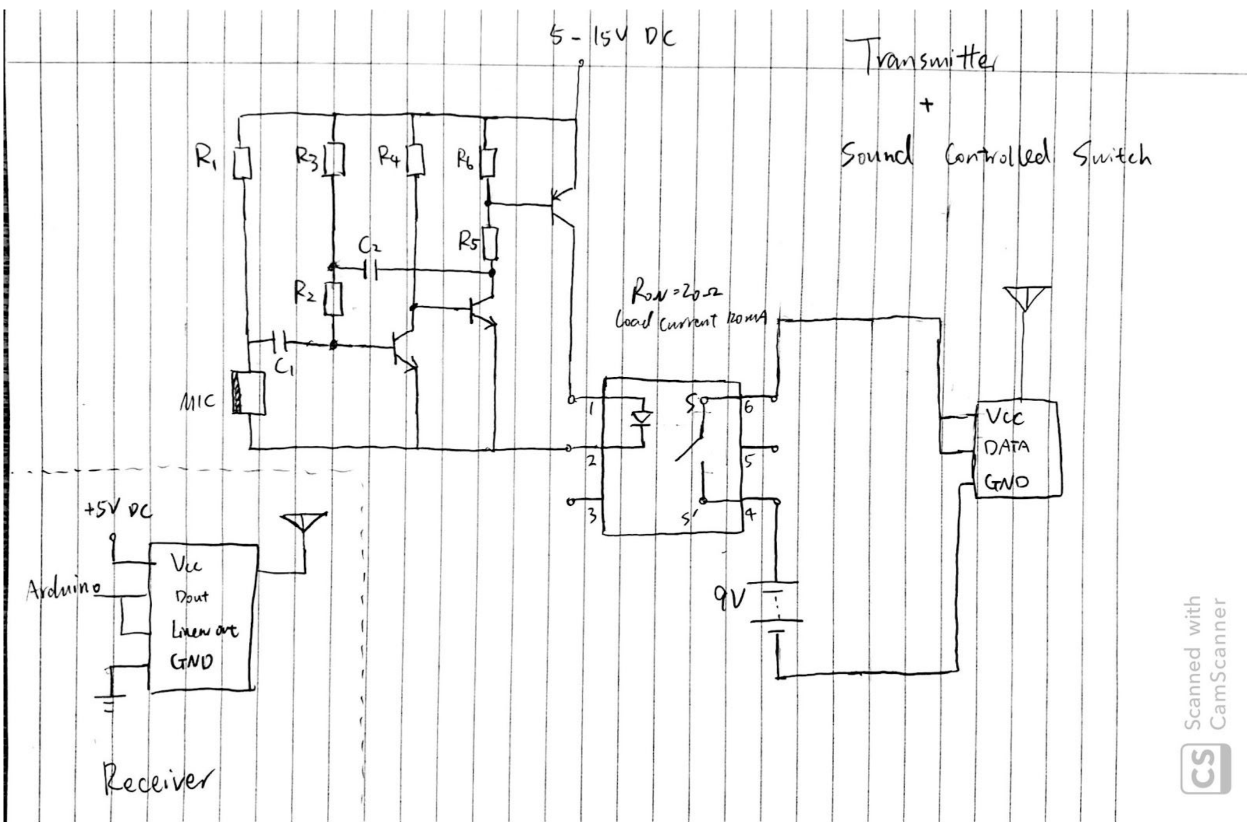
The power supply for the entire circuit is a 12 V battery pack. It connects to Arduino via power jack, and Voltage regulators to output 5V for ultrasonic distance sensor, and 3.3V for color sensor, microphone, and LED Bar graph sets. The iRobot is powered by its own rechargeable battery pack installed on the bottom of the robot.

Requirements	Verification
1. Provides 12V from the battery pack 2. Voltage regulators provides 5V and 3.3V 3. The iRobot battery pack works	1. Using oscilloscope to measure the voltage, and make sure it is steady within the 2% range of the specified output. 2. Using oscilloscope to measure the voltage, and make sure it's within the 2% range of the specified output.

	3. iRobot Create can be turned on and move powered by its own battery.

2.7 Tolerance Analysis

In this project, the link that puts the tightest requirement on the system is the sound controlled switch module. It has the highest degree of uncertainty, since many parameter(e.g. resistance and capacitance) values can only be determined through repeated adjustment. Also, there is a possibility that the motor sound of the robot being too loud that the switch will be turned ON even within a rather large distance.



3. Cost and Schedule

4. Ethics and Safety

The robot's chassis is powered by a nickel-metal hydride(NiMH) battery. Its most common hazard is overcharging, which could eventually lead to explosion. Therefore, attention is needed when recharging the battery.

The supply voltages of the arduino(5V), color sensors(3.3V), ultrasonic sensor(5V) are all much lower than the 12V voltage supplied by the external battery. As a result, the role of the voltage regulator circuit is critical in terms of protecting the electronic devices mounted on the robot. We should be very careful when connecting the sensors with the power supply to avoid short circuits.

Working in labs also carries potential damages both to ourselves and our project. We may need to assemble the sensors with the chassis with the main part of the robot, and we need to be very careful when soldering. We need to strictly follow the rules on the lab safety training manual to avoid potential harms such as burns and electric shock.

Although this robot has its limitation in terms of resembling a true sea slug, simulating living organisms with advanced robotic and biologic technology will not only help scientists to acquire higher volume data with ease, but also reduce the exploitation on the environment caused by taking living samples from their natural habitat. We are responsible for making the behavior of our simulated sea slug as similar as the actual sea slugs so that our simulated sea slug will act as the accurate prototype for further research and studies. In sum, the sea slug simulator should be considered as a scientifically and environmentally ethical project.

[1] Brown, Jeffrey & Caetano-Anollés, Derek & Catanho, Marianne & Gribkova, Ekaterina & Ryckman, Nathaniel & Tian, Kun & Voloshin, Mikhail & Gillette, Rhanor. (2018).

Implementing Goal-Directed Foraging Decisions of a Simpler Nervous System in Simulation. eneuro. 5. ENEURO.0400-17.2018. 10.1523/ENEURO.0400-17.2018.

[2]