Sea Slug Simulator

ECE 445 Project #55
Jianzhi Long, Yunhan Wang, Ziwei Qiu
TA: Ruhao Xia

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. 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 a LED bar graph to represent the HP (health percentage) of the robot.

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 High-level requirements

- The robot must change its directions before hitting the wall of the testing environment
- The robot must have the correct HP display. Its HP will decrease steadily when there is no intake of nutritious food. Its HP will increase by a fixed amount every time it finds nutritious food, and have no change when it finds non-nutritious food.
- The robot must avoid the speakers representing the predators of sea slug when there is audio signal generated from the speaker.

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. The Microcontroller will receive data collected by ultrasonic, color sensors and microphones and transmit corresponding signals to guide the movement and behavior of the robot based on the input signals. The robot also equips a LED bar graph to indicate the current health percentage 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

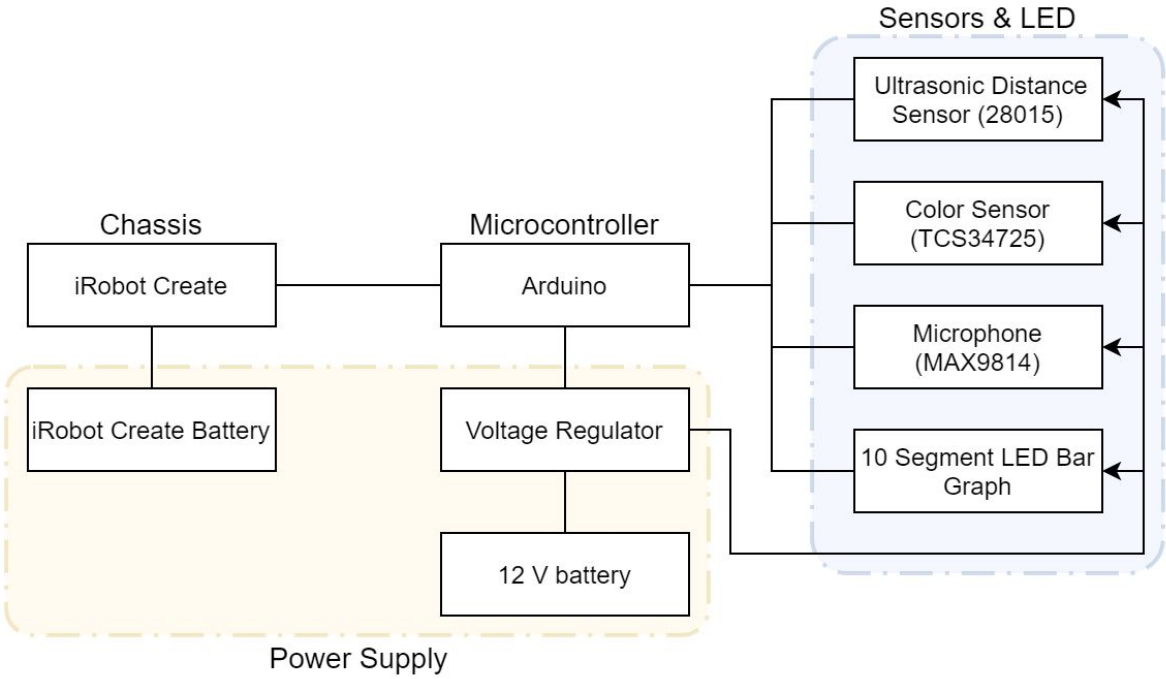

Fig.1 Block Diagram of robot system

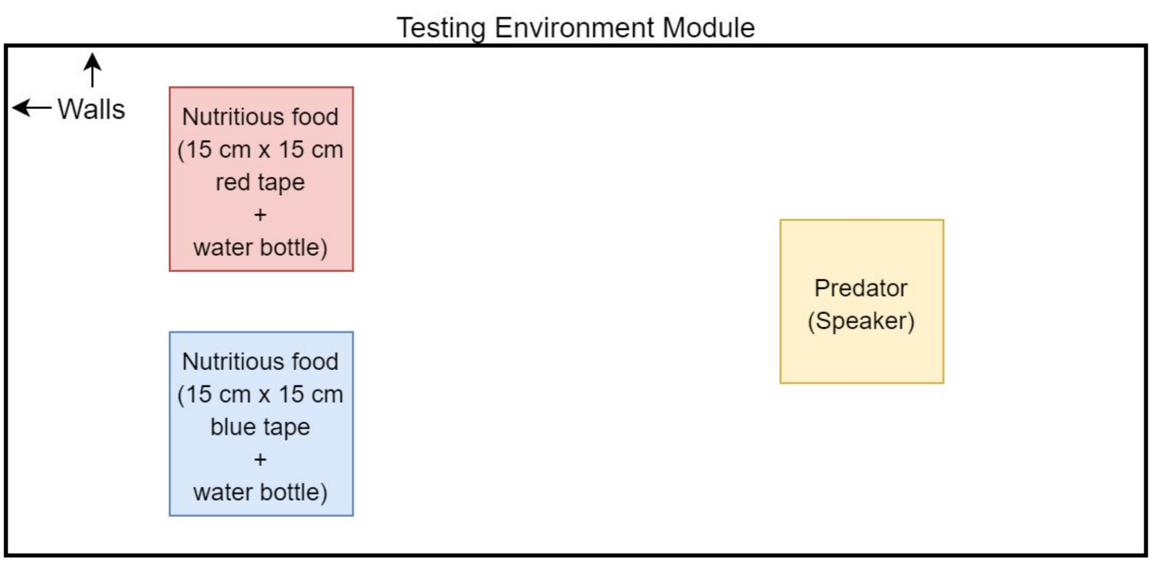

Fig.2 Block Diagram of the testing environment

2.2 Functional Overview

Microcontroller

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

The sea slug's HP value drops at a steady rate when there is no food intake. When it consumes food, its HP value increases by a fixed amount. Also, the sea slug's HP drops by a large amount when it comes in contact with its enemy.

The sea slug has random movement as its default state of motion, provided that its HP is above a threshold value, and it is far away from its enemies. Also, in the default state, it avoids all kinds of objects including its food.

When the HP of the sea slug falls below the threshold value, it prioritizes finding food. After investigating the food, the sea slug 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 the sea slug is in close proximity with its enemy, it prioritizes its escape 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 enemy. It is also connected to the LED bar graph that acts as a display of the sea slug's HP.

Sensors & LED

- 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.
- Color Sensor

    - The TCS34725 color sensor works by filtering the light reflected from an object and quantifying its RGB composition. The robot detects the presence of food with color sensors.
    - 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 eight color sensors placed evenly along the side of the circular shape of the robot, 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 in any direction.
- Microphone
    - The microphone is used to detect the imaginary predators in the testing environment. A microphone is placed at the front of the robot.
    - The MAX9814 Electret Microphone Amplifier has a 20-20KHz electret microphone. It receives the sound made by 2 or 3 speakers placed randomly on the testing environment. The timing of the playing sound is controlled by humans. We want to simulate the situation in nature when a predator suddenly shows up by playing sound through the speakers. We will specifically design an audio clip representing the presence of the predators.
    - Once the microphone receives the sound, it will perform a frequency analysis to determine whether the sound is from the speakers or ambient noise. If the sound is from the speakers, then the robot will run away from the source of the sound(aka predators).
- 10 Segment LED Bar Graph
    - We use a 10 Segment LED Bar Graph to represent the HP of the robot. If the robot has full health, all LEDs will be lit. Each LED indicates 10% of its maximum HP.

Power Supply

We use a 12 V battery to power the Arduino and the sensor circuit. We will use multiple voltage regulators to make sure the voltage for different components meets the requirements.
The iRobot is powered by its own rechargeable battery pack installed on the bottom of the robot.

Testing Environment

The testing environment will be set up in the CSL Studio building. Its main components are:

- Wall

The wall marks the boundary of the testing environment that resembles the sea slug's habitat. It is made of double-layer white-colored plaster.

- Food Objects
  - Nutritious Food
    The nutritious food will serve to increase the seal slug's HP value. It is a fixed spot covered by red tapes, with an additional filled water bottle marking its 3-D presence.
  - Non-nutritious Food
    Taking non-nutritious food will not increase or decrease the sea slug's HP. It is a fixed spot covered by blue tapes, with an additional filled water bottle marking its 3-D presence.

- Predator Objects
  There will be 3 predators represented by 3 mini-speakers(momoho BTS0011) that produce sound at a certain frequency that is very different from the frequency of the sound produced by the robot's motor. The mini-speakers will be connected to three smart phones via bluetooth. When the sea slug approaches a predator, we will manually turn on the corresponding speaker and the robot is expected to turn away from the audio source.

2.3 Risk Analysis

The connection between iRobot Create and Arduino is the most critical part of the project. Since we rely on Arduino to take inputs from sensors and output the actions corresponding to the environment, we need to make sure the robot can receive the signals given by Arduino and act properly. Especially we need to make sure the motors can be adjusted by Arduino's outputs, so the robot can be slowed to turn and to avoid bumping into objects.

The other significant risk is the iRobot itself. We need to know how to utilize its motors and sensors. Even without all the sensors to detect the environment, we need to use Arduino to control the robot and let it move forward, backward, rotate, and stop. If we can not control the robot even without all the sensors, the robot will not work at all.

3. 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(3.3V) and microphone(3.3V) 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.

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. In sum, the sea slug simulator should be considered as a scientifically and environmentally ethical project.