Huron Heights Secondary School

Light Following Euglena Summative Report

Petar Isakovic

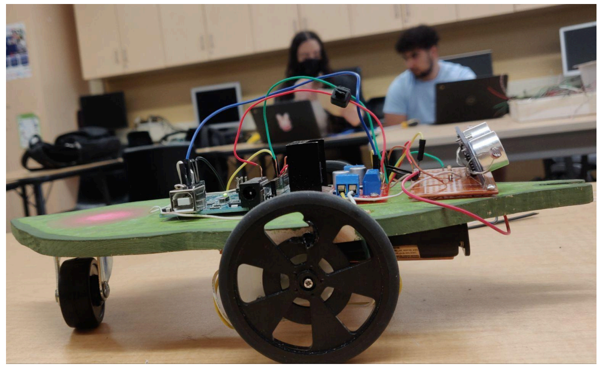
Grade 11 Computer Engineering Technology

Mr. Sheikh

June 22, 2023

Introduction

In this report my partner Danish and I will provide all of the skills and knowledge acquired throughout the semester by designing and building a light-tracking robot. Not to mention that this entire project will be inspired by the euglena which is a single-celled organism that has autotrophic-like abilities (due to its eyespot) that allows it to detect and move towards areas of bright light so that it can photosynthesize. Furthermore, this project will utilise the SPICE design method in order to have a well structured framework for all of the design and construction process of this project. Additionally, this report will provide a comprehensive overview on our design process and will have detailed steps for each step that was included in this process throughout the project. In fact, we will also include images of the initial design on paper, to all of the other engineered drawings used to visualise and refine our robot, so that we can ensure a clear understanding of all of the robots components and mechanisms. However, it's also important to note that this project was extensively planned and organised, which is why a detailed parts list that accounts for every essential component necessary for its construction will also be provided within this report. Not to mention that throughout this project we also focused on achieving a balance between creativity, design and all concepts thought within this course, which is why our product not only has the natural light-tracking abilities of a euglena, but it also has the design features of a Euglena (such as its shape and colour). Throughout the project, me and my teammate have not only expanded our understanding of robotics, but have also improved our problem-solving, critical thinking, and even project management abilities. This is why we believe that our light-tracking robot represents everything we learned in this course and will showcase our growth and achievements within this class. Therefore, in this report we will devise into the SPICE-inspired design process, the construction of the robot and even the evaluation of its performance so that any reader can understand how we developed a euglena robot.



Procedure

Situation/Scenario

Designing a robot that tracks and moves toward areas of strong light in the style of Euglena.

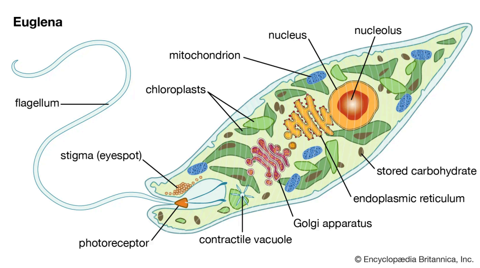
Problems/Possibilities

Incorporating light detection, distance sensing, navigation, algorithm development and even power/cable management into a circuit after designing a prototype on ThinkerCad/Breadboard using engineered drawings and a detailed materials list within a timeframe of 1 month.

Investigation/Ideas

Gathering information:
During the investigation and ideas phase of the SPICE design process, extensive effort was dedicated to gather information on not only what a Euglena is (and how they move) but also on potential mechanisms that we could use to replicate the movements of this organism.

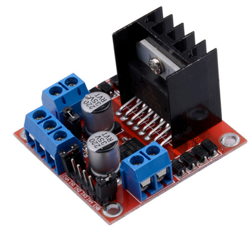
1. Euglena
    a. The Euglena is a single-celled organism that has a discoidal shape/ovate/lobate/elongated shape
        i. *Base of the robot can be designed/cut out in a way that matches the body shape of a euglena*
    b. They have a pigment that give off a green colour due to its chlorophyll
        i. *Paint the robot a green colour to represent the chlorophyll like abilities of the Euglena*
    c. It can can move towards areas of bright light
        i. *Use light-dependent resistors as s sensor that can be used to detect and track light sources*



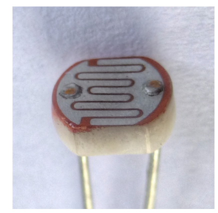
2. Phototropism
    a. When light falls on the Euglena's eyespot it produces a hormone called auxin, allowing the euglena to curve towards the light (which is why the Euglena can move closer to the light source
        i. *Use a L298 driver that will simulate the speed and the direction that the euglena will travel (depending on where the light is around the robot)*
3. Photophobic response
    a. When Euglena's are exposed to extreme/intense light, they tend to stop growing towards the light (Protects itself from excessive light exposure)
        i. *Use a distance sensor to force the Euglena to stop moving once it has come to close to the source of light so that it does not break the robot (like how the Euglena is able to protect itself from the light)*

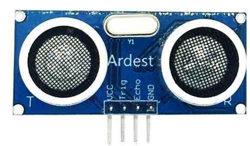
Brainstorming

After gathering all information that was needed me and my partner brainstormed ideas for the design of the light-following robot, by created various different creative ideas while primarily focusing on how we would ensure that the light detection would work properly and how the robot would know to move in the direction of the light with the L298 driver and photoresistors.



1. Positioning
    a. Two light dependent resistors should be used
        i. One will detect if there is light on the left side of the robot
            1. If there is light on the left side of the robot, than left motor would turn backwards while the right motor turns forward (to spin the motor left)
        ii. One will detect if there is light on the right side of the robot
            1. If there light on the right side of the robot than the robot would turn its right motor backwards and its left motor forwards so that the robot would turn right to face the light
        iii. The two light dependent resistors should be placed between the distance sensor
            1. Distance sensor is used to stop the robot from driving into the light source
            2. The reason the distance sensor should be between the light sensors is because if the light is in between the light dependent resistors than the robot should be going straight (only way to prevent the robot from going straight is if there is a distance sensor in the direction that the robot is moving)



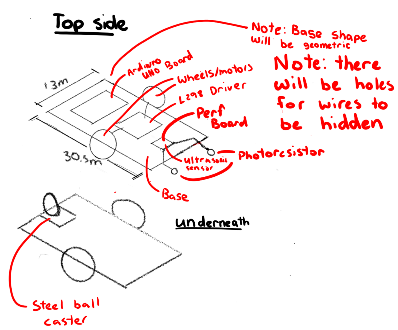


2. Visual Design:
    a. Painting the wooden base of the robot green (to make it look like a Euglena)
    b. Drilling holes within the wooden base of the robot
        i. Allows wires to run underneath the board (so that there is better cable management)
    c. Don't strip wires a lot (make sure that only the ends of the wires are exposed while the rest of the wire is protected to ensure that no exposed wires are connecting)
3. Building it quickly
    a. Using only 2 wheels instead of 4
        i. Use a steel ball caster to replace the other two wheels (so that the back part of the robot is not only stable but will also move corresponding to the directions of the front two wheels)
    b. Splitting the workload
        i. Since there are two people in our team (in total) than while one person is doing one part of the project the other person is doing something different (use time effectively)

Materials List		
Components	**Quantity**	**Material Dimensions**
Photoresisters	2	
Steel ball caster	1	5 m x 4.5 m x 3.5 m
L298 motor driver	1	4.5 m x 4.7 m
Moter	2	
Wheels	2	
Perfboard	1	3.7 m x 5.1 m
Batteries (1.5v)	4	
Battery Case	1	6.5 m x 6.9 m
Base (wood)	1	30.5 m x 13 m x 0.7 m
Ultrasonic sensor	1	4.5 m x 2.5 m
Male to male jumper wires	20	
Male to female jumper wire	6	
Arduino uno board	1	5.3 m x 6.8 m
Resistor	2	
Phillips screws	12	
Screw nuts	2	
Motor Mounts	2	

Sketching

Based on all of the gathered information and brainstorming sessions, me and my teammate drafted visual representations of what we wanted our final product to look like so that we could visually propose the robot's structure, sensor placement and overall functionality. Furthermore, the sketches allowed us to continue to iterate and refine the design, and it ensured that me and my teammate were on the same page (when it comes down to what we were actually going to build physically). This iterative process is also what led to further enhancements being proposed and added to the circuit (biggest reason as to why additional features like the distance sensor were incorporated). Therefore, these visual representations served as a valuable tool for conveying the intended direction of the project before continuing onto the prototyping and implementation of our project.



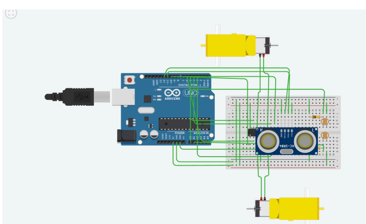
Choose/Create

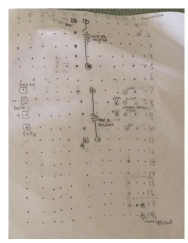
Choose

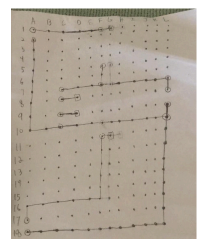
The solution that my teammate and I decided to build and construct was our final iteration of our sketch considering that it incorporated all of our ideas together (distance sensor working with photoresistor). However, we also decided that we would only create the euglena design for the wooden base of the board (discoidal shape and green colour) if we had time at the end of our project (due to a concern of running out of time), which is why we did not draw out the curvy-like shape pattern in our sketch of the wooden base for the robot. In addition, although we knew that a steel ball caster would not have been provided by the teacher, my teammate was able to find a spare caster that he had in his home (meaning we would be able to use only 2 motors instead of 4). Furthermore, we also knew a friend in the classroom who had access to a 3D printer that would allow us to create custom free motor mounts (so our actual motors would be able to hold themselves in place).

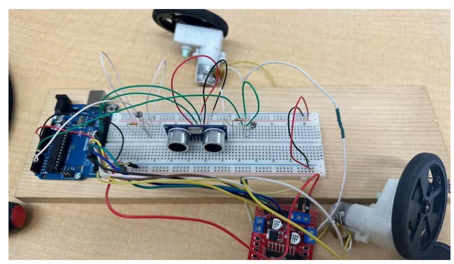
Create

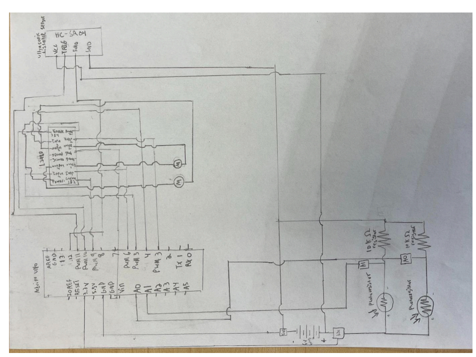
During the creation phase, my teammate and I started to design the physical structure of the robot using ThinkerCad by utilising the available tools and components in the ThinkerCad library to create a virtual representation of the robot's body. Furthermore, we were also able to code the entire robot within ThinkerCad in C++, which allowed us to test if our design/plan would actually work before building the prototype of our project. This is why, once the ThinkerCad diagram plan was completed, we were than able to immediately begin building our prototype using a breadboard which allowed us to physically test our code to ensure that it not only works on the ThinkerCad software, but so that it also works in the "real world". However, this is when we realised that the ThinkerCad circuit did not incorporate a battery, which forced us to change the plan slightly so that there would be a battery powering the arduino (instead of the computer). Therefore, once we got our prototype of our perfboard to fully function (meaning that the motors would rotate towards the light sensed from the photoresistors) we than needed to make a perfboard diagram that we would need to figure out where our components would need to be placed on our actual project (considering that we wouldn't be able to use a breadboard (since it can not hold wires very strongly)) so that we could solder proper/strong connections to each of the components so that they can connect smoothly with strength.







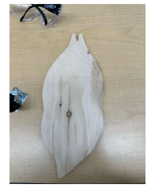


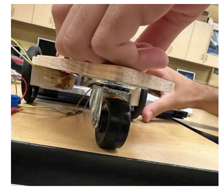


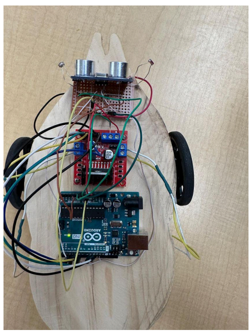
VIDEO OF PROTOTYPE WORKING

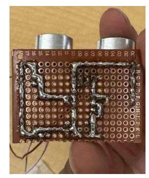
Begging of Construction

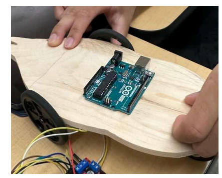
At the beginning of the construction phase me and my teammate first got all of the materials that we would need from our materials list (can also be seen based on our design in TinkerCad) so that we could carefully organise the components to ensure we had everything we needed for the assembly process. After that, we started constructing the base of the robot using a wooden block that we carefully measured and cut to its desired dimensions. After that, we attached the steel ball caster, which provided stability and smooth movement for the robot. Additionally, we then began assembling the electronic components by connecting the Arduino Uno board onto the wooden block (opposite side on which the steel ball caster was placed). Than, we began to attach our photoresistor, ultrasonic distance sensor and even 10k ohm resistors into our perfboard, and we then soldered them all together using a soldering iron before screwing the perfboard onto the front of the board (so that the distance sensor was pointing out). Furthermore, we were able to attach the L298 motor driver to the arduino Uno board, by making sure that the appropriate wiring connections and pin configurations were being made. Not to mention that we then used the 3D printed motor mounts to secure the motors in place so that we could ensure smooth motion. After that, we attached the battery case onto the bottom of the base of the board so that the wires could reach into the top of the perfboard (by going through the "mouth"/front design of the robot's base we made). Finally we added batteries into the case and tested our robot to see if it worked properly and once we confirmed that the robot was able to run smoothly, (since we had a bit more time left) we were able to paint the base of our board green so that it would match the design/colour of the euglena (due to its chlorophyll). Furthermore, to improve cable management we drilled holes in the base so that we could run all cables below the base of the board to make it look more aesthetically appealing.











Project	Time Spent	Accomplished	Date
Sketching/Designing	2 hours	Build layout	May 26, 2023
Research	1 hour	Finding information on the Euglena, photoresistors, distance sensors and everything else being used within the robot	May 26,2023
Schematics	1 hour	Completion of Perfboard layout and Schematic Layout	May 26,2023
Measurements	0.75 hours	Measuring all components and placing them properly onto the base of the robot	June 2,2023
Prototype Build	0.75 hours	Building the prototype on breadboard	June 2,2023
TinkerCAD Drawing	1 hour	Completing the Tinkercad version of the robot	June 2,2023
Coding	2.5 hours	Coding the robot completely	June 8,2023
Soldering	2.5 hours	Attaching everything on perfboard	June 19, 2023
Building Robot	3 hours	Attaching it all together	June 21,2023
Total	14.5 hours		

CODE

```
const int sensorPin = A0;
const int sensorPin2 = A1;
const int motor1pin1 = 4;
const int motor1pin2 = 3;
const int motor2pin1 = 6;
const int motor2pin2 = 5;
const int trigPin = 11;
const int echoPin = 12;
int max = 255;
float distance = 0;
int initalLightingOfRoom;

void setup()
{

  pinMode(motor1pin1, OUTPUT);
  pinMode(motor1pin2, OUTPUT);
  pinMode(motor2pin1, OUTPUT);
  pinMode(motor2pin2, OUTPUT);
  pinMode(9, OUTPUT);
  pinMode(10, OUTPUT);
   digitalWrite(motor1pin1, HIGH);
  digitalWrite(motor1pin2, LOW);
  digitalWrite(motor2pin1, HIGH);
  digitalWrite(motor2pin2, LOW);
  analogWrite(9, 255);
  analogWrite(10, 255);
   pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  Serial.begin(9000);
  initalLightingOfRoom = analogRead(sensorPin);
}


void loop()
{

  distance = getDistance();

if(abs(analogRead(sensorPin) - analogRead(sensorPin2)) < 40) {
    digitalWrite(motor1pin1, max);
    digitalWrite(motor1pin2, LOW);
    digitalWrite(motor2pin1, max);
    digitalWrite(motor2pin2, LOW);
}
else if(analogRead(sensorPin) > analogRead(sensorPin2)){
    digitalWrite(motor1pin1, max);
    digitalWrite(motor1pin2, LOW);
    digitalWrite(motor2pin1, LOW);
    digitalWrite(motor2pin2, max);
  }
  else{
    Serial.print(max);
    digitalWrite(motor1pin1, LOW);
    digitalWrite(motor1pin2, max);
    digitalWrite(motor2pin1, max);
    digitalWrite(motor2pin2, LOW);
  }


  Serial.println(distance);
  if (distance <= 5) {
  max = LOW;
  }
  else{
    max = HIGH;
  }

  delay(10);
}

float getDistance()
{
  float echoTime;                   //variable to store the time it takes for a ping to bounce off an object
  float calculatedDistance;         //variable to store the distance calculated from the echo time

  //send out an ultrasonic pulse that's 10ms long
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  echoTime = pulseIn(echoPin, HIGH);      //use the pulsein command to see how long it takes for the
                                          //pulse to bounce back to the sensor

  calculatedDistance = echoTime / 148.0;  //calculate the distance of the object that reflected the pulse (half the bounce time multiplied by the speed of sound)

  return calculatedDistance;              //send back the distance that was calculated
}
```

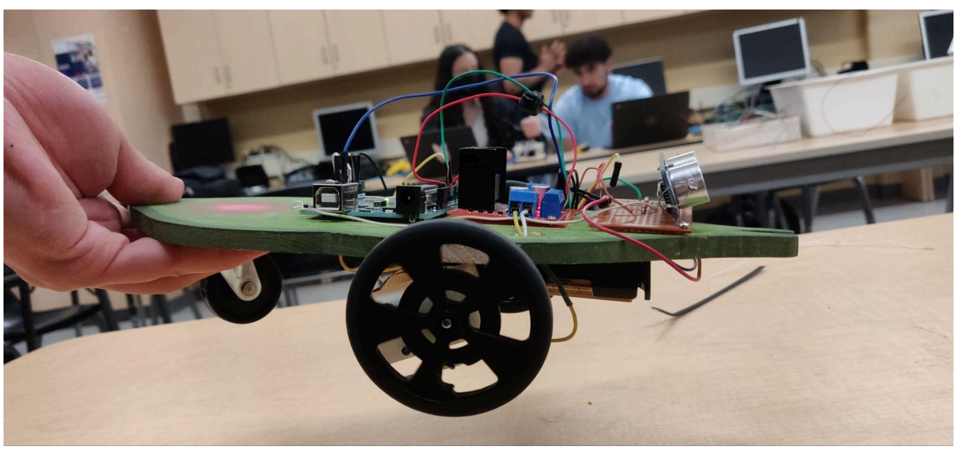
Evaluate

During the evaluation phase of SPICE, my teammate and I conducted an assessment to ensure that our prototype met the desired criteria and performed as intended. This phase involved testing, analysing and refining the robot's functionality, performances and overall effectiveness.

1. Functionality: We first verified whether the robot was able to simply detect light sources by printing the light values that were being read within the serial monitor. However, when we saw that the value of the photoresistor was never changing (no matter the amount of light that was being shined) we immediately realised that the legs of the photoresistor were connected together (instead of being separated), which is why the resistance didn't change (but by spreading the legs of the photoresistor we were able to read the correct photoresistor values). However, when we tried printing the ultrasonic distance sensor value in the serial monitor we noticed that it would always print a distance of 0, but after replacing the distance sensor with a newer one, we realised that we were given a faulty distance sensor originally considering that the distance sensor started to display power distance values in the monitor when we swapped it for a new one.
2. Efficiency: We examined the efficiency of the robot's light detection and navigation mechanisms, and we kept making minor adjustments to code to try to adjust the movements to be as smooth as possible.
3. Reliability: We checked for loose wire connections and loose solder joints and we tried to add more solder to these joints or improve the strength of the wire we were currently using (by replacing it with a different wire (or by stripping it more)). Furthermore, we used a multimeter to check if there were any areas within the circuit that were supposed to be connected but had no current flowing through them.
4. Safety: We considered safety aspects during the evaluation phase by ensuring that our 10k ohm resistors were properly connected into our circuit to ensure that the photoresistor do not overheat (considering that when there is a decrease in resistance, there will always be an increase in current which will cause the there to be an increase in power and will than in turn cause an increase in energy (which can be transferred into thermal energy (a.k.a fire)).

Conclusion

In conclusion, our project to design and create a line-following robot was successful. Throughout the SPICE design process, we were able to get all the necessary information of the Euglena organism and implement its behaviour and design onto our own robot/circuit through brainstorming, drawing detailed designs, using ThinkerCad and even making our own prototypes. In other words, our light-following robot was able to show remarkable responsiveness to changes in light intensity and was able to accurately follow any/all light sources. Not to mention that it is clear that by using photoresistors, motors and an Arduino microcontroller, we were able to have efficient enough light detection so that we could have precise navigation. Additionally, by spending a lot of time planning our robot on ThinkerCad we were able to test the robot's structure and code virtually which made the physical construction build go by a lot quicker (since there were definitely fewer errors/setbacks than most projects). Therefore, by implementing the SPICE design process me and my teammate Danish were able to achieve our project goals and successfully create a light following robot that has reliable performance. This is why, through effective collaboration, research, planning and execution we were able to develop a light-following robot that shows how we can combine biology-inspired behaviours with modern technology.



Works Cited

Admin. "Phototropism - Definition, Mechanism, Examples, Discovery." *BYJUS*, 6 Aug. 2020, byjus.com/biology/phototropism/#:~:text=Phototropism%20Examples,for%20its%20growth%20and%20survival.

"L298, a Dual H-Bridge Motor Driver Module." *Latest Open Tech From Seeed*, 30 Oct. 2020, www.seeedstudio.com/blog/2019/10/08/l298-all-about-l298-motor-driver/#:~:text=Application%20of%20L298n,-L298n%20Motor%20Drivers&text=With%20the%20L298n%20dual%20H,it%20spin%20at%20any%20speed.

"Build a Speedy Light-Tracking Robot (BlueBot Project #2): Science Project." *Science Buddies*, www.sciencebuddies.org/science-fair-projects/project-ideas/Robotics_p022/robotics/light-following-robot. Accessed 22 June 2023.

Developer, Wired, et al. "Wiring & Driving the L298N H Bridge with 2 to 4 DC Motors." *14core.Com | Ideas Become Reality*, 28 Dec. 2015, www.14core.com/wiring-driving-the-l298n-h-bridge-on-2-to-4-dc-motors/#:~:text=Connect%20the%20Arduino%20Digital%20Pins,5%20to%20module%20PWM%202.

"Euglenoids." *Euglenoids - Arctic Bioscan Wiki*, arcticbioscan.ca/wiki/w/Euglenoids#:~:text=A%20freshwater%20genus%20common%20in,and%20increase%20its%20photosynthetic%20efficiency. Accessed 22 June 2023.

Hana, et al. "L298N Motor Driver - Arduino Interface, How It Works, Codes, Schematics." *How To Mechatronics*, 17 Feb. 2022, howtomechatronics.com/tutorials/arduino/arduino-dc-motor-control-tutorial-l298n-pwm-h-bridge/#:~:text=L298N%20Driver,peak%20current%20up%20to%202A.

"Light-Seeking Robot." *Light-Seeking Robot - SparkFun Learn*, learn.sparkfun.com/tutorials/light-seeking-robot/all. Accessed 22 June 2023.

"Perfboard." *Wikipedia*, 16 Feb. 2023, en.wikipedia.org/wiki/Perfboard.

"Phototropism." *Wikipedia*, 9 Mar. 2023, en.wikipedia.org/wiki/Phototropism.

Sebastian VillateSebastian Villate 37311 gold badge33 silver badges55 bronze badges, et al. "Why Does My Circuit Work on a Breadboard, but Not on a Perfboard? I Am New to Soldering." *Electrical Engineering Stack Exchange*, 1 Dec. 1965, electronics.stackexchange.com/questions/437787/why-does-my-circuit-work-on-a-breadboard-but-not-on-a-perfboard-i-am-new-to-so#:~:text=A%20perfboard%20is%20not%20like,to%20interconnect%20the%20holes%20yourself.

Www.robotiksistem.com. *Light Follower Robot*, www.robotiksistem.com/light_follower_robot.html#:~:text=Light%20follower%20robot%20is%20a,LDRs%20(light%20dependent%20resistors). Accessed 22 June 2023.