Carnegie Mellon University
Electrical & Computer ENGINEERING

ScentBot

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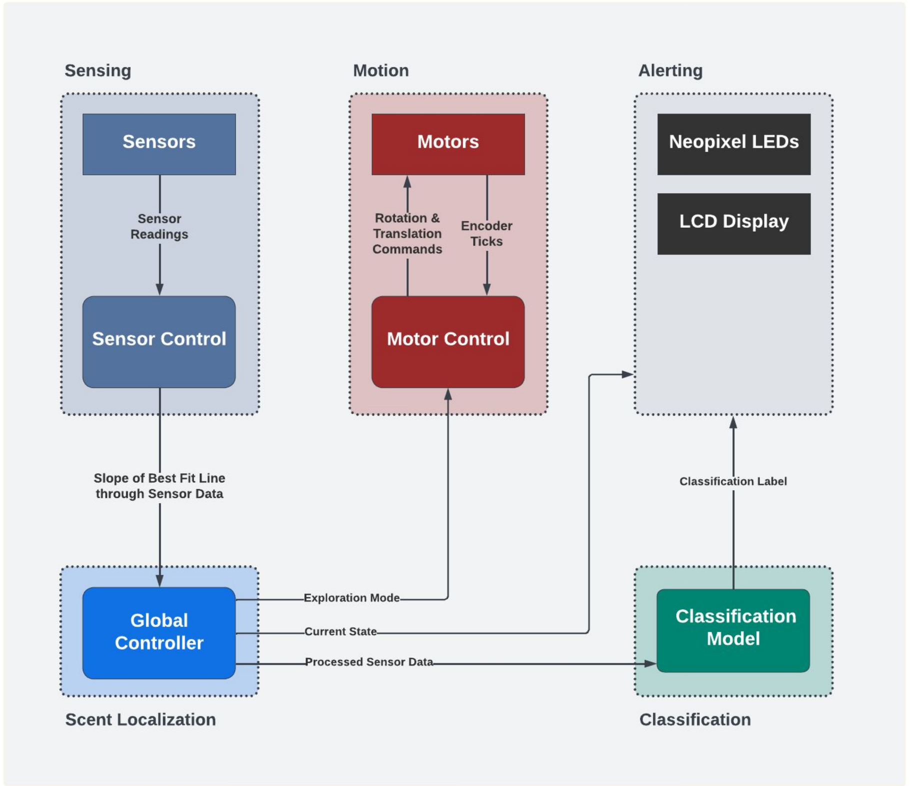
http://course.ece.cmu.edu/~ece500/projects/s23-teamc8/

Introduction

Anosmia (the loss of sense of smell) has been a major focus of public health in recent years due to the COVID-19 pandemic. In order to combat this issue, we have designed ScentBot, **an autonomous mobile robot which can detect and classify potentially hazardous domestic scents**.

ScentBot uses a simple sensor array and machine learning algorithm to autonomously traverse a map and identify a scented object. Object detection and classification is typically done with computer vision, but these algorithms wouldn't be able to distinguish water from other clear hazardous chemicals. We have designed a system that can overcome this challenge by using scent detection algorithms.

System Architecture



System Architecture Diagram

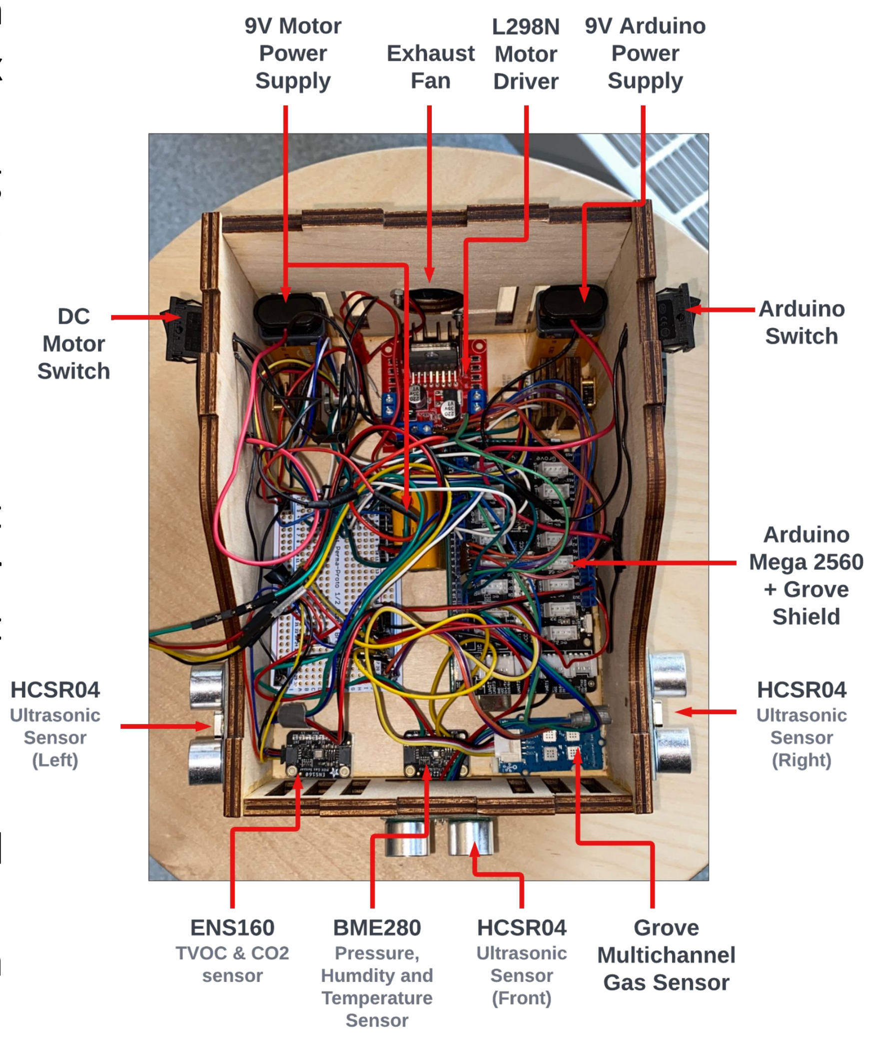
Our robot is comprised of 5 main subsystems:

(1) **Sensing**: The sensing subsystem receives raw sensor readings from our sensor array which consists of TVOC, CO, CO2, NO, C_2H_6O (ethanol) concentrations along with data on temperature, humidity, pressure and altitude, as geographical factors affect the performance of our sensors and the embedded ML model. It computes a line of best fit every sampling period to determine the increase or decrease in scent concentration.

(2) **Motion**: Utilizing a positional controller and Runge-Kutta odometry, the motion control subsystem receives random coordinates from the global controller and computes x and y coordinates from a direction and angle for the robot to translate to. It also contains the logic for obstacle avoidance and self-correction from three ultrasonic sensors placed on the robot.

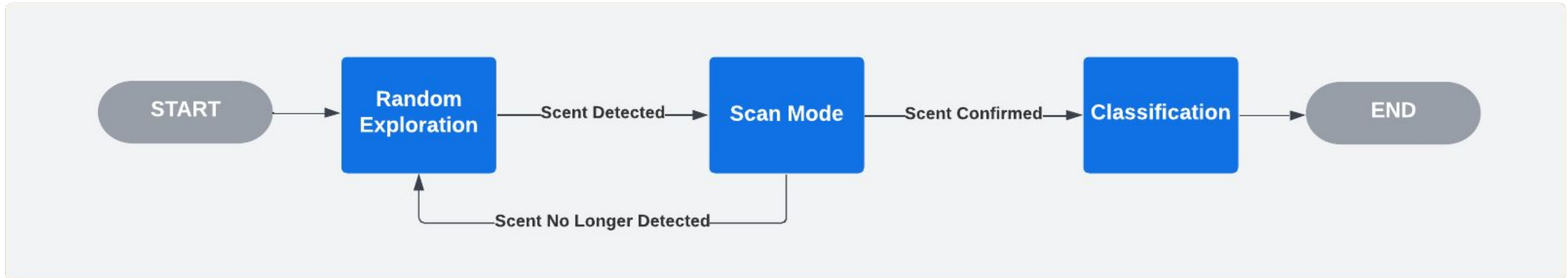
(3) **Scent Localization**: The scent localization subsystem is activated when there is an increasing slope of scent concentration observed during the robot's traversal. The robot initiates a 180° scan of the environment where it detected the scent. Increasing slopes during this scan period determine the maximum index to which the robot traverses to and re-initiates the scan. If decreasing concentrations are observed, the robot exits into random exploration mode.

(4) **Classification:** If at any point during scent localization the robot detects a high concentration of sensor readings through a hard threshold, it indicates that it is very likely the object is in front of the robot. Here, the Support Vector Classification (SVC) multiclass classification model will receive normalized sensor data from that sampling period and return a label for "alcohol", "paint thinner" or "unidentified" scent.



ScentBot assembled: Top View

(5) **Alerting:** The user is communicated with clearly through the use of and LCD display and Neopixel LED lights through each state of the robot. When a scent is confirmed, the Neopixel will turn purple to indicate paint thinner, and green to indicate alcohol, with the corresponding message displayed on the LCD.



State machine diagram

Results and Discussion

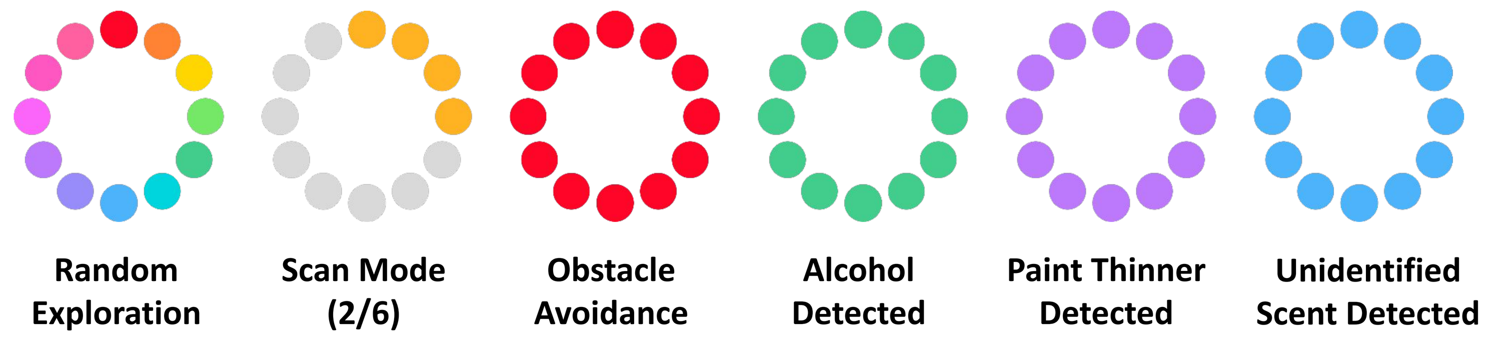
To create a minimum viable product, our team defined several use-case requirements for ScentBot. It must achieve a > 95% classification accuracy while attaining collision free navigation in a 2m x 2m space. It must be able to identify scented objects with a radial distance of > 0.5m in under 3 minutes. Additionally, the sensor array must cost < $150 to make our product accessible to an everyday user.

The table shown summarizes our test results across 64 trial runs for identifying scented objects using ScentBot. We tested 32 possible configurations per scent by dividing the arena into a 3x3 grid, with the starting point of the robot as one of the four corners and the scented object placed at least 1m away in any of the remaining squares.

As seen, we achieved most of our use-case requirements. Our obstacle avoidance, however, was affected due to blind spots present with the placement of our ultrasonic sensors.

Test	Performance
Accurate hazard classification	**98.4%** classification accuracy for scented object
Safe navigation	Made contact with obstacle **32%** of the time
Efficient navigation & low latency	Average convergence time for 2x2m space: **161.6s**
Maximum detection distance	Can detect object from an average distance of **0.22m**
Accessibility	Cost of sensor array: **$66.89**

Test results in localizing toward scented object



Neopixel Color Key

Conclusions

We were able to successfully build a robot which is able to autonomously navigate a confined space and detect and classify a subset of household hazardous substances - isopropyl alcohol and paint thinner. The system is designed to be accessible and user-friendly, while also providing accurate and timely detection of harmful fumes by machine learning with cost-effective hardware.

Regarding future work, we would like to extend our project by introducing networking. This will give us the ability to store historical data and alert users if a scent is classified in situations where the robot is unmonitored.

With the scalability of our sensor array and capability of our TinyML classification to handle multiple classes, our project can be adapted to domestic use solutions catered to recognizing different hazardous scents, as well as potential industrial applications. Through this project, we propose an alternate scent-based navigation mechanism that can be particularly useful in low visibility situations. With our solution, we hope to contribute to the improvement of public health, safety, and welfare.

Acknowledgements

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