Interim Report

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Introduction

Task: Ozone Source Detection
Our task is to detect the source of an ozone leak using robotics and A.I.

Robot Architecture

The Nvidia Jetbot was chosen as the robot architecture. The Jetbot is a wifi enabled robot driven by a Nvidia Jetson Nano Developer Kit. The Nvidia Jetson Nano Developer Kit is a small, powerful computer for embedded applications. The Jetson Nano gives the robot the ability to make decisions, locally, on board the robot in real-time. It is equipped with a GPU with 128 CUDA cores that is designed for A.I. applications. The Jetson Nano offers the same GPIO (General Purpose Input/Output) pin layout as a raspberry pi single board computer and four USB 3.0 ports which make it perfect for the task at hand. The ozone sensor provided by Spec Sensors was mounted on the front of the robot with custom made 3D printed mount, that way the sensor is oriented with the same direction as the robot's orientation. The Jetbot is a differential driven vehicle steered by two wheels, one on each side of the robot and 360 degree rolling casters on the front and rear. The Jetbot can be programmed remotely from a web browser by typing in the Jetbot's IP address into a web browser that is displayed on the Jetbot's OLED screen. All programming can be done within Jupyter Notebooks through JupyterLab with Python 3. The Jetbot runs Ubuntu Linux underneath and is accessible through the JetBot's remote programming environment as well.

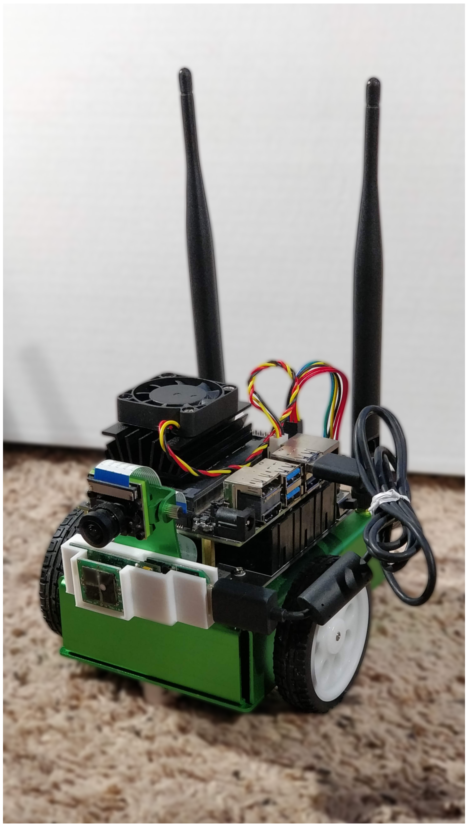

Figure 1: Jetbot with ozone module.

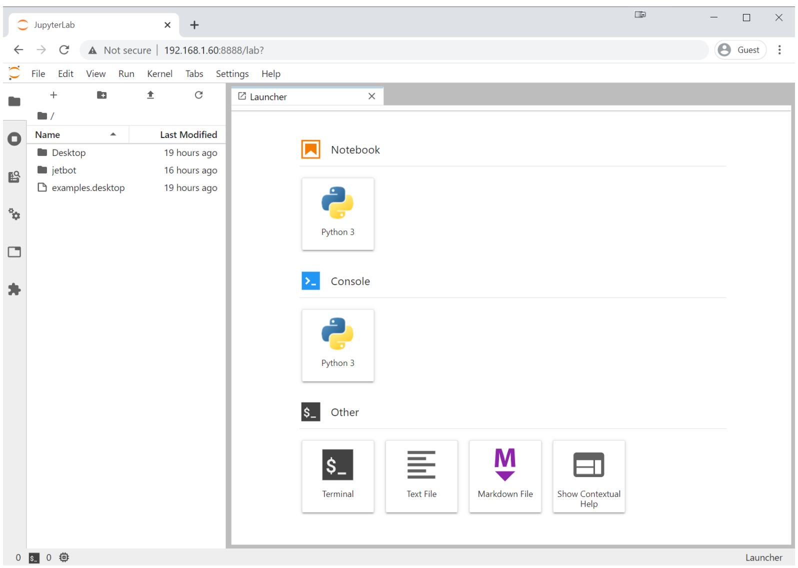

Figure 2: All development can be done remotely with JupyterLab on any web browser

Initial Testing

Our initial belief was that ozone would leak evenly from a source. Assuming that, then the ozone concentration measured in the air would lessen the further the source. We designed a "square routine" for the Jetbot to perform where the Jetbot would drive in a square taking four readings of ozone concentration, one at each corner of the square. The Jetbot would then return to corner with the highest reading and make a movement in that corner's direction and then repeat the "square routine" again. This would be repeated multiple times. If the ozone concentration reading was above a certain threshold, the Jetbot would stop and would output a message stating that an ozone source had been detected. The size of the square was tweaked during testing to try to find the optimal size for testing. The results from the "square routine" testing were inconclusive.

After inconclusive results from our first test, we decided to begin testing in a single dimension. We designed a similar test to the square for single dimensional test. We designed the "line routine". This routine entails having the Jetbot take a reading of the ozone concentration at a certain point then move forward a certain distance and take a second reading. The Jetbot would then make a directional move in the direction towards the point with the highest ozone concentration. This routine would repeat until the Jetbot would repeat until an ozone concentration threshold is met. If the ozone concentration reading was above a certain threshold, the Jetbot would stop and would output a message stating that an ozone source had been detected. The results from the "line routine" testing were inconclusive.

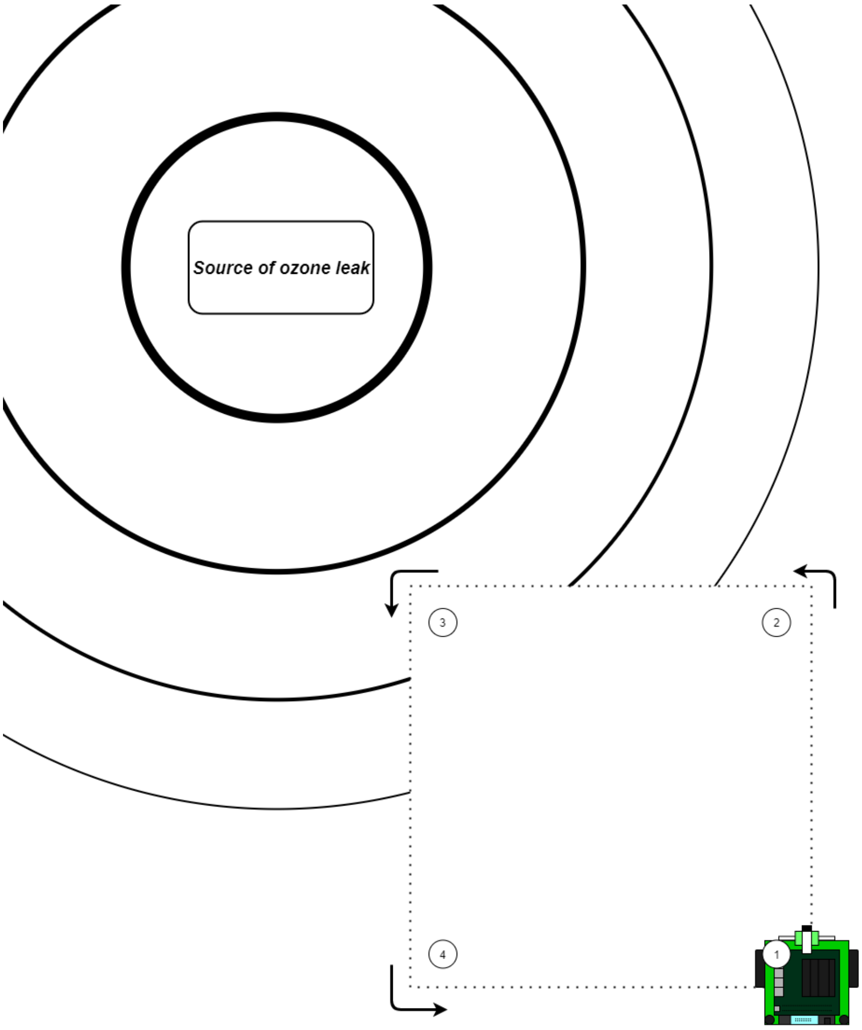

Figure 3: Jetbot performing square routine

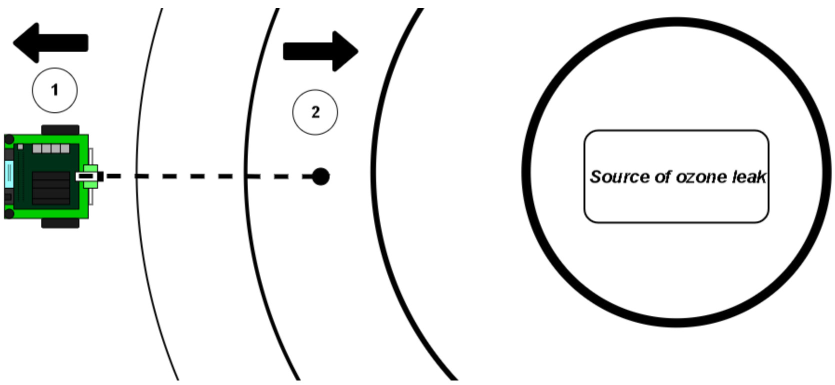

Figure 4: Jetbot performing line routine

Investigation of Ozone Dispersal

After inconclusive results from the "square routine" and "line routine" tests, we turned our attention to the ozone generator, the ozone sensor, and the spread of the ozone. We designed an experiment to determine how the ozone from the ozone generator spreads. We also ran some tests with the robot to determine how many readings the Jetbot needs to get an accurate reading for O3. In the experiment, we placed the Jetbot at one foot intervals away from the ozone source, starting at 8 feet away and had the Jetbot take a reading for an allotted amount of time. We then plotted the average O3 reading for every interval. Since the robot takes 1 reading per second, when the robot sat at point for 256 seconds (4:15 minutes) it took 256 readings, and we took the average of those readings and plotted the point. The darker lines represents the more time spent at each interval. We ran this test 9 times for different amounts of times (readings). The results of these tests may explain why the Jetbot was moving away from the ozone source as much as it was moving towards the source in all our previous trials.

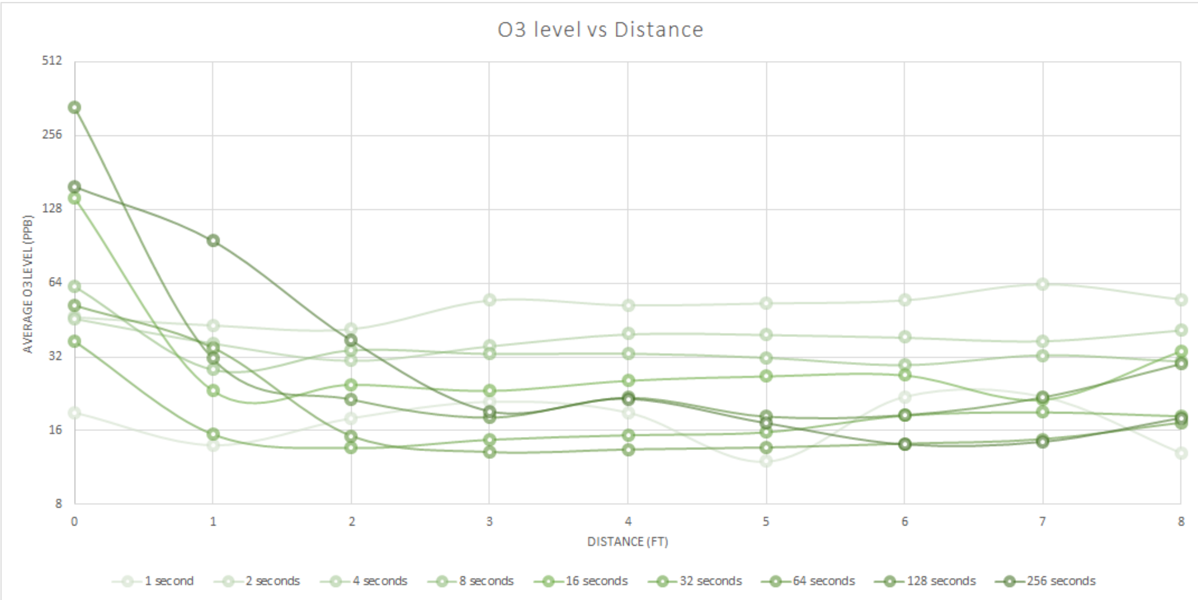

Figure 5: Ozone levels at varying distances

From the results of previous tests, we inferred that after two feet from the source the ozone concentration in the room was leveling out and would be difficult to determine the distance of the ozone source from any further distances. We designed a new test for the Jetbot to just drive towards an ozone source and to stop once a threshold of ozone concentration was met. We decided that 75 ppb at n=30 readings would be a fair threshold to stop at. The results from these new tests were inconclusive. We became concerned because this should have been a simple test that should have had a high success rate. Our attention turn towards ozone generator itself. We designed a test to measure the ozone concentration at a distance of one foot from the ozone source for a given amount of time.

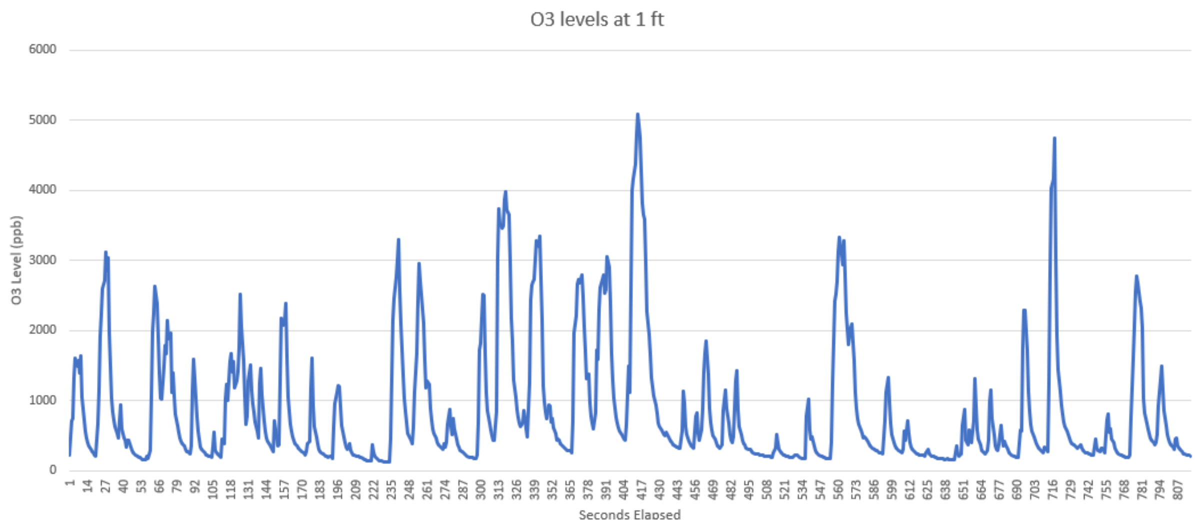

Figure 6: Ozone levels at one foot

Normalizing Ozone Dispersal

The results of measuring the ozone output from the ozone generator provided was concerning. We believed that there was going to be a constant stream of ozone outputted from the ozone generator. We found this not to be the case, this would explain why the Jetbot could not find the ozone source in any previous testing. We reached out to David Peaslee to see if we could get a more consistent ozone generator for testing. He is currently having one sent to us. Meanwhile, we decided to find a way to normalize the out put from the ozone generator that was provided. We found that using a container for letting the ozone build up and slowly leak out of would normalize our output.

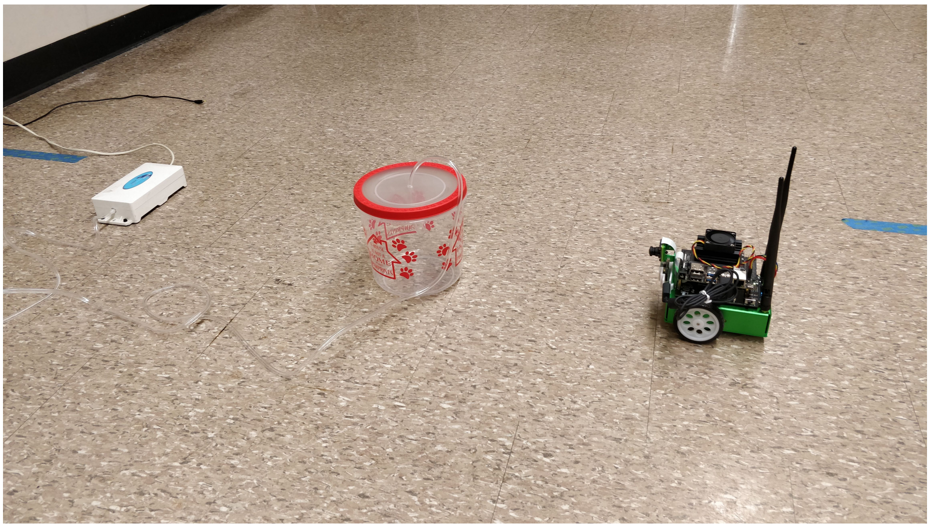

Figure 7: Jetbot measuring ozone output from normalizing container

We found that normalizing the output worked as expected.

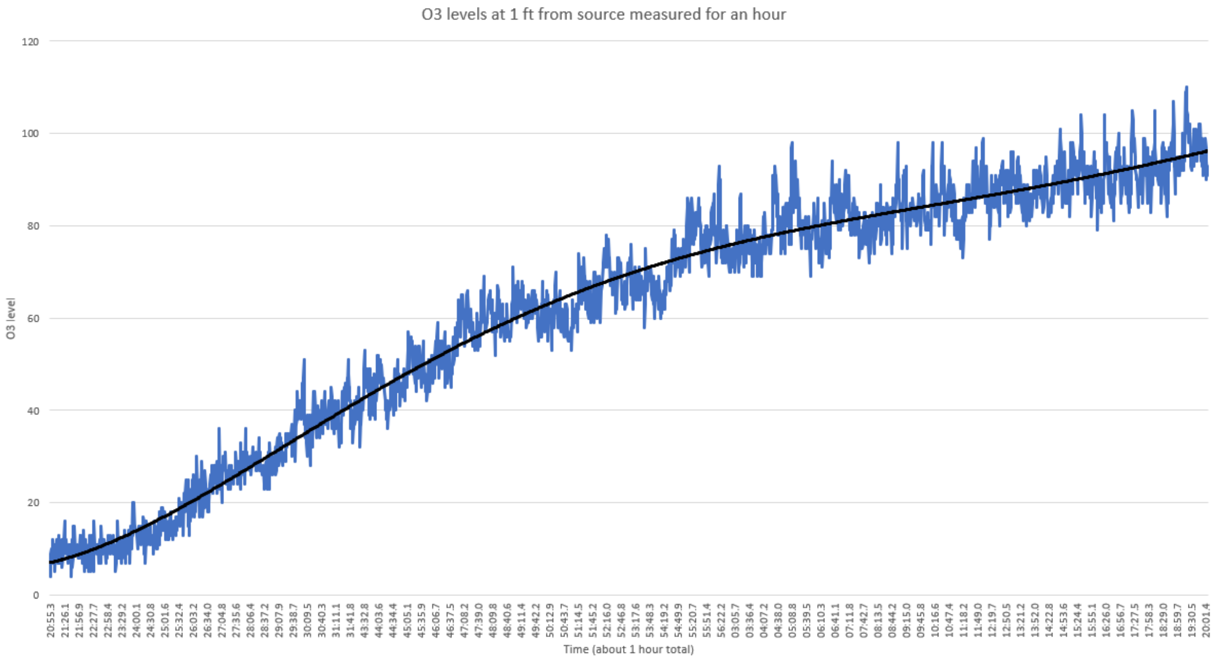

Figure 8: Normalized zone levels at one foot

We will be repeating our previous tests with a normalized ozone output in the future. With a normalized ozone output, this should lead to more consistent and repeatable experiments in the future.

Proof of Concept: Heat Source Detection

Since the ozone source detection testing led to some issues, we decided to prove that the Jetbot has the ability to move towards a heat source. To ease are concerns that the Jetbot could find the source, we ran similar tests to that of the ozone source tests. To start, we measured the heat source from three feet with the Jetbot.

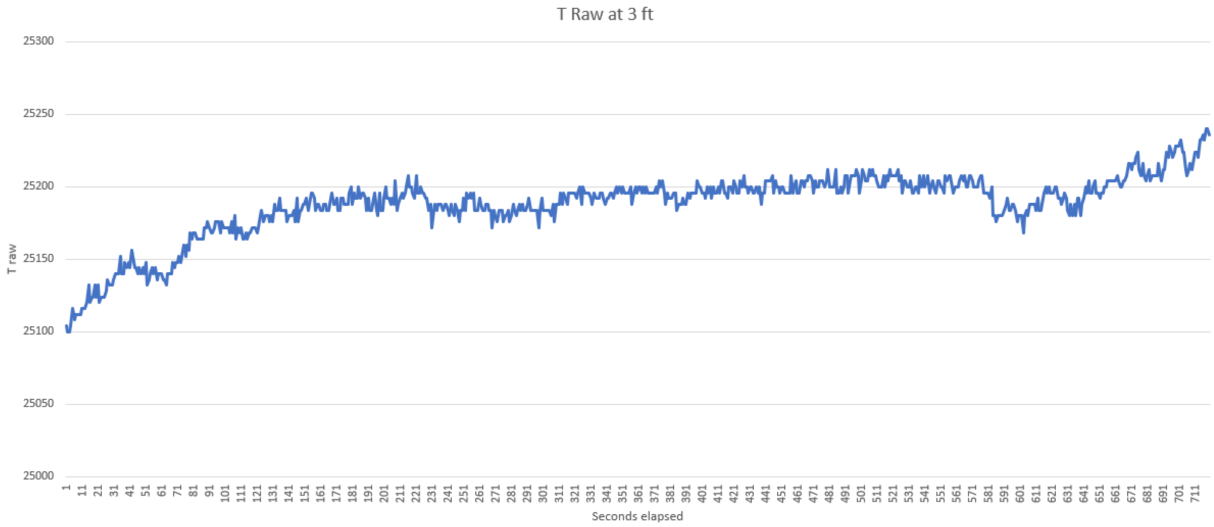

Figure 9: Heat levels at three feet

It was exciting to see that there was a consistent level of heat at 3 feet. This was expected. We decided to adjust the "line routine" to detect heat instead of ozone. The results from the "line routine" tests were about 75% successful. We believe that a higher success rate can be achieved by adjusting the distance between the two points that the Jetbot takes readings at and tuning the threshold that stops the Jetbot when it detects the source.

Future Concerns and Tests

Testing with new ozone generator

We plan to redo previous ozone detection tests with a new ozone generator and with the normalizing container.

Ozone dispersion through an environment

We would like to measure ozone concentration at different intervals simultaneously using multiple sensors so we can understand how ozone travels from a source.

2D heat source detection

We plan to adjust the "square routine" to detect a heat source.

Adding localization to the Jetbot

The Jetbot currently does have a method a method of locating itself in a 2D space. We are brainstorming ideas to fix this issue. This may be done with computer vision with QR code like images placed around the Jetbot's environment, with ultrasonic sensors to measure distance, or using a low cost lidar solution.

Ozone concentration threshold

Since there will be local minimums and maximums of ozone concentration while finding the source, we will want to find a way to raise the threshold in environments that have a greater amount of ozone leaking. This would happen automatically and would help the Jetbot get closer to the source before stopping.