Wind Detection and Avoidance Using a Crazyflie Micro Drone

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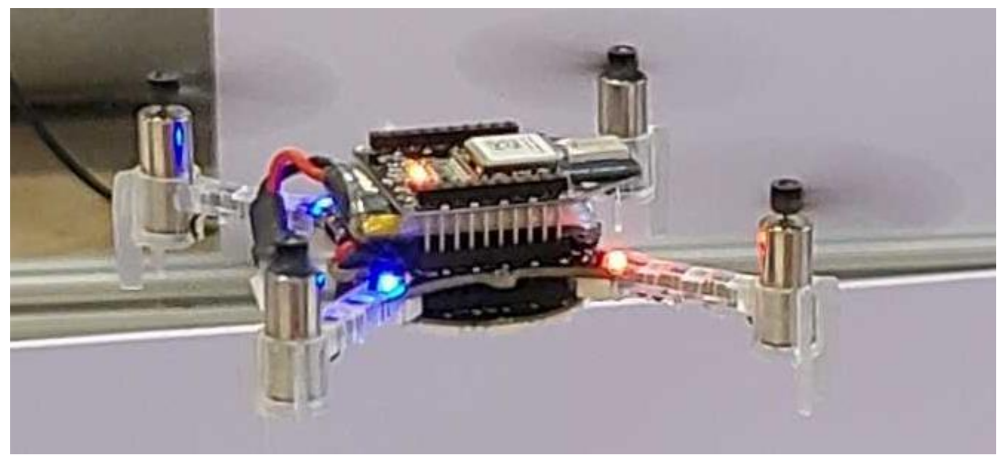
Introduction

Operating UAVs in urban environments can be difficult due to complex wind patterns. Being able to detect wind without additional sensors can allow for better operation in last mile package delivery, infrastructure inspection, and urban air mobility.

Objective: Develop an artificial neural network to detect wind presence using only sensors already onboard a micro aerial vehicle.

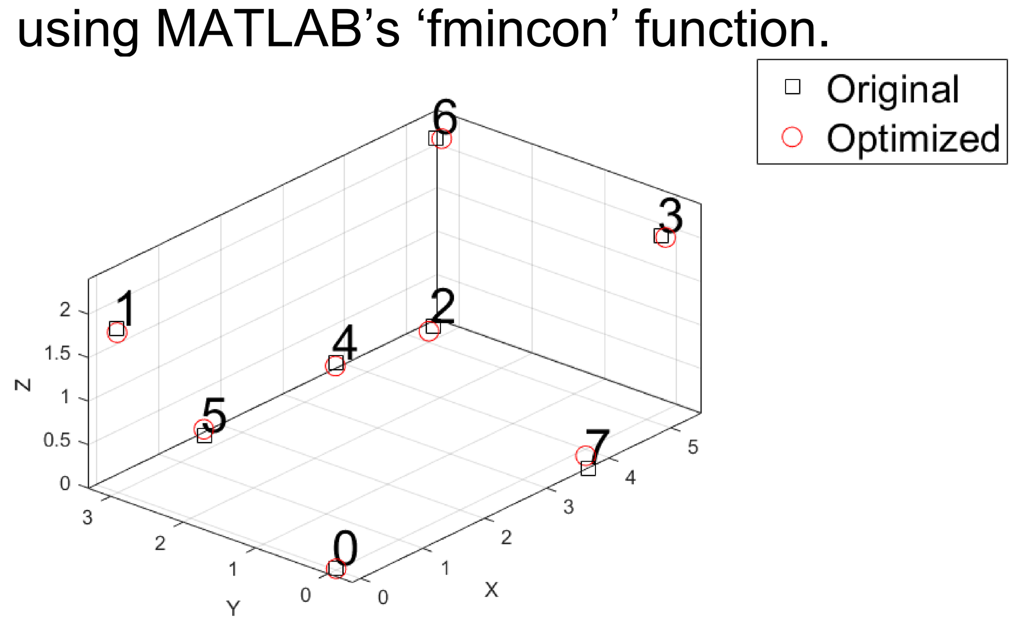


Crazyflie 2.1 Drone

Methods

Controlling the Crazyflie

- Autonomous control of the Crazyflie was achieved through python scripts and the Crazyflie python library (cflib).
- Absolute position was determined using the Loco Positioning System with eight anchors broadcasting Ultra Wide Band to a tag on each Crazyflie. The position was calculated using Time Delay of Arrival.
- The locations of the anchors were optimized through constrained nonlinear optimization using MATLAB's 'fmincon' function.



Loco Positioning System Setup with Location Optimization

Artificial Neural Network

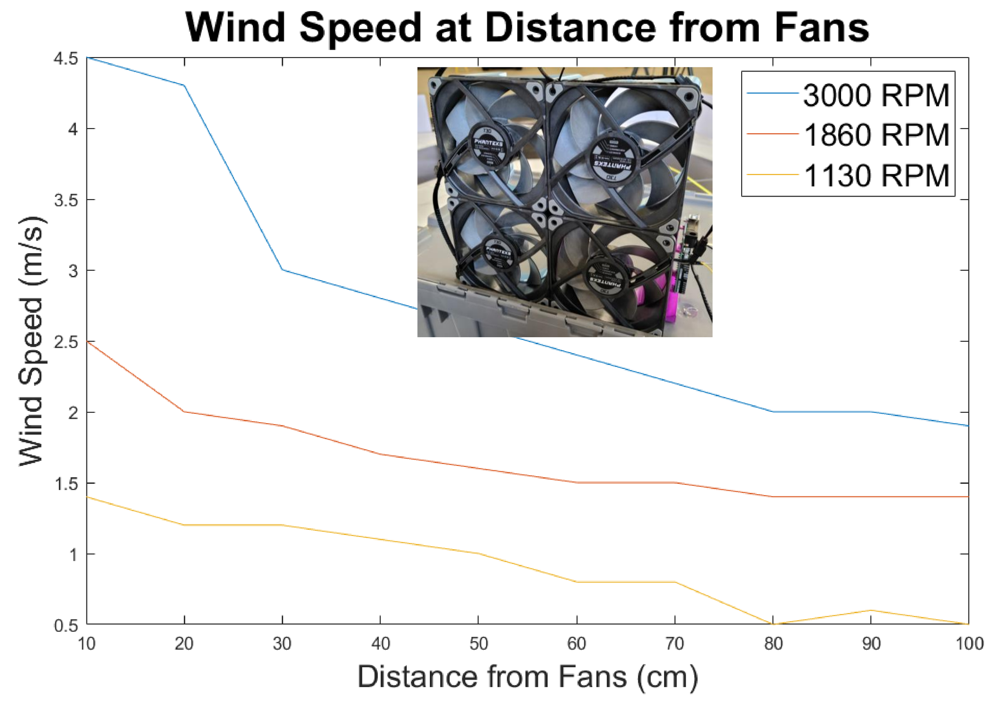
To detect wind presence, a binary classification artificial neural network was created using TensorFlow.

Collecting Training Data

The model training data was collected by logging position and gyroscope data while flying a variety of trajectories in various wind conditions. Wind presence was determined by comparing the Crazyflie's position to the known location of the wind.

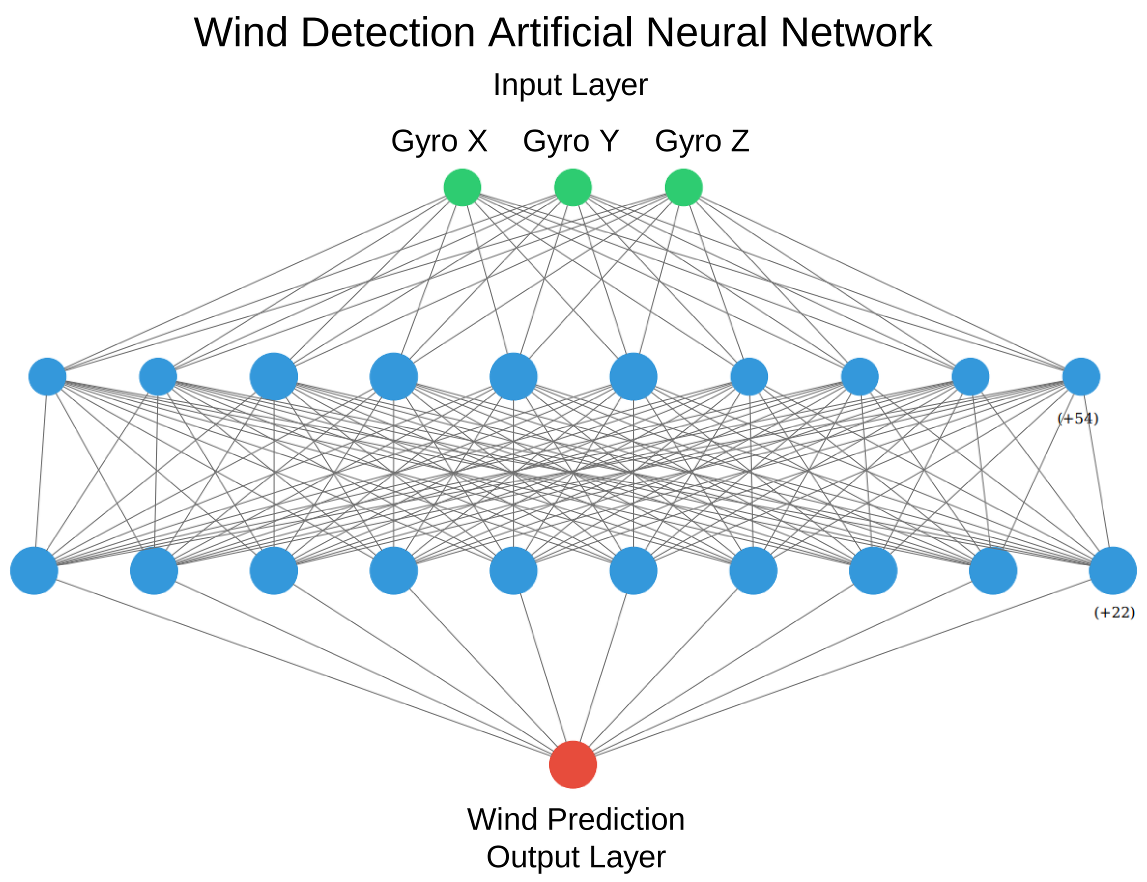
Fan Configuration

Artificial wind was created using a configuration of four 120mm computer fans. Wind speed was regulated using Pulse Width Modulation waves from an Arduino.



Relationship Between Wind Speed and Distance from Fans at Various Fan Speeds

Model Architecture

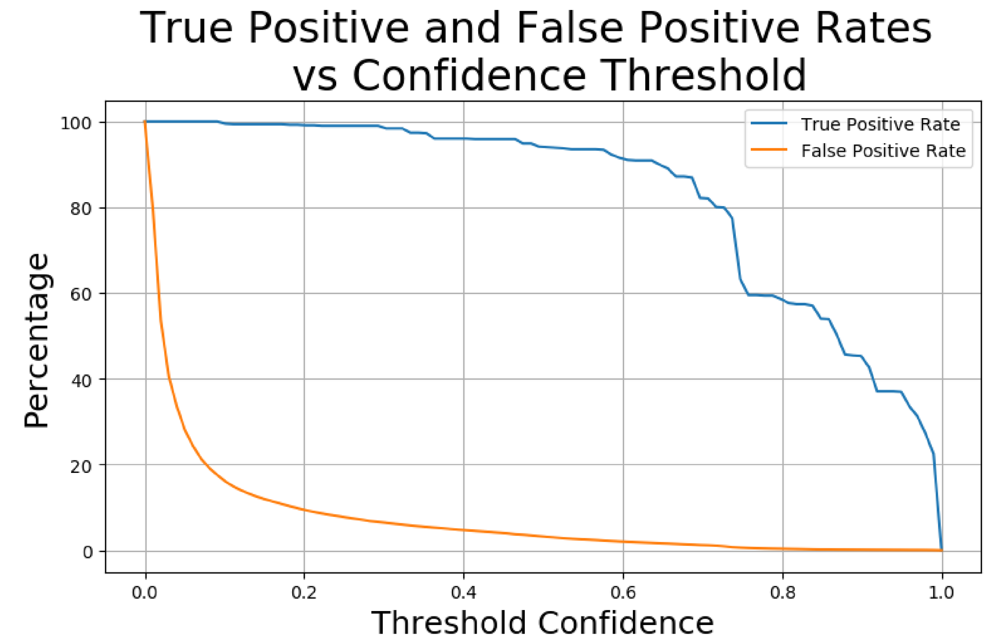


Artificial Neural Network Architecture

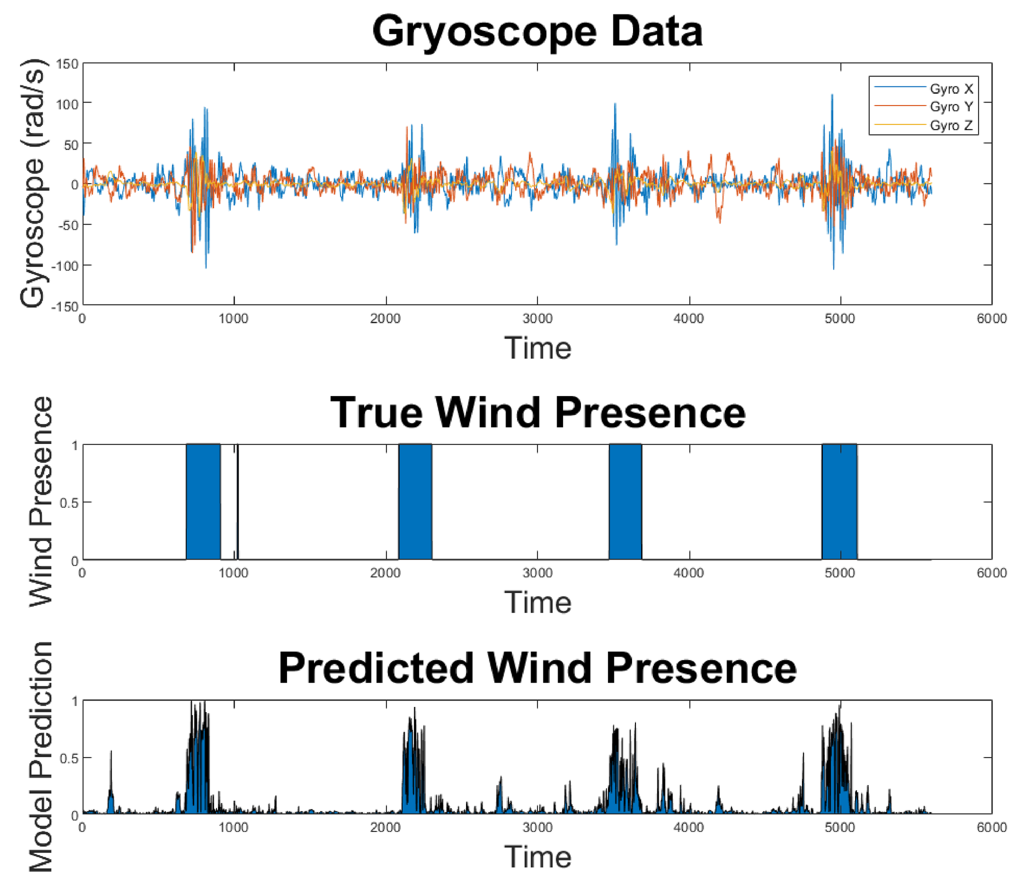
Results

ANN Model Performance

Model evaluation is based on ability to achieve accurate true positives and minimize false positives. To accurately modify the trajectory only where there truly is wind, it is necessary to reliably detect wind presence, while avoiding false alarms.



Ability of Model to Correctly Predict Wind Presence and Avoid Wind Absences



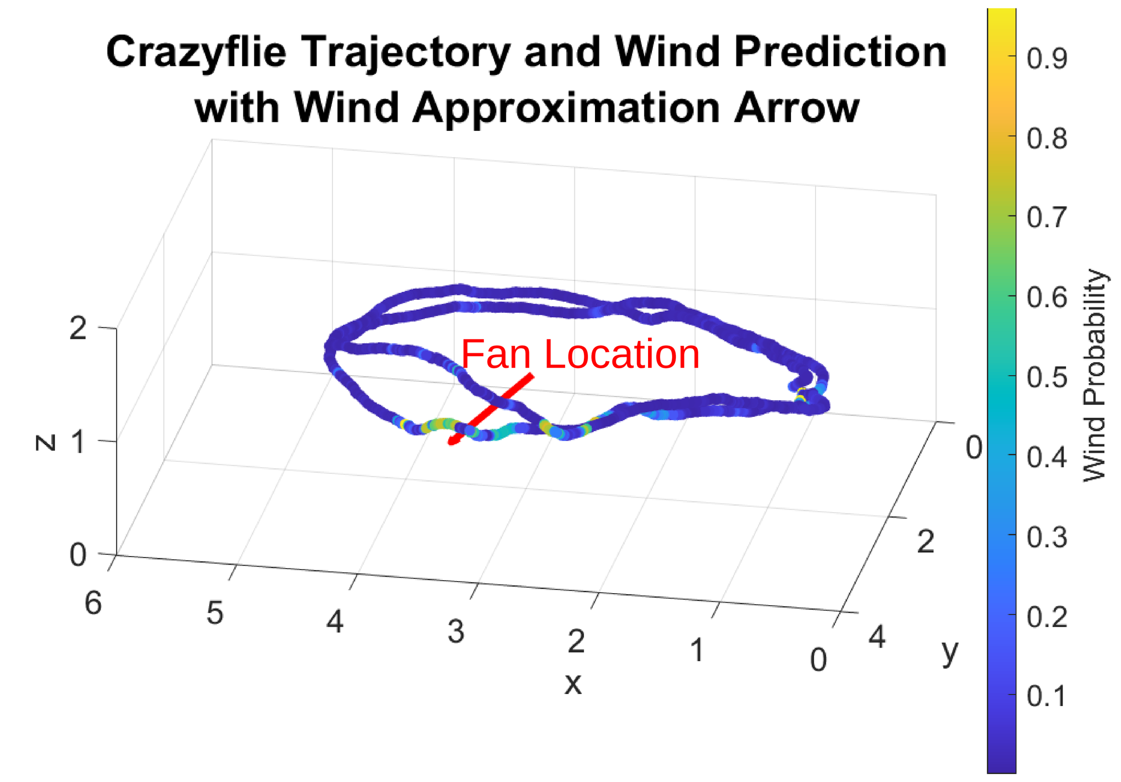
3-Dimensional Gyroscope Data, Actual Wind Based on Absolute Positioning System, and Wind Detection Model Prediction

Wind Avoidance Algorithm

The Crazyflie trajectory is generated as smooth splines through specified waypoints. Initial waypoints were given. If wind was detected during the first loop, a waypoint was added to cause the Crazyflie to avoid the wind by flying higher.

Conclusions

Using the onboard gyroscope of the Crazyflie, an artificial neural network was successfully trained to detect wind presence and an algorithm was successfully deployed to adjust the trajectory to avoid the wind.



Loop Trajectory with Outward Blowing Wind. Crazyflie Adjusts Trajectory of Second Loop to Avoid Wind.

Future Work

Swarm Wind Detection and Avoidance

The next step in this research is to apply the same algorithm and wind detection model to a swarm of drones. In addition, the wind avoidance algorithm can be improved to allow for the avoidance of several spatially dispersed and time-varying wind sources.

Wind Speed Measuring

Another area of interest with this research would be to expand the ANN to include additional sensor data including accelerometer and/or barometer and train the model to predict the wind speed, not just the presence of wind.

Acknowledgements

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