Development of an Unmanned Aerial Vehicle (UAV) for Episodic Air Pollutant Measurements

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Aim

• Using UAVs to collect three-dimensional time series data of pollutants such as particulate matter (PM) and CO$_2$.

• Develop data driven methodologies to design/build plume models.
Motivation

• Plume Detection
• Estimating the area of impact caused by wildfires, chemical explosions and refinery pollution.
• Quantitative and qualitative data collection of invisible plumes.
• Fugitive VOC emissions from sources such as refineries.
• Source estimation of wildfires/chemical leaks.
State of the Art

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- Characterization of the Particle Emission from a Ship Operating at Sea Using Unmanned Aerial Vehicle

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The measurement device houses the main circuit board. The CO and CO₂ sensors are plumbed in line with a micropump and the particulate matter sensor is exposed to ambient air through a window on the side of the enclosure.
Sensor Package

Our sensor package consists of non-regulatory grade low cost sensors. They consist of:

- PMS7003: PM Sensor (size and mass)
- MH–Z19B: CO\textsubscript{2} Sensor (NDIR)
- Grove Multichannel Gas Sensor (NO, CO, NH\textsubscript{3}, CH\textsubscript{4})
- MAX31855 Thermocouple
- DS18B20 Thermistor
- BME280: Pressure/Temperature/Relative Humidity Sensor
- (External) ResponseONE Ultrasonic Anemometer
Controlled Burn – Plume Detection

Our site for this experiment was near the town of Winters, California.

We conducted a controlled burn of agricultural waste in a large area of land away from agricultural fields and human population.

We flew the drone into the plume and tried to keep it centered at the smoke despite changing wind speeds and direction.

Smoke emission rate was also a very dynamic factor during our data collection.
General Notes

• Since battery life of our drone was a limiting factor of the experiment, we collected the data in two sets during the burn:
  • Set 1 was collected as soon as the burn commenced.
  • Set 2 was collected once the battery from Set 1 had drained and replaced.

• In the following slides, the data is plotted against a common axis of time in seconds.

• Take-off and landing times of the drone can be inferred from the ‘Pressure’ sub-plot. Since Pressure and Altitude are inversely related, a decline in pressure corresponds to an increase in altitude and vice versa.
Set 1 Flight Path

- Flight Path
- Take-Off and Landing Spots
- Our Burn Site
- Final Stage burning of other agricultural waste
Set 1
Set 1
Set 1

PM1.0

PM2.5

PM10

PM Number (> 0.3μm/0.1μm)

CO

Temperature

Pressure

Relative Humidity

Temperature (°C)

Pressure (kPa)

Relative Humidity (%)

Carbon Dioxide

Ammonia

NO2

Methane

CO2 (ppm)

NH3 (ppm)

NO2 (ppm)

CH4 (ppm)

Time (s)

Time (s)

Time (s)

Time (s)
Set 1 2-D Path
Set 1 3-D
Set 1

Concentration heat map

Wind Direction
Set 2
Set 2 Flight Path
Set 2 2-D Path
Set 2

Concentration heat map

Wind Direction
Conclusions/Limitations

- We flew our low-cost air quality package on a UAV and were able to detect plumes (visible and invisible).
- Our measurements are consistent with progressive stages (flaming and smoldering) of the fire.
- The series of experiments can be used to measure different chemicals in various plumes with the installation of an appropriate sensor package.
- Constraining Factors:
  - Lack of opportunities to conduct experiments
  - Flight Regulations
Work in Progress/Future

- Data collection tests in different sites
- Create a plume distribution map
- Plume model creation combining machine learning and first principles
- Implementing plume tracking in 3-D
Wind Direction

Plume Acquisition and Tracking
Plume Acquisition and Tracking
Plume Acquisition and Tracking

Wind Direction