

# Demo Abstract: A Sensorless Drone-based System for Mapping Indoor 3D Airflow Gradients

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## ABSTRACT

With the global spread of the COVID-19 pandemic, ventilation indoors is becoming increasingly important in preventing the spread of airborne viruses. However, while sensors exist to measure wind speed and airflow gradients, they must be manually held by a human or an autonomous vehicle, robot, or drone that moves around the space to build an airflow map of the environment. In this demonstration, we present DAE, a novel drone-based system that can automatically navigate and estimate air flow in a space without the need of additional sensors attached onto the drone. DAE directly utilizes the flight controller data that all drones use to self-stabilize in the air to estimate airflow. DAE estimates airflow gradients in a room based on how the flight controller adjusts the motors on the drone to compensate external perturbations and air currents, without the need for attaching additional wind or airflow sensors.

## CCS CONCEPTS

• Computer systems organization → Sensor networks; Sensors and actuators.

## KEYWORDS

public health, edge computing, artificial intelligence, pervasive sensing

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## 1 INTRODUCTION

The growth of low-cost intelligent devices has made our environments more intelligent and greatly improved our quality of life.

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Many of our devices and computers have sensors that can sense, actuate, and understand the physical world for a variety of different applications. One application of particular interest is monitoring airflow within indoor spaces.

Indoor ventilation and airflow has garnered more attention because of how effective proper airflow is in preventing the spread of airborne diseases in indoor environments [2]. One way to measure airflow in an environment is to deploy wind sensors throughout [1]. However, unless a large quantity of sensors are deployed, it is not possible to obtain fine-grained estimates of airflow and ventilation everywhere.

A more scalable solution is to have a person move around the space and take measurements. To reduce labor, we can even have robotic vehicles, such as drones, to automate this task. In recent years, we have seen a drastic fall in price of and size of drones. As such, we envision that drones will be utilized as a powerful mobile sensing and actuation platform for a variety of indoor applications [5], not only outdoors.

To measure airflow in a space or any other physical phenomenon, existing works typically load different sensors onto the drone [4]. However, such solutions are inefficient because they require sensors to be small in size and often require an additional processing unit to sample and log readings.

In this work, we explore a mini-drone's capability in estimating indoor airflows out-of-box, without adding external sensors. DAE only utilizes the readings and data logged from the flight controller, which all drones have and use to adjust for wind and other perturbations while flying, to estimate airflow. Drone flight controllers can adjust the motor speed, as well as have access to data from typical sensors found on most drones, such as inertial measurement units (IMU), barometers, and cameras. These built-in sensors can give drones a comprehensive understanding of the ambient environment.

## 2 SYSTEM ARCHITECTURE

Figure 1 shows the architecture of the proposed system. The system consists of a low-cost mini-quadcopter that flies throughout an indoor space to estimate airflow, without needing additional external sensors.

With an 80 USD mini-drone, when holding its position in the air, an air current can disrupt its altitude and position. The drone's change in altitude and position can be estimated through in-built sensors such as an inertial measurement unit (IMU), commonly

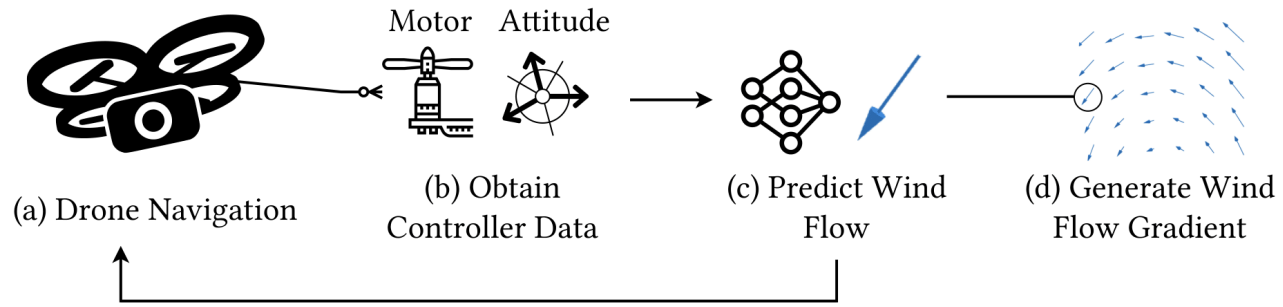


Figure 1: System architecture.

found on most drones. Furthermore, the flight controller will attempt to stabilize the drone and maintain its position in the air with the help of additional sensors such as an optical flow, camera, distance sensor and altimeter. The flight controller's power output to the drone's motors can also provide useful information for estimating the amount and direction of airflow.

## 2.1 Workflow

To estimate the airflow gradients of an entire space, the drone first navigates through the space. Second, at regular intervals, the drone stops, while DAE reads data from the drone's flight controller and built-in sensors. The data DAE collects include the altitude and orientation of the drone (pitch, yaw, roll), IMU (3-dimensional acceleration, gyroscope, and magnetometer), and the output power to each of the drone's motor. Next, these features will be input into a deep neural network that estimates the magnitude and direction of the airflow at that position (i.e., the airflow gradient), which we use to incrementally build a map of the wind flow gradient.

## 2.2 Drone Navigation

To navigate the space, we incorporated a SLAM algorithm [3], that simultaneously localizes and maps the location of the drone. DAE maps the estimates of the magnitude and direction of the airflow onto the generated map at the drone's estimated location.

## 2.3 Wind Flow Estimation

To estimate airflow, once the drone stops at a location, DAE measures the state of the drone through its flight controller, the power applied to each of its motors, and its built-in IMU. These features are then input into a deep neural network to estimate the airflow. To train the model, we fly the drone in a wind tunnel that provides ground truth information. We vary the direction and magnitude of the wind from the wind tunnel and collect the corresponding sensor information from the drone.

## 3 ENABLED APPLICATIONS

We envision that by incorporating drones and DAE into future homes and office spaces, we can impact the following domains of applications and services.

- **Work Space Comfort Optimization:** People have different preferences on the temperature and air quality of their workspace. A fine-grained map of indoor airflows would allow workers to find seat assignments that best meet their preferences.

- **Human movement coordination:** A map of the indoor airflow can give insight into areas of the building that sees the least amount of clean and fresh air, which could contain more airborne diseases. Making this knowledge available to occupants, may help people avoid areas where airborne diseases are festering, which is especially pertinent during global pandemics.
- **Design of HVAC and ventilation systems:** Having a fine-grained map of the airflow of a space would be useful in designing efficient ventilation systems that can quickly filter in clean air to all parts of the space.

## 4 DEMONSTRATION DESCRIPTION

In this demonstration, we will show how DAE can map the airflow of a small and blocked off space. The drone will fly around this space, estimating and mapping airflow gradients in real-time. Additionally, we will have items that generate stronger airflows on hand (e.g., hair dryers and vacuums), which we will use to change the airflow of the demonstration area to show how DAE can measure changes in airflows.

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