Balloon/Drone-based Aerial Platforms for Remote Particulate Matter Pollutant Monitoring

Xingguo Xiong, Soumil Shah, Jani Pallis
Department of Electrical/Mechanical Engineering, University of Bridgeport, Bridgeport, CT 06604

Abstract

Air pollution is the world's leading cause of environmentally related deaths, and results in tremendous environmental, social and economic costs. Particulate matter with diameter of 2.5 microns or less (so called PM2.5) is especially harmful for human health because they can penetrate into the deeper part of the lungs. Monitoring PM pollutants concentration distribution and understanding their diffusion pattern are essential to evaluate their effects on human health and environment. Traditional PM2.5 air pollution monitoring utilizes stationary ground-mounted air pollution sensors to monitor air pollution in certain fixed locations. However, such stationary air pollution sensing lacks flexibility and can only sense air pollution on ground surface. In this research, a balloon/drone based aerial platform for remote particulate matter pollutant monitoring is developed. It can measure PM2.5 air pollution in the air at different altitude and trace the diffusion of air pollutants. The data can be transmitted to ground station via wireless communication, and then uploaded to cloud server. In this way, users can check data online anywhere using computers or smart phones. The proposed aerial platform can also be used for security surveillance, wildlife migration tracking, climate change monitoring, geographical survey and other potential applications.

Introduction

Air pollution is the world's leading cause of environmentally related deaths, and results in tremendous environmental, social and economic costs. World Health Organization (WHO) estimates air pollution is responsible for almost 7 million premature deaths in 2012. According to a United Nations Environment Program (UNEP) 2014 report, the cost of air pollution to the world's most advanced economies plus India and China is estimated to be $3.5 trillion USD per year in lost lives and disease healthcare. Particulate Matter pollution poses serious threat to human health and global environment. Monitoring PM pollutants concentration distribution and understanding their diffusion pattern are essential to evaluate their effects on human health and environment.

Traditional PM2.5 pollutant concentration monitoring is carried out by static PM2.5 sensors placed in fixed ground stations. However, PM2.5 air pollution is dynamic and fluidic. The air pollutants diffuse from place to place and varies at different heights. Stationary PM2.5 sensors lack the flexibility to trace the origin of pollution or to focus on certain points-of-interest. To monitor the Particulate Matter pollution with more details and improved flexibility, a movable platform is preferred. The goal of this research is to develop balloon and Drone based aerial platforms for remote PM2.5 air pollution monitoring and analysis. The platform integrates PM2.5 sensor with GPS and altitude/pressure sensor, anemometer wind sensor, temperature sensor and humidity sensor. The balloon and drone based PM2.5 monitoring platforms can float or fly in the air for a length of time to collect data about PM2.5 concentration, location/altitude, wind speed, temperature, pressure and humidity. It can sense PM2.5 pollution remotely and transmit the data back to user via wireless communication. Based on the measurement data, a detailed 3D heat map of PM2.5 concentration distribution can be plotted. Such heat map can clearly show distribution of high and low PM2.5 concentrations, enabling a more accurate description of PM2.5 air pollution. Such balloon/UVA based aerial platform not only can be used for PM2.5 sensing, but also can be extended as a general aerial monitoring platform for other environmental and geographical conditions (e.g. studying the climate change, monitoring forest fire or ecological rehabilitation, etc.).

System Design

The proposed balloon/drone based aerial platform for PM2.5 air pollution sensing is shown in Figure 1. Such platforms integrate PM2.5 sensor with GPS, barometric pressure sensor, wind sensor, temperature sensor, humidity sensor into a single system. It can be used to monitor PM2.5 pollution and record it with location, altitude, wind speed, temperature and humidity. Based on the measurement data, a 3D heat map of the PM2.5 pollutant concentration will be plotted.

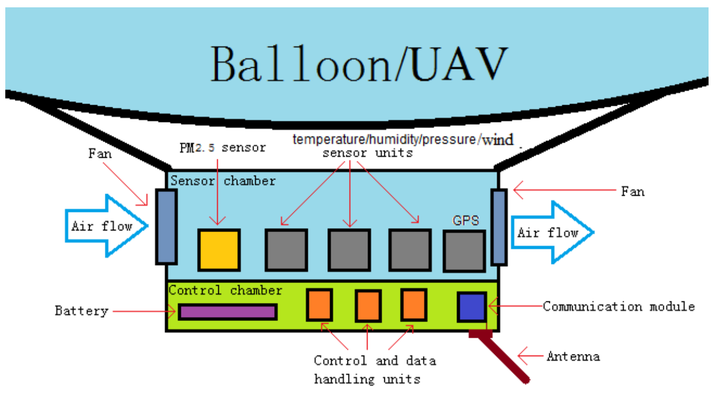


Figure 1. Block diagram of balloon/drone based aerial platform for air pollution monitoring

Wireless communication plays important role in the data transmission of the balloon/drone based PM2.5 sensing system. The sensed PM2.5 air pollution data can be saved on the microSD card loaded on the payload of the drone/balloon. It can also be transmitted back to the ground station via wireless communication. The ground station then uploads the data into cloud server (internet), which can be downloaded to computers/tablets and smart phones anywhere by the user. The proposed signal communication of the aerial monitoring system is explained in Figure 2. Considering the high altitude of the drone/balloon system, ultra long range radio frequency communication is needed. We use 2x RFD 900MHz Ultra Long Range Radio Telemetry modem for the communication between the drone/balloon and the ground station.

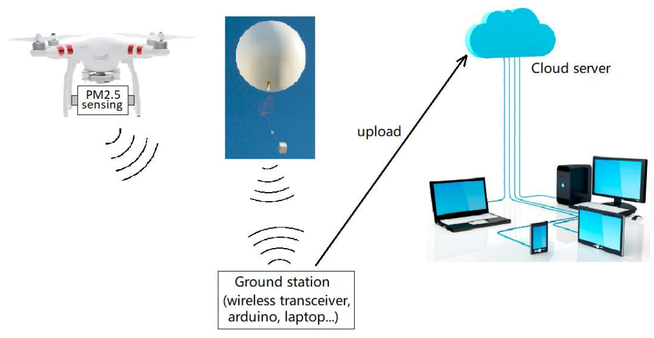
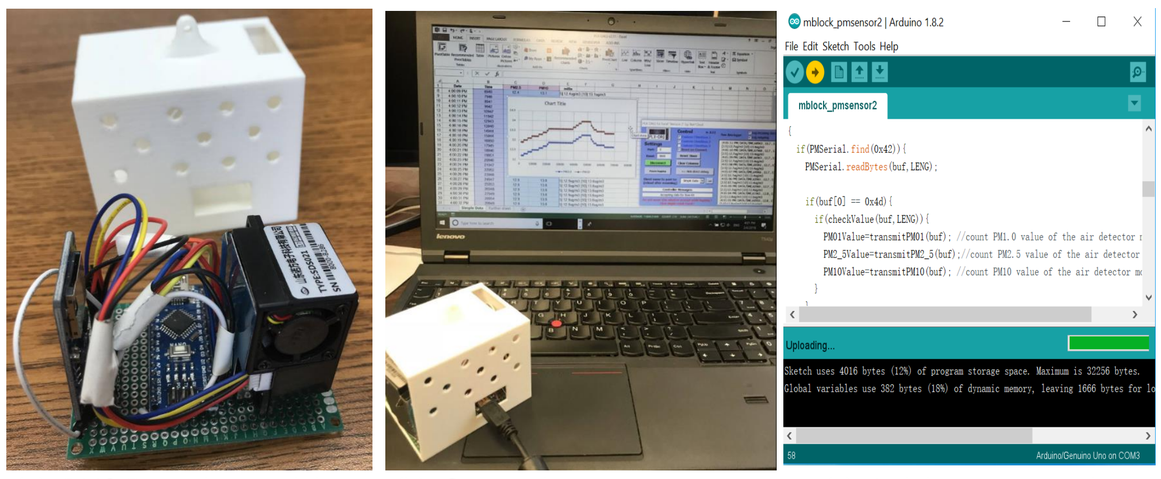


Figure 2. Wireless communication of balloon/drone based PM2.5 sensing system

System Implementation

Since drones and balloons have very limited payload capacity, the overall weight budget for the aerial sensing system is very tight. For example, DJI Phantom 4 drone has payload capacity of 462g. The maximum payload of Hubsan H109S X4 drone we purchased is in the similar load range. Some professional drones may have very large payload, but the price is very expensive. The flight time will also be reduced as payload increases. We limit the overall weight of our PM2.5 sensing system to be within 400g. The LiPo battery (Venom 20C 2S 4000mAh 7.4V Hard Case LiPo Battery) used to power the sensing system is ~238.1g. Thus only very limited weight budget is left for the sensing module. In order to process the information, we used Arduino Nano with a microSD card module. The PM2.5 sensor should be very small size with Arduino interface. We used SparkX SDS01 PM2.5/PM10 Particle Sensor. All the electric components are integrated on a customized PCB board. We used 3D printer to print a package to hold the components so that they can be anchored on the drone/balloon.



(a). PM2.5 sensing module (b). Connection to computer (c). Arduino programming

Figure 3. Arduino-based PM2.5 sensing system

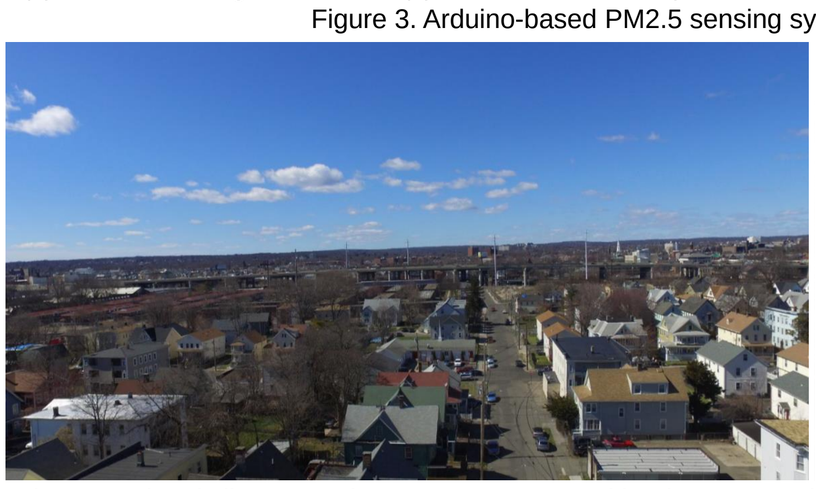


Figure 4. The skyline around UB campus captured by drone

Figure 5. Drone in the air

Example PM2.5, PM10, temperature and humidity measurement results collected by the air pollution sensing system is shown in Figures 6. It was set to capture one set of data every second.

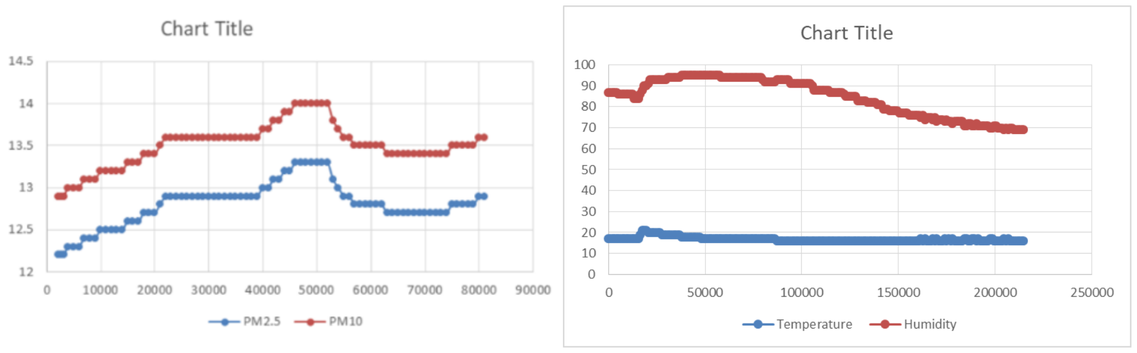


Figure 6. Captured data of PM2.5, PM10, temperature and humidity

The annual PM2.5 concentration in Connecticut in 2017 was plotted in Figure 7 (data source: EPA AirData). From the plot, we can see that New London and Litchfield counties have relatively lower PM2.5 concentration compared to other counties. This may be because of its lower population density and less traffic pollutions. It also shows that the air pollution in winter months (Nov. – Feb.) is generally highest of the year. This may be because in the winter oil/fireplace home heating contribute to the increase of PM2.5 pollution. Based on the measurement data, we can perform analysis on the trend/pattern and diffusion mechanism of air pollution.

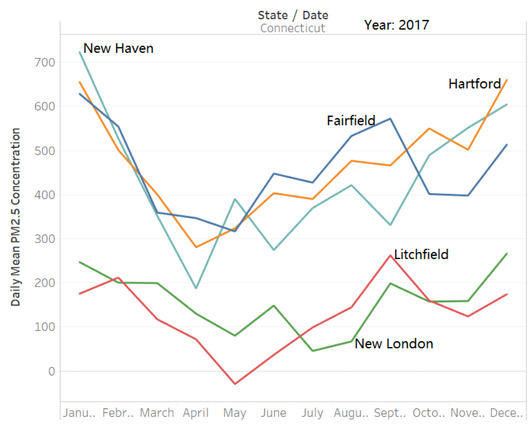


Figure 7. PM.5 pollution in Connecticut in 2017 (Source: EPA AirData)

Conclusions

In this poster, a drone/balloon based PM2.5 air pollution aerial monitoring platform is proposed. The drone/balloon based platform can remotely monitor air pollution above ground at different locations. It is a good supplement to the traditional air pollution ground sensing. The proposed system is being implemented and tested. It may be used for wildlife tracking, security surveillance, ecological rehabilitation monitoring and other applications. The sensing module and wireless communication system have bee developed. We are testing the drone/balloon system in the field to collect more data of PM2.5 air pollution in Connecticut area and perform analysis on the collected data.

Acknowledgement

This research is funded by NASA Connecticut Space Grant Consortium as Faculty Research Grant, Award No. NNX15AI12H. The authors are grateful for the support from NASA CT Space Grant Consortium.