Unmanned Aerial Vehicles for Air Pollution Monitoring

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Tracking the source of air pollution plumes and monitoring the air quality during emergency events in real-time is crucial to support decision-makers in making an appropriate evacuation plan. Internet of Things (IoT) based air quality tracking and monitoring platforms have used stationary sensors around the environment. However, fixed IoT sensors may not be enough to monitor the air quality in a vast area during emergency situations. Therefore, many applications consider utilizing Unmanned Aerial Vehicles (UAVs) to monitor the air pollution plumes environment.

Keywords: UAV ; unhealthy polluted area ; Air Quality Index ; IoT ; DQN

1. Introduction

In recent years, the world witnessed many emergency situations regarding air pollution. These situations are caused by either accidents in industries, natural disasters, or terrorist attacks (e.g., gas leakage in Visakhapatnam, India in May 2020 [1], Fukushima nuclear disaster, Japan, in March 2011 [2]) which can cause a harmful environment for humans and requires a rapid response from decision-makers for evacuation.

A distributed air monitoring network was developed to keep an eye on the density within an area. Internet of Things (IoT) sensors played a vital role as a promising technology for application services monitoring and detecting air quality. However, an enormous number of IoT sensors should be deployed to cover vast areas. These IoT sensors are usually located at a fixed location, sensing locative and temporal variability of air quality [3]. Nevertheless, the existing distributed air monitoring system could be insufficient in large areas to collect air quality data [3]. In response, a new technology covering the large area and improving air quality monitoring is required.

The Air Quality Index (AQI) factor represents how much the air is polluted. The AQI is a global uniform index (scale from 0 to 500) for monitoring the air quality in an area. The index is divided into six ranges, where the range from 151 to 200 is denoted as “Unhealthy” in which general people, as well as sensitive people, could be affected badly [4]. It has to be noted that [4] reports that the AQI barely exceeds the 200 level in the United States. In any AQI monitoring application, the environment is a significant property, where the value of AQI can be the worst suddenly. A sub-optimized solution is needed for monitoring the AQI environment effectively.

In research and academia, deep learning has been widely used in different areas since the evaluation of hardware equipment. Some existing solutions utilize artificial neural networks (ANNs) to predict air pollution. For instance, the authors in [5] claimed that combining numerical models and real-time data in data assimilation techniques presented an outstanding possibility to produce a precise air pollution map. However, because of the air pollution plume dynamics, a circumstantial locative provisional settlement in an emergency event is highly required to act effectively in real-time.

An Unmanned Aerial Vehicle (UAV) is a small aircraft (drone) that can be controlled remotely or pre-programmed. Many applications use UAVs for military, surveillance, search and rescue, localization, remote sensing, and telecommunications. Moreover, the UAV can be used for air pollution monitoring and tracking applications. For example, the authors in [6][7][8][9][10] presented air monitoring systems using UAVs to measure air quality and pollution concentration in a predefined area utilizing different types of sensors. Another example in [11][12] developed a pollution source tracking algorithm for multi-UAVs, including strategies to prevent collisions between the UAVs.

In general, UAVs monitor and track the air-polluted environment by navigating and sensing from one area to another. To control the UAV navigation effectively, several navigation methods have been introduced (e.g., spiral [13][14], and billiard [3][6][11]). In the spiral navigation pattern, the movement focuses on a central spot with a chain of circular trajectories revolving around the center. On the other hand, in the billiard navigation pattern, the navigation starts from a corner of the selected area and then covers the entire region by moving back and forth. The authors in [14][15] claimed that the spiral UAV navigation pattern takes a significantly shorter time compared to the billiard navigation pattern to cover the entire area. However, those existing solutions require a long time to track the source of air pollution. Therefore, It is essential to utilize the UAV resources efficiently for a short time to track single or multiple polluted areas.

2. Utilizing the UAVs for Air Pollution Monitoring

The research effort regarding utilizing the UAVs for air pollution monitoring can be classified into two categories: (1) monitoring an area, and (2) finding the polluted area. The following subsections summarize these research efforts.

2.1. Monitoring AQI in the Entire Area

Nowadays, various UAV-related applications and services have been introduced for air pollution monitoring, for instance [6][7][8][9][10]. The authors in [6] employed UAVs using lightweight air pollution sensors for measuring particle matter and ultrafine particles. The experimental results showed good measurement accuracy regarding horizontal and vertical variations in ultra-fine matter concentrations. The authors in [7] proposed a vision-based UAV technique to monitor the AQI. An onboard high-definition camera was used to capture the aerial panoramic image along with various directions, and the UAV collected the AQI from all directions (360-degree images). Under different air conditions, the targeted area was divided into disjointed hexagonal grids to collect the AQI data effectively. Subsequently, authors in [7] proposed a feature-based image matching method to recognize the AQI from the images (using Haze Model and Medium transmission). The authors claimed that their results presented a good AQI observation accuracy with low power consumption.

The authors in [8] utilized a Quadrotor UAV to monitor air quality based on IoT technology. The UAV was integrated with sensors used to detect various gases and temperatures. The position of the monitored area was recognized using the Global Positioning System (GPS), and the measured data was transferred into two servers, a web server and a mobile SMS server. Authors in [9] showed a new air quality measurement to prevent atmospheric ground-based volatile organic compound pollution. The authors designed a mission planning strategy to obtain the trajectory of the UAV during data collection. Fine characterization used in [9] system effectively reduces measurement errors.

2.2. Tracking Unhealthy Polluted Area

Tracking the source of air pollution is a demanding application [11][12][16]. For instance, gas leakage may cause massive destruction when a lack of proper gas observation is not performed. Thus, finding the source of gas leakage is essential to prevent harmful circumstances.

Authors in [11] utilized multi-UAVs for tracking a source of the gas leakage by combining the particle swarm optimization algorithm and artificial potential field algorithm.

The authors used an ad hoc network to avoid collisions between UAVs for high-quality communication. However, the multi-UAV in [11] system could not support a complex multi-pollution environment. Moreover, authors in [12] proposed multi-UAV source tracking of air pollution by utilizing particle swarm optimization. The objectives in [12] were to avoid a multi-UAV collision while finding the source of air pollution.

Finding the source of air pollution quickly is beneficial and significant. However, the existing solutions use more resources (e.g., multi-UAV) and consume time to find the unhealthy area. **Table 1** represents a comparison of different existing methods along with advantages and disadvantages.

Table 1. Comparison of different existing methods.

Study	Purpose	Method	Advantages	Disadvantages
[17][18]	Monitoring	Arduino sensor modules	Air quality monitoring system	Not used for tracking. Navigation pattern not defined
[11]	Tracking	Particle swarm optimization and artificial potential field	Used multi-UAV under ad hoc network to avoid collision	Could not support in the complex multi-pollution environment
[14][15]	Tracking and Monitoring	Spiral Pollution-driven UAV Control	Covered the all polluted area	Navigation time is large due to spiral navigation pattern

Study	Purpose	Method	Advantages	Disadvantages
DUPT	**Tracking**	**DQN**	**Find out the unhealthy area within a short duration of time in both single and multi-pollution environments**	**Monitoring the air pollution environment with multi-UAV is out of this research scope**

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