CHEMICAL ENGINEERING TRANSACTIONS
VOL. 67, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Valerio Cozzani, Bruno Fabiano, Davide Manca

ISBN 978-88-95608-64-8; **ISSN** 2283-9216
DOI: 10.3303/CET1867098

Application of UAV in Monitoring Chemical Pollutant Gases

Yao Yao[a], Shanlin Wei[a], Honghui Zhang[a], Qiong Li[b]

[a]College of Physics and Telecommunication Engineering, ZhouKou Normal University, ZhouKou 466001, China
[b]Zhoukou Academy of Agricultural Sciences, Zhoukou 466001, China
yaoyao24212@163.com

The purpose of this paper is to effectively monitor the air pollution condition and prevent pollution in advance through the research. In this paper, UAV carrying digital imaging and gas analysis instrument was used to monitor the air quality of Qilu Industrial Park. With UAV and relevant technology, we found the abnormal air composition in different heights above the park. This research has proved the wide prospect of UAV's application in chemical pollutant air monitoring.

1. Introduction

In recent years, to deal with the aggravation air pollution, UAV has been widely used to monitor the chemical pollutant air.The high efficiency and accuracy performed by UAV inthe chemical pollutant air monitoring has facilitated the establishment of UAV monitoring system by the governments. This paper investigates into the effects of UAV's application in chemical pollutant air monitoring to provide reference for the environmental protection industry.

2. Literature review

In view of the application of unmanned aerial vehicles in the study of air pollutants, China has begun to gradually pay attention to it. At the moment, it is in the preliminary stage of research. The most application is only the monitoring of atmospheric environmental indicators and environmental emergency. Lu et al. stated that the indicators for monitoring included the ozone index, temperature index, pressure index, carbon dioxide index and so on. For example, the Institute of Atmospheric Physics of the Chinese Academy of Sciences developed and designed micro unmanned aerial vehicle (UAV), in which two of the models were designed to realize the modification of the ozone sensor and particle detection equipment, thereby improving the accuracy of UAV flight monitoring data (Lu et al., 2015). The design ofUAV platform, recording sensor and ground system reached the requirements of research and development design. The Anhui Institute of Science and Technology of CAS carried out the research and design of UAV platform, and combined with the spectral detection system to further realize the two-dimensional distribution of air pollution components.
Compared with the domestic research situation in China, the research technology in foreign countries is relatively mature. The Titan gas analyzer designed by MIDAC enterprises in the United States is able to measure the pollution components and pollution concentration in the range through the measurement of gas and the remote sensing technology and so on (Villa et al., 2016). The Titan system consists of I- series FTIR spectrometer with more functional modules, a metal gas measurement pool with anti-corrosion and permanent calibration function modules, and AutoQuant software package. Through the application of the software package, it can collect, record, analyze, monitor and display the concentration of information. Bayat and so on pointed out that many advanced countries began to carry out a comprehensive and in-depth study on the cooperative monitoring of air pollutants by UAV. The multi UAV cooperative system can obtain information data on the sensing equipment and realize the generation of environmental maps through the algorithm of map data modeling. It can also be understood as a map of gas distribution through the introduction of the contaminated gas data, and the analysis of the distribution map to understand the environmental information of the polluted air mass. It also provides an effective reference for task allocation and path planning (Bayat et al., 2017).

Please cite this article as: Yao Y., Wei S., Zhang H., Li Q., 2018, Application of uav in monitoring chemical pollutant gases, Chemical Engineering Transactions, 67, 583-588 DOI: 10.3303/CET1867098

There are many kinds of algorithms for image segmentation, which include histogram threshold, feature space clustering and region-based method. All the algorithms mentioned above can be summed up in the category of "bottom-up segmentation algorithms", which is mainly divided according to the data of the image. However, these algorithms cannot meet the actual needs of the identification task. Baron and Saffell stated that the main reason is that the image segmentation did not belong to the underlying processing of the image, and it was more closely related to the identification task (Baron and Saffell, 2017). More and more researchers began to lock the research direction in the application of learning algorithm in image segmentation. The specific learning algorithms include Bayesian learning, artificial neural network and K- nearest neighbor. Through the application of the above learning algorithms, Qiu et al. introduced the problem-related prior knowledge. In fact, many learning methods are based on the assumption that the sample data tends to infinity. The number of samples cannot be infinite when the actual problem is solved. Therefore, the generalization ability of the algorithm is still in a large limit and it cannot provide the accurate data for the users. On the other hand, the learning speed of the algorithm is relatively slow, and in this environment, it cannot meet the needs of users (Qiu et al., 2017). Karma and so on pointed out that, in this regard, it is necessary to understand the learning algorithm above, and further improve it on this basis, so as to achieve better performance of the learning algorithm andeffectively enhance the performance of the segmentation algorithm (Karma et al., 2015).

Peng et al. stated that research on the application of the aerial image to the target location mainly included the characteristics of the background motion of the image sequence presented in the image sequence of the first class artificial intelligence of Huazhong University of Science and Technology, which was based on *The Ground Motion Target Tracking of the Aerial Image Sequence* (Peng et al., 2015). After a large number of research and analysis, the research institutions of Shanghai Jiao Tong University in China put forward a study on the deployment of transport vehicles through square implementation of the Huber function first level uniform sparse sampling estimation of the affine transformation parameters. Through the use of aerial image information, this method can only lock the moving target from the motion background of the image, instead of determining the specific location information of the moving target.On the maritime supervision level, the research and analysis of the target tracking algorithms are mainly focused on the research of the aerial photograph or the shore-based CCTV system. For example, Xiao Fei, a researcher at Dalian Maritime University, launched a large number of studies on *The Software of the Main Control Center of the Target Linkage CCTV System*. Scholar Li Xiaolin carried out a large number of researches of *Research on the Detection and Tracking Method of Moving Target Detection Based on (VTS) CCTV*. Scholar Shen Rui launched a large number of researches on *Automatic Tracking Technology and Realization of Ship Based on VTS Images*. Scholar Tao Jin, a researcher of Jimei University, studied the algorithm of *Research on ECDIS Target and Maritime CCTV Intelligent Association*. Li et al. pointed out that direction of the above research is based on the algorithm, but it is not for the purpose of determining the location of the target (Li et al., 2017).At present, Wang Ying, a researcher at Dalian Maritime University, proposed a video surveillance target positioning technique in the binocular stereo vision theory in *The Application of CCTV Target Positioning Technology in the VTS Field* by a large number of research and analysis (Pang et al., 2018).

To sum up, in the above research work, the air pollution problem occurring in some cities is mainly focused on. With the continuous and rapid development of the economic globalization, the level of modern economic growth in China is increasing rapidly. At the same time, the problem of air pollution is also increasing. With the increase of the population and the number of motor vehicles, the air quality and the pollution of the straw are produced by the large factories. Therefore, based on the above research status, the real time aerial images of UAV are studied and the images are segmented, so as to identify the atmospheric pollution source in the image. The air pollution source is quickly calculated and located through the unmanned aerial vehicle's own positioning system, and the air pollution source searching efficiency and success rate are improved.

3. UAV Monitoring Test and Data

3.1UAV Monitoring System

Given that the exhaust gas emissions into the air have caused serious environmental pollution, this flight test was conducted in Qilu Industrial Park in Zibo City of Shandong province by an unmanned gyroplane (Huanying No. 1) carrying the high resolution camera and pollutant air monitoring instrument. By this UAV, thehighresolutionimagesofthemonitoredareaandthegasconcentrationdataofnitric oxide (NO), carbon monoxide (CO) and sulfur dioxide (SO2) are obtained to be used for the air pollution condition analysis. Located in the northeast part of Linzi District Zibo city, Qilu Industrial Park is the third professional Chemical Industrial Park approved by the country. Its total planning area is 42km2 and its continental monsoon climate results in an annual average temperature of 12.2 ℃. The existing built-up area is 22km2, in which huge amounts of propylene, aromatics, trimethyl-propane, sodium formate and tert-butylamine and other chemical raw

materials are produced. Therefore the UAV monitoring of air pollution in this area is an important task of the environmental protection department.
The remote sensing system of the UAV consists of the flight platform, flight navigation and control system, ground monitoring system, task equipment and data transmission system. The flight platform for obtaining the gas concentration at different heights is the unmanned gyroplane system of a HD400 unmanned helicopter, burning fuel for power. The composite gas detector (i BRD Mx6) carried by the UAV for obtaining pollutant gas concentration load is pump-suction multi-gas detection equipment, getting rid of inaccurate data caused by airflow apparatus and the fuselage vibration.
The sensor technical parameters used by the Mx6 gas detector to detect the 3 gases are shown in Table 1. The optical image base map of the monitored area is composed of 1070 optical images with the resolution of 0.2m. Such high resolution images can be used to identify the surface land of the area, and consequently providing reference for the supervision of the pollution source presented by result of this test.

Table1: Sensor Technical Parameters

Type of Gas	CO	NO	SO_2
measuring range	0-999	0-999	0-99.9
Resolving power	1	1	0.1

3.2 UAV Flight Test

This test was conducted from 3rd to 9th of May in 2014. In the air, the video camera, high resolution optical camera and composite gas detector carried by the UAV were used to obtain the gas concentration data, high resolution optical images and high definition videos at the height of 100 to 350 meters above the industrial park. At the same time, on the ground, the composite gas detector, handheld GPS and handheld weather station are also used to obtain the data. The gas concentration data from both ground and air were analyzed to show the pollutant air distribution and their spread above this area. Based on the function division of this park, the ethylene joint chemical zone and refinery chemical zone which are located along the railway are the main sources for chemical exhaust gases. Therefore, on the south side of the railway, a monitoring zone was setup to monitor the air quality of the industrial park.
Another monitoring zone was setup in the rural area on the north side of the railway, to monitor the impact of spreading pollutant air on the nearby residential areas. Both of the areas monitored by UAV are 1.2kmx1.2km, above which the onboard composite gas detector collected pollutant air samples at the heights of 150, 200, 250 and 300meters. The monitoring results are intended to be impacted by the vibration of the propeller and the exhaust gas of the UAV itself, therefore the distance between flight routes were set to be 50 to 100meters. In addition, the UAV flied into the wind in single direction to collect data. The gas detector collected air samples with an interval of 100meters. The route design (Figure 1) and flight schedule (Figure 2) are presented below.

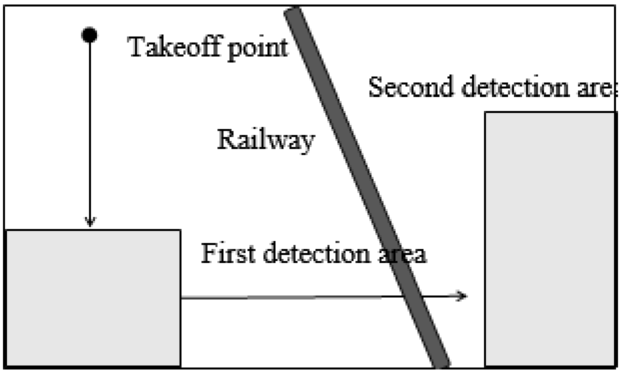

Figure 1: Route design map

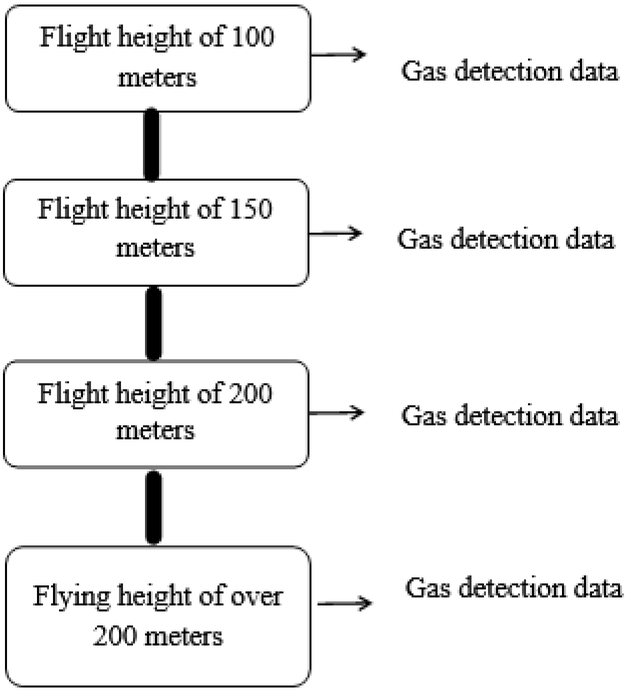

Figure 2: Flight schedule

4. Result Analysis

4.1 Test Results

In the first region, the concentration data were obtained for the gases at the heights of 150 and 250 meters above the area. In the second region, the data were for gases at the heights of 200, 250 and 350 meters. To maintain the comparability between the ground and UAV data, the ground test adopted the same composite gas detector (i BRD Mx6) as the one that is carried on the UAV. Meanwhile, to qualitatively analyze the ability of the UAV system in emergency remote monitoring of the pollutant air in the industrial park, the built-in data process system was used to eliminate the system errors. The gas concentration of CO, NO, SO2 obtained from both in the air and on the ground and their effective points are presented in Table 2 and 3. The gas concentration data obtained by the gas detector are composed of discrete data. All the gas concentration data have been normalized for better comparative analysis. In this paper, the standard deviation method is used for original data linear transformation, and the result values are mapped to [0-1]. The transfer function is shown in Equation (1):

$$X^2 = \frac{x - \min}{\max - \min} \tag{1}$$

In the above equation, X is the normalized value of the gas concentration sample data; x is the gas concentration sample value; max is the maximum value of the gas concentration sample data; and min is the minimum value of the gas concentration sample data.

Table 2: First Regional Monitoring Data

Type of Gas	Height(m)	Effective Point	Maximum Value	Minimum Value
CO	0	9	3	1
	150	130	36	4
	250	130	39	2
NO	0	9	12	10
	150	130	11	7
	250	130	6	4
SO2	0	9	0.4	0
	150	130	1.8	0.6

Table 3: Second Regional Monitoring Data

Type of Gas	Height(m)	Effective Point	Maximum Value	Minimum Value
CO	0	9	3	1
	150	130	36	4
	250	130	39	2
	350	131	803	3
NO	0	9	12	10
	150	130	11	7
	250	130	6	4
	350	131	21	4
SO2	0	9	0.4	0
	150	130	1.8	0.6
	350	131	15.7	0.6

Then, the normalized data is interpolated to obtain the raster data. The Kriging interpolation method can be used to get the best overall interpolation precision. This method is used in this paper to interpolate the acquired gas concentration data, and the interpolation formula is shown as Equation (2). In this equation, Z (si) is the measured value at the ith position; λi is the unknown weight of the measured value at the ith position; s0 is the predicted position; and n is the measured value.

$$Z^{x}(S_0)=\sum_{i=1}^{R}\lambda_i(S_i) \quad (2)$$

4.2 Test analysis

The pollutant gases move in both horizontal and vertical gradients, for which the advantage of the collaboration of ground monitoring and UAV monitoring can be given full play. The superimposed analysis of the grid data of the concentration of pollutant gases at different heights in the monitoring area shows that the first area is located at the edge of the chemical plants which are the important source of pollutant gases, therefore, the concentrations of CO, NO and SO2 obtained at the heights of 150 and 250 meters and on the ground are relatively low. Among the data, CO concentration does not change with heights, and there are a few peaks in all the three heights; NO are more evenly distributed in the monitoring area, its concentration decreases with the increasing height; the concentration of SO2 obtained on ground and at the heights of 150 meters are comparatively high, while that from 250 meter are low. Such trend is due to the larger molecular mass of SO2 and thus its difficulty in spreading in the air. The pollutant gases varying with heights are shown in Figure 3.

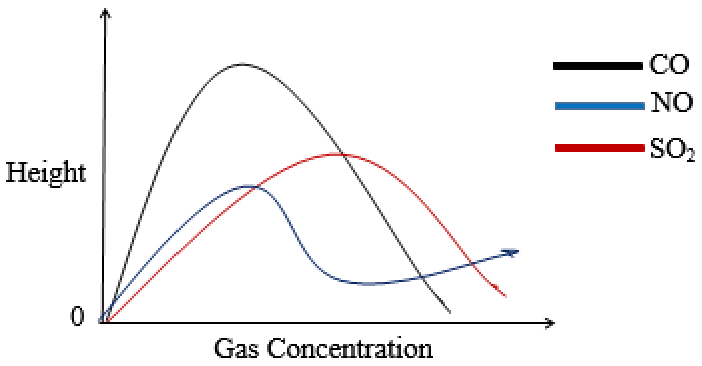

Figure 3: High Change Chart of Gas Content

The second area is located above the refinery chemical zone. The gas concentration data obtained on ground and at the height of 200 meters are relatively high, and that from the heights of 250 meters and 350 meters are low. The high CO concentration in the southern part at low height is caused by the chemical chemistry with high CO emission. The NO concentration data obtained at all 3 heights and on ground are high, and it does not obviously decrease with the increasing height, proving the high NO emissions of the chemical plants in this area. The SO2 concentration data obtained on ground and at 200 meters are comparatively high, while that of 250 and 350 meters are low. The superposition of the concentration data of gases at different heights shows regional peaks of CO, NO and SO2 concentrations in the western part of the zone. Based on the optical imagesfrom the UAV and the ground verification, three high chimneys were found at the western edge of this area, whose gas emissions impact the monitoring results.

5. Conclusion

The UAV-carried pollutant air monitoring system are expected to be an effective emergency tool for monitoring pollutant air thanks to its high resolution, flexibility, quick response, subjectivity, accuracy and impregnability of the terrain. This paper, by combining ground monitoring and UAV monitoring data of CO, NO and SO2 concentration collected by the Mx6 gas detectors, found that by conducting the 3-dimensional spatial distribution analysis of pollutant air outliers from both vertical and horizontal gradients, the pollution enterprises and sources that violating relevant regulations can be identified and supervised.

In addition, based on the research of this paper, CO, NO and SO2 presents different spread features in vertical gradient, for instance, the SO2 concentration around the pollution source decreases with the increase of height. Therefore, the vertical spread features of different pollutant gases may be used as a scientific basis for actual environmental supervision and pollutant abatement in chemical industrial parks. The continuously improving UAV remote sensing technology can be a technical support for environmental protection and will have more extensive prospects in the field of environmental protection.

Acknowledgement

Henan scientific and technological breakthrough-international cooperation project: Research on the effect of the radio wave propagation in the troposphere and ionosphere (No.182102410065)

National key research and development program: Development and experimental demonstration of new varieties of soybean mating cultivation techniques in Huang-Huai-Hai area (No.2017YFD0101406)

References

Baron R., Saffell J., 2017, Amperometric Gas Sensors as a Low Cost Emerging Technology Platform for Air Quality Monitoring Applications: A Review. ACS sensors, 2(11), 1553-1566, DOI: 10.1021/acssensors.7b00620

Bayat B., Crasta N., Crespi A., 2017, Environmental monitoring using autonomous vehicles: a survey of recent searching techniques. Current opinion in biotechnology, 45, 76-84, DOI: 10.1016/j.copbio.2017.01.009

Karma S., Zorba E., Pallis G.C., 2015, Use of unmanned vehicles in search and rescue operations in forest fires: Advantages and limitations observed in a field trial. International journal of disaster risk reduction, 13: 307-312, DOI: 10.1016/j.ijdrr.2015.07.009

Li X.B., Wang D.S., Lu Q.C., 2017, Three-dimensional investigation of ozone pollution in the lower troposphere using an unmanned aerial vehicle platform. Environmental Pollution, 224, 107-116, DOI: 10.1016/j.envpol.2017.01.064

Lu Y., Macias D., Dean Z.S., 2015, A UAV-mounted whole cell biosensor system for environmental monitoring applications. IEEE transactions on nanobioscience, 14(8), 811-817, DOI: 10.1109/tnb.2015.2478481

Pang X., Shaw M.D., Gillot S., 2018, The impacts of water vapour and co-pollutants on the performance of electrochemical gas sensors used for air quality monitoring. Sensors and Actuators B: Chemical, 266, 674-684, DOI: 10.1016/j.snb.2018.03.144

Peng Z.R., Wang D., Wang Z., 2015, A study of vertical distribution patterns of PM2. 5 concentrations based on ambient monitoring with unmanned aerial vehicles: A case in Hangzhou, China. Atmospheric Environment, 123, 357-369, DOI: https: 10.1016/j.atmosenv.2015.10.074

Qiu S., Chen B., Wang R., 2017, Estimating contaminant source in chemical industry park using UAV-based monitoring platform, artificial neural network and atmospheric dispersion simulation. RSC Advances, 7(63), 39726-39738, DOI: 10.1039/c7ra05637k

Villa T.F., Gonzalez F., Miljievic B., 2016, An overview of small unmanned aerial vehicles for air quality measurements: Present applications and future prospectives. Sensors, 16(7), 1072.