STM32-based Integrated UAV Air Monitoring System

Qihan Zhao*
Wuhan University of Technology,
Wuhan, China

Pengbo Zhang
Wuhan University of Technology,
Wuhan, China

Yong Chen
Wuhan University of Technology,
Wuhan, China

ABSTRACT

With the increasing severity of air pollution, it has become an urgent problem to conduct large-scale targeted detection of various evaluation indexes of air pollution degree. Based on the current status of air monitoring, this paper designs an integrated UAV air monitoring system based on STM32 by combining UAV technology with integrated MCU sensing and detection technology with high mobility and wide coverage. It can not only realize real-time air quality detection, but also reduce the cost and time of air detection. At the same time, the evaluation index can be sampled from the three-dimensional space, which has the advantages of fast sampling speed, good timeliness and high stability.

CCS CONCEPTS

• **Computer systems organization** → Embedded and cyber-physical systems; Sensor networks.

KEYWORDS

Air monitoring, STM32, Sensing detection, AD conversion, PID

ACM Reference Format:

Qihan Zhao, Pengbo Zhang, and Yong Chen. 2023. STM32-based Integrated UAV Air Monitoring System. In *2023 4th International Conference on Computing, Networks and Internet of Things (CNIOT '23), May 26–28, 2023, Xiamen, China.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3603781.3603921

1 INTRODUCTION

In recent years, with the rapid development of our national economy, air pollution has become a serious problem that all countries must face. It has become an important technical problem that all the indicators of the degree of air pollution are tested in stereoscale. Along with the industrial exhaust emissions, the air nitrogen, sulfide and other corrosive gases and particulate matter content is increasing [1]. The main sources of air pollutants are industrial emissions, winter heating emissions, motor vehicle exhaust emissions, dust weather, construction dust, etc. The total concentration of pollutants in the north is higher than that in the south, and the content of pollutants varies with different regions and seasons. During winter heating, the concentration of PM10, PM2.5 and SO2 rose sharply due to the increase of coal burning in the Figure 1.

At present, the air monitoring mainly includes portable manual detection device, fixed point base station detection and mobile monitoring points. However, the above three methods are mainly aimed at the air monitoring at lower levels. At the same time, they fluctuate greatly under the influence of environment and have low detection stability. Therefore, they cannot complete the overall detection of regional air. Currently, there are few sampling ports for the peripherals of air testing instruments, and only one kind of pollution gas is used for detection. Therefore, comprehensive detection of a wide range of various air pollution substances cannot be completed, and the flexibility is poor [2]. Therefore, an integrated air detection system with high flexibility, wide coverage and strong mobility is urgently needed to solve the problem of increasingly serious air pollution. In 2014, EDC developed a HIM-6000 instrument that can simultaneously detect multiple gas contents. By setting dual detection ports, it uses replaceable external sensing probes to detect multiple pollution gases. In 2018, Yichang Company developed SEM2000-M UAV environmental detection platform, which combines the remote sensing technology of UAV for emergency detection and air pollution detection. The environmental detection platform is equipped with wireless communication module to transmit detection data in real time to complete monitoring. In 2019, a team at the University of Barcelona developed a nanocrafter equipped with an air probe that can detect indoor air through autonomous navigation [3-4].

Based on the above status quo, a comprehensive air monitoring system based on STM32 is designed in this paper. Time division multiplexing transmission of various sensors is realized through single-chip peripheral IO port, and the air quality detection system installed on UAV is adopted. Compared with traditional air detection methods, the system can collect the air quality of any point in three-dimensional space [5]. The spatial distribution characteristics of pollutants can be analyzed more comprehensively, accurately and conveniently. In terms of sensors, the sensor module is used to sample the main indicators of air pollutants.

2 MONITORING SYSTEM DESIGN SCHEME

The integrated UAV air monitoring system based on STM32 mainly detects air pollution at different heights in real time and dynamically, and transmits the collected data of different evaluation indicators to the signal receiving end through the wireless transmission system. The system realizes the remote control real-time detection and dynamic display of different indicators of air monitoring values. At the same time, the attitude of the UAV is monitored and data is collected through the gyroscope sensor set by the system. The attitude of the UAV is obtained and the self-attitude adjustment can ensure the stable operation of the device. The following figure shows the schematic diagram of the monitoring system, which

*Corresponding author: z2993737597@163.com

CNIOT '23, May 26–28, 2023, Xiamen, China

ACM ISBN 979-8-4007-0070-5/23/05…$15.00
https://doi.org/10.1145/3603781.3603921

Figure 1: Picture the air pollution situation

is mainly composed of the main control module, attitude sensing module, integrated sensing module and wireless communication module [6].

Its monitoring system mainly includes the following parts:

- Main control module: mainly coordinates all modules of the whole system, accepts analog signals transmitted by different sampling modules for AD conversion, and controls the operation of the overall device to adjust the attitude of the UAV;
- Attitude detection and adjustment module: the current operating status of the UAV is obtained mainly through real-time signal detection of the UAV, and PWM wave generated by the main control module is accepted and adjusted by the control device to achieve the purpose of stabilizing the operation of the device;
- Integrated sensing module: It carries out cyclic sampling of a variety of pollution gases including PM2.5 through built-in high-frequency sampling, in which time division multiplexing technology is adopted to solve the occupation problem of STM32 parallel port.

Design When the UAV is used to monitor the air in the area block, the multi-sensor module will sample the gas in it, and the signal processing module will carry out AD conversion and serial communication input, so as to carry out data analysis and processing of the component data [7]. The converted digital signal will be uploaded to the system terminal through the wireless communication module, and the terminal will realize data reception and analysis and processing.

3 HARDWARE DESIGN SCHEME

The hardware part of the design mainly includes the microcontroller main control module, integrated sensing module, attitude sensing module. Which is controlled by STM32 as the main control, the control system of the multi-dimensional sensor signal acquisition, the sensor to the air for high-frequency sampling, which in view of the air signal needs to be monitored in real time, need to ensure that the sensor module and AD module signal transmission of the same frequency, to achieve efficient signal at [8-9]. At the same time, according to the 9-axis attitude angle sensor JY901 collected by the UAV operating status, to achieve multi-angle adjustment of the UAV operating attitude, the specific hardware design scheme is shown in Figure 2 below.

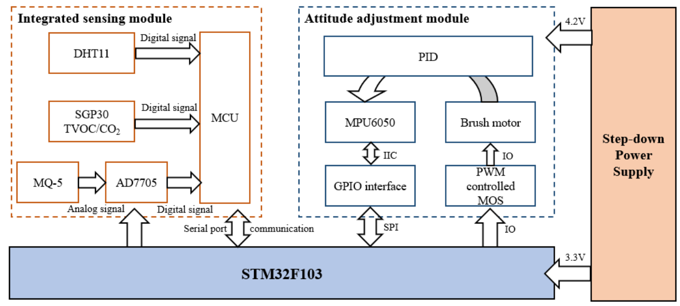

Figure 2: Overall hardware block diagram

Figure 3: Diagram system design test system diagram

3.1 Main Control Module

The main control module is mainly composed of the main control system and peripheral circuits. Its specific functions are as follows: The main control system reads and writes the data collected by the 9-axis attitude Angle sensor JY901 through the I2C bus, and transmits it to the remote control module for display and output through the communication module. At the same time, after receiving the adjustment signal, PWM wave can be generated and transmitted to the attitude detection and adjustment module to control the attitude of the UAV. The concept diagram of system design and detection is shown in Figure 3 below.

According to the above design requirements, STM32F103C8T6 is selected as the main control chip of the main control unit in this project. The working frequency of the chip is 72MHz, and the FLASH register of 512KB is included inside.

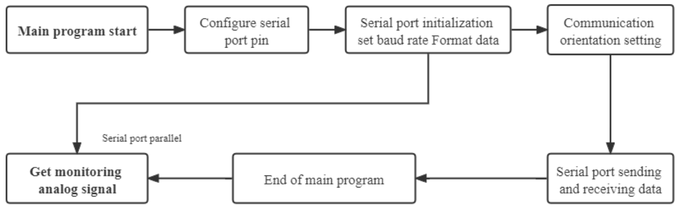

Figure 4: Flow chart of MPU6050 reading data

3.2 Attitude detection module

For the attitude detection module is mainly through the highly integrated attitude sensor to the UAV three inclination angle and acceleration measurement, taking into account the air environment may increase the integrated sensor error, magnetometer, GPS and other attitude detection components by the interference of magnetoelectricity and affect the reliability of its detection data[10]. By comparing the basic parameters of the sensor gyroscope, the 9-axis attitude angle sensor JY901 sensor is selected as the actuator for collecting attitude data. MPU6050 sensor with its high sensitivity meets the design requirements, while its data interface supports different baud rate output, which can realize the high frequency collection and processing of sampled data and ensure the real-time dynamic display of UAV attitude data. Figure 4 below shows the flow chart of the MPU6050 sensor reading data.

3.3 Communication Module

The data transmission of the STM32-based integrated UAV air monitoring system is mainly divided into two parts, namely data uploading and data receiving. Data upload refers to uploading the collected environmental parameter data to the cloud platform via GSM module, while data reception refers to wireless communication with the UAV through the ground station to realize real-time monitoring and control of the data.

3.4 Attitude adjustment PID control system

This paper presents an unmanned aircraft system based on series-level PID control, which uses a position controller and a speed controller working in series, the output of the outer-loop PID position controller as the expected value of the inner-loop PID speed controller, and the PWM duty cycle controlled by the output of the inner-loop PID speed controller to achieve accurate control of the UAV position and speed. The system also includes a balance position stabilization control system, which monitors the angle between the UAV balance position and vertical direction through the MPU6050 attitude sensor, and uses a differential control system to assist the balance position stabilization control system to reduce overshoot errors. In addition, the system includes a PID motion control system to control the speed of the UAV through proportional and integral control to maintain the stability of the UAV. The application of this system in the integrated UAV air monitoring system can achieve efficient and accurate control results. The structure of the specific carrier UAV part is shown in Figure 5 below.

(1) PID motion control system

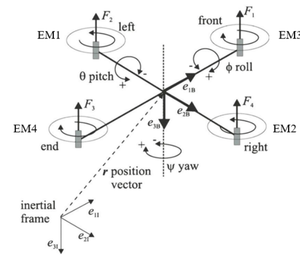

Figure 5: Schematic diagram of the structure of the carrier drone part

Path movement is integrated UAV air monitoring system for a long time need to maintain the state, in the process of carrying out the movement needs to ensure the overall UAV stability, while needing to identify their own path, in the process of path movement and will not have a change in the state of movement.

$$U_d = K_{P2} \cdot e\,(v) \tag{1}$$

where K_P : the speed proportionality constant of this part of the PI control system

And then given that the motion state and tendency do not change during the path operation, so it does not bring a large fluctuation value during the operation, the system expectation deviation only depends on the external environmental factors, the system input side to introduce integral control to reduce the steady-state error, then.

$$U_d = K_i \int_0^t e\,(v)\,\mathrm{d}t \tag{2}$$

where K_i : the integration constant of the speed system controller. From the above calculations can be obtained in this control system, the control system stability of the PI control system stability logic block diagram is shown in Figure 6, whereV_L ,V_R are the left and right motor speed values obtained from the coded data sensor monitoring.

This PI control system regulates the speed of the integrated UAV air monitoring system by superimposing the drive voltage obtained from the initial speed of the input quantity through proportional and integral operations, and then converting it into the duty cycle of the PWM control signal through the master control system.

(2) Balance position stability control system

In this project, the angle between the UAV balance position and the vertical direction is monitored by the MPU6050 attitude sensor. When the integrated UAV air monitoring system is tilted due to

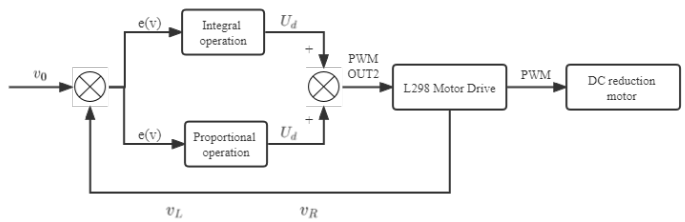

Figure 6: Design of PI control system for linear motion

Table 1: PID coefficient setting table

Closed loop	P	I	D
Motor EM1 Speed ring	3.374	3.5162	0.0179
Motor EM2 Speed ring	3.4842	3.4120	0.0181
Motor EM3 Speed ring	3.152	3.601	0.0165
Motor EM4 Speed ring	3.1231	3.5124	0.01846

motion and external human factors, the rotor assumes clockwise rotation and the rotor is then subjected to reverse torque F, causing the UAS to tilt. For a smaller tilt, a motor drive module is required to provide recovery force to the balance drive motor F_1 to keep the UAV upright.

The repulsion force provided by the motor drive is proportional to the maximum tilt deviation during tilting of the device, which is related to:

$$F_1 = K_P \cdot e(\theta) \tag{3}$$

where K_P is the proportionality constant of the equilibrium position stabilized proportional differential control system.

However, when the system receives a large external influence, resulting in a large error in the drive voltage and desired torque, it will make the system reply force applied lagging resulting in a large overshoot error, in this part of the design using differential D control system, so that it introduces a damping force proportional to the speed and desired torque and opposite to the reply force F_{f2} That is:

$$F_f = K_d \frac{\mathrm{de}(\theta)}{\mathrm{d}t} \tag{4}$$

where K_d is the differential constant of the equilibrium position stabilized PD control system. Thus there is:

$$F_2 = \mathrm{F} + F_f = K_P \cdot e(\theta) + K_d \frac{\mathrm{de}(\theta)}{\mathrm{d}t} \tag{5}$$

The timing system control period set by the system module is 20ms. after system modeling and several practical tests, the PID coefficients finally selected for this system are shown in Table 1, where the left and right motors are driven at different times and torques for stabilization, straight ahead and steering, and the corresponding coefficients are set respectively.

3.5 Overall software design

The system threshold is set according to the normal value range of different assessment indexes, which is achieved by setting the

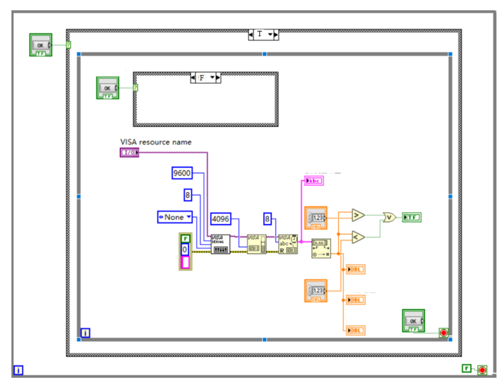

Figure 7: Block diagram design of the upper computer program

criteria of different assessment indexes. CO and SO_2 are used as pollution gas detection objects, and the alarm threshold of the system is set to 30010-6. When the gas volume fraction reaches 10010-6, the system starts to detect the presence of pollution gas and displays the pollution gas concentration information at the terminal display in real time; when the pollution gas volume fraction exceeds 30010-6, the alarm light starts to light up and the data is prompted by GSM communication The data is stored. The following figure shows the display and alarm of the terminal in the simulated situation. The interactive interface of the terminal can display the current fluctuation of the pollutant gas, and the line graph can clearly show the change of the pollutant gas concentration in different areas during the air detection process. The specific monitoring interface is shown in Figure 7.

As can be seen from Figure 8 below, in order to ensure the normal communication between the upper computer and the lower computer, we first need to configure the VISA protocol and the

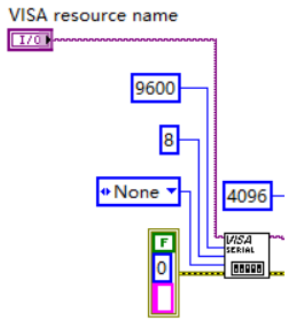

Figure 8: Serial port reading

serial port control, and set the corresponding parameters, including baud rate, serial port number, number of bits sent, stop bit and parity bit. At the same time, in order to improve the stability of the serial port reading data, each time the program is executed, the above parameters are assigned initial values. The serial port read control needs to be configured to set the number of accepted bytes to 8 bits in order to receive the value of int type sent by the microcontroller. Finally, the read data is stored in the read buffer and output to the next link.

4 SYSTEM VALIDATION

Through system design, monitoring parameters can be selected according to actual requirements, such as TSP, PM2.5, PM10 and other particulate matter parameters and CO, O_3, SO_2, NO_2, VOC and other gas parameters. Meanwhile, STM32's integrated UAV air monitoring system can detect height, location, pollutant distribution concentration and other data. At the same time, the monitoring system is convenient in operation, accurate in measurement, reliable in operation, light in volume and small in size, which provides an effective monitoring means for the analysis of air quality in three-dimensional space. The implementation scheme of this system is shown in Figure 9(left). First, the designated monitoring area is selected and the pollution gas is monitored by the monitoring system carried by the UAV. The monitoring data is transmitted wirelessly through the GSM communication system to ensure the stability, accuracy and real-time performance of the system transmission.

In the PC terminal design the upper computer to receive the transmission signal, through the threshold value of the system selected to achieve the monitoring of the normal value of different assessment indicators, while in the PC terminal will be different regions and height of the air pollution situation through the graph to display, the system specific monitoring effect is shown in Figure 9(right).

5 CONCLUSION

This paper designs an integrated pollution and air monitoring system based on STM32 according to the current air detection problems. The system designs an integrated multi-pollution index air monitoring system, which can complete the high-precision detection of a variety of air pollution gases. By carrying the air detection system on the UAV, the monitoring of air pollution at different heights can be realized with high flexibility and stability. The detected data of different air pollution indicators can be transmitted to the PC through the wireless transmission system. It can be visually converted into a two-dimensional graph for analysis and processing. The curve of air pollution gas concentration change after treatment can be viewed in the remote computer upper computer. The recent fluctuation of pollution gas concentration can be viewed through the terminal upper computer and the current type and specific concentration of pollution gas can be displayed at the same time, which has a good application prospect.

ACKNOWLEDGMENTS

This research was supported by Independent Innovation Research Fund Project of Wuhan University of Technology (Fund number: 236805007)

REFERENCES

[1] WANG Shiyu. Research on Information Collection and Trajectory Planning Strategy of UAV Based on Aerodynamics [J]. Beijing university of posts and telecommunications, 2021.
[2] XU X L. Design and implementation of air quality detection system based on UAV [J]. Xiking school, 2020.
[3] YAO X M. Real-time monitoring technology and system of air CO_2 concentration based on unmanned aerial vehicle [J]. Northwest agriculture and forestry university of science and technology, 2020.
[4] Xie L H. Air Pollution source location technology and experimental research based on unmanned aerial vehicle [J]. China university of measurement, 2020.
[5] XIE Tao. Design of Multi-parameter Air Quality Detection System Based on Four-rotor UAV [J]. Anhui University of Science and Technology,2019.
[6] Chen H S. Research and application of PM_ (2.5) and its precursors concentration monitoring system based on UAV [J]. China university of measurement, 2019.
[7] YAN Fenfen. Research and Design of Environmental Air Detection Device based on quadrotor aircraft [J]. Tianjin University of Technology,2016.
[8] LIU W F. Application of real-time database in air quality automatic monitoring system [J]. Huazhong University of Science and Technology,2015.
[9] DENG Tuo. Design of Wireless Sensor Network for Indoor Air Monitoring [J]. Wuhan University of Technology,2015.
[10] Yu Kesheng. Research on Indoor Air Monitoring System Based on Embedded Linux [J]. Huazhong University of Science and Technology,2013.

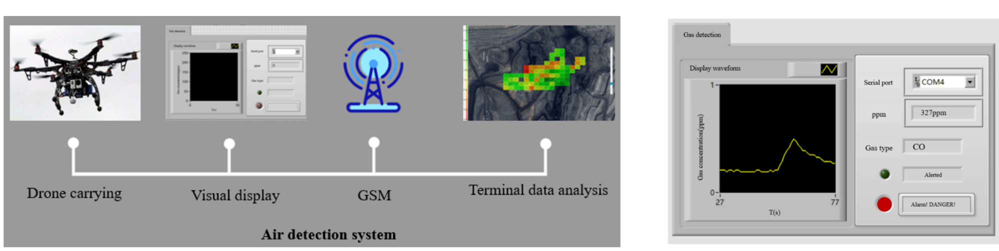

Figure 9: System monitoring logic diagram(left) and System test diagram(right)