

# UAV real-time data acquisition and visualization system based on 3D route planning

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**Abstract:** Aiming at the problems in the traditional Unmanned aerial vehicle (UAV) data acquisition and display system, the data acquisition from the limited sensors at the UAV cannot be transmitted back in real time, and the data acquisition from the ground stations can only be displayed in two dimensional flat. The real-time common data transmission link technology of multi-interface sensor data was studied and the Raspberry Pi data acquisition and control hardware system based on the micro quad-rotor UAV was developed. In addition, the automatic and manual three-dimensional (3D) route planning methods for the flight target areas were proposed, the UAV real-time data acquisition and display visualization system based on the 3D flight planning was developed and constructed. Through the simulation test, the system verified the accuracy of 3D route planning control, real-time data acquisition and visual display, enhanced the portability and convenience of the system, and expanded the application scene.

**Keywords:** Unmanned aerial vehicle (UAV), 3D route planning, real-time data acquisition, display visualization system

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## 1 Introduction

Micro quad-rotor UAV have been widely used in human life and production, especially in scenes with vast terrain, complex ground environment, and aerial data collection, which have the advantages of flexibility, speed, and efficiency that other data collection methods cannot realize<sup>[1]</sup>. The traditional UAV data acquisition system consists of two parts: UAV and ground station. Among them, the UAV includes basic modules such as the body, flight controller, flight power unit, airborne data acquisition sensors, and airborne communication device<sup>[2]</sup>, which are responsible for flight routes and data collection; The ground station includes PC ground station and ground communication device which are used to realize the functions of UAV route planning, control and data processing visualization. However, the traditional UAV data acquisition system cannot complete the continuous planning of multi-altitude flat route at a task schedule<sup>[3]</sup> and realize the real-time transmission of the specified type data from the UAV<sup>[4]</sup>. Besides, the collected data only can be displayed on a two-dimensional flat<sup>[5]</sup> at the ground station.

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In order to improve the real-time and intuitive display in the traditional system of UAV data collection and display, and expand the application scenarios and convenience of the system, this paper firstly developed a multi-sensor information collection system for the 3D flight area of the UAV. The specific performances are: 1) Propose a method for continuous planning of multi-altitude flat routes in the target area, which realizes the planning and design of the UAV 3D routes; 2) Add onboard microcomputer Raspberry PI as a data management device on the UAV. It not only can pack onboard data for real-time transmission, but also facilitate user to replace sensors according to application scenarios, enhancing the portability of the system. As an infrastructure for mapping and geographic information, ArcGIS provides some new tools to create 3D visualization. It can not only integrate real 3D, BIM, point cloud and other 3D data, but also realize the efficient loading of data. At the same time, it also provides an open JavaScript API, which enables users to create custom applications. Therefore, this paper also develops and constructs an interactive ground station application program based on QT and ArcGIS API for JavaScript to realize the map loading, flight routes planning, flight data collection and 3D display of sensor data on the map. Finally, this paper integrates hardware system and software program, and designs a multi-data real-time acquisition and 3D display system based on Raspberry Pi sensor platform, micro quadrotor UAV and PC ground station. The diagram of system principle block is shown in Figure 1.

## 2 Overall framework of the system

The overall design of the system includes the UAV and the ground station. Using MavLink protocol, the data of two sides are transmitted through 433MHz wireless serial port. Among them, Raspberry Pi and sensors are mounted on the UAV to realize the acquisition of flight control data and multi-type sensor data. Since the maps used by many UAV ground station software are two-dimensional flat maps, which cannot satisfy the 3D display of data on the map. The ArcGIS API for JavaScript provided by the

server GIS framework in the ArcGIS platform can call the ArcGIS server service to realize the display of 3D map and the drawing of points, lines and polygons on the map. QT is a cross-platform C++ graphical user interface application development framework. Using the communication mechanism between JavaScript and QT, QT can interact with the created 3D map, and realize the bidirectional communication between the ground station map data and the UAV. Therefore, based on ArcGIS API for JavaScript, this paper develops and designs a 3D visualization platform for UAV planning control and data acquisition. In addition, we embed the platform in the ground station software developed by QT to realize the map loading, flight routes planning, flight data collection and 3D display of sensor data on the map. The overall block diagram of the system technical route is shown in Figure 2.

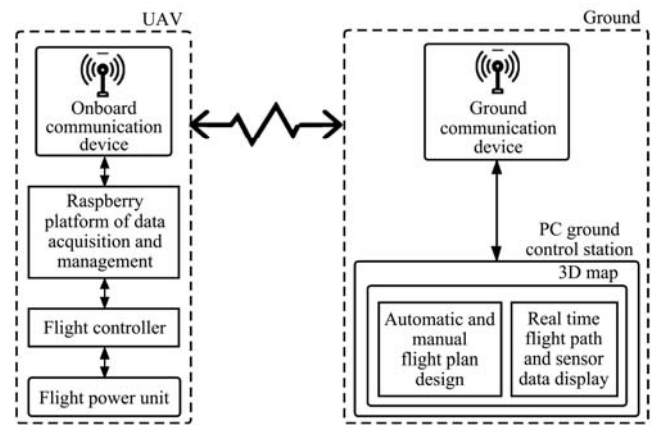


Figure 1 Diagram of system principle block

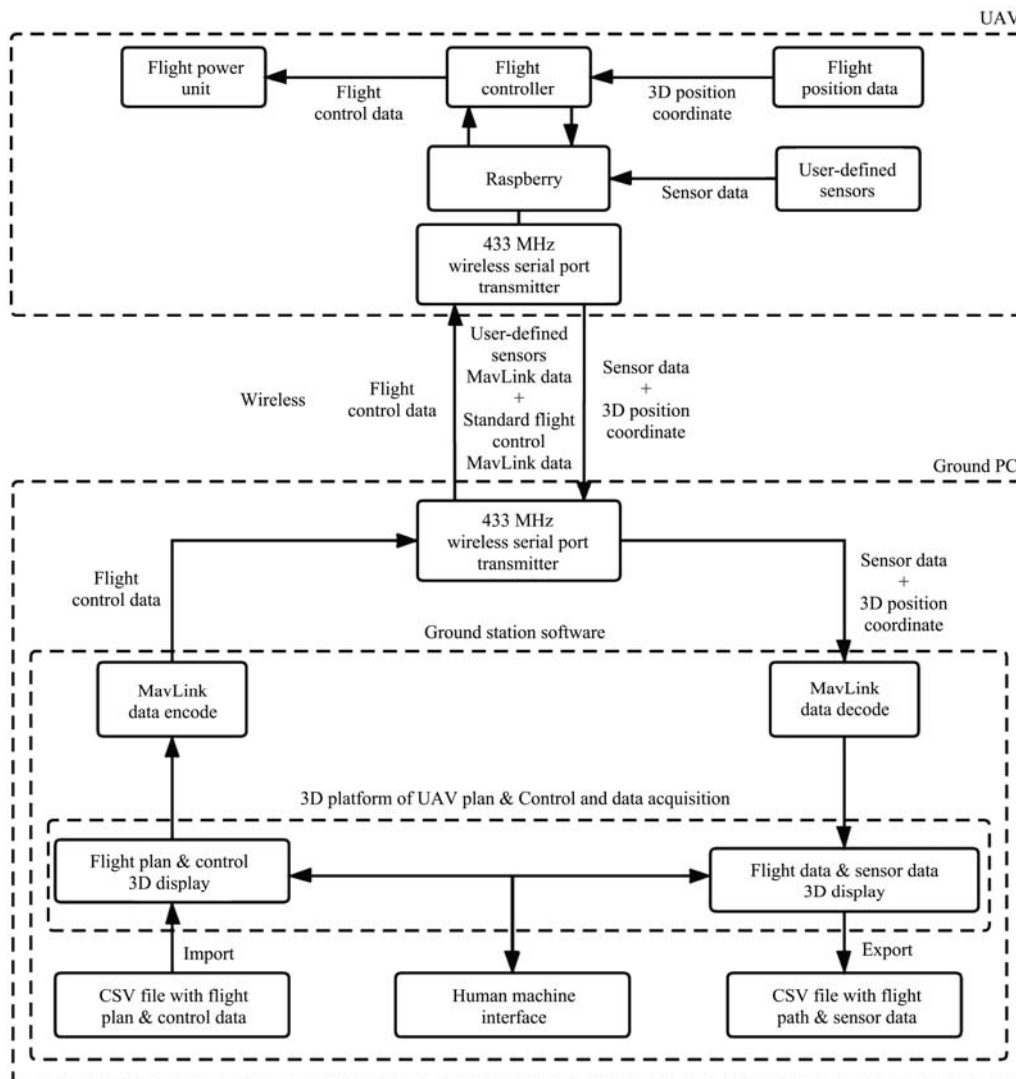


Figure 2 Diagram of system technical route

### 3 Introduction of system function

#### 3.1 Flight route 3D planning

Flight route planning with full coverage of target area is restricted by UAV battery, load, terrain and other factors so that the system needs to carry out overall route planning under multiple constraints (the constraints of manual setting, mapping density, etc.)<sup>[6]</sup>. At present, there are two ways of flat route planning: manual planning and automatic planning. Manual planning can be customized according to the planned route, and the drawing

points can be directly dragged on the map interface to adjust the longitude, latitude and height. Automatic planning requires the users to manually draw the target polygon area according to the actual needs and then set the flight interval, takeoff height, height interval and the number of flat route layers. If the target polygon region is a convex polygon, the system algorithm can automatically generate the planned route based on the flat route planning directly. If the target polygon is a non-convex polygon, it is necessary to divide the non-convex polygon manually into multiple convex polygons. And then these convex polygons could be carried out

for automatic flat route planning. Compared with manual planning, automatic planning is more superior for its accuracy and efficiency.

During the flight, UAV needs to reduce the speed or even hover to change flight direction when it meets the corner. Therefore, the number of turns is the main factor affecting the efficiency of single flight route of UAV. The existing flat route planning algorithms are based on cattle farming reciprocating method<sup>[5]</sup> or the spiral method<sup>[6]</sup>. Since the acquisition environment of this paper requires collecting multi altitude data information, and in most cases, the number of turns of cattle ploughing reciprocating method is less. Therefore, based on the cattle farming reciprocating method, this paper proposes a multi altitude flat route continuous planning method for target area, which realizes the automatic and manual planning and design of 3D flight area. The flat route is shown in Figure 4, and the 3D planning of flight route in the target area is shown in Figure 5.

The algorithm flow chart is shown in Figure 3 and the specific steps of the algorithm are as follows:

1) Get the latitude and longitude coordinates of the vertices of the polygon area drawn by the user, traverse the vertex coordinates, select the maximum and minimum longitude and latitude values to construct an outer rectangle;

2) Calculate the distance in the north-south direction (the width of the rectangle) from the latitude information of the outer rectangle, and then determine the maximum number of routes and the latitude information of each route according to the route interval set by the user;

3) Traverse the adjacent straight lines of the target polygon, and calculate the abscissa (x, y) of the intersection point between each route and the target polygon according to formula (1), where x is the longitude information of the intersection point. In the formula (1),  $y_0$  is the longitudinal coordinate of the straight reciprocating horizontal line, and  $(x_1, y_1)$  and  $(x_2, y_2)$  are the endpoints of any side of the polygon;

$$\begin{cases} y = y_0 \\ \frac{x - x_1}{x_1 - x_2} = \frac{y - y_1}{y_1 - y_2} \end{cases} \quad (1)$$

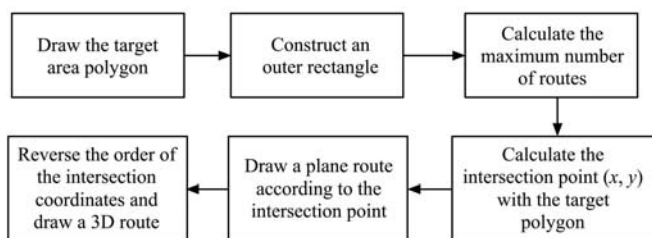


Figure 3 3D route automatic planning algorithm flow chart

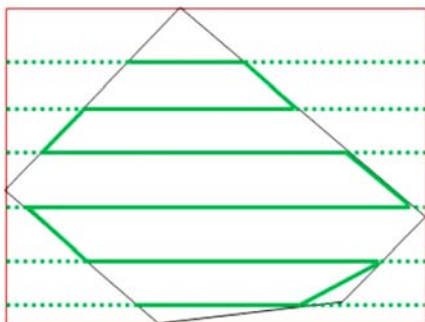


Figure 4 Automatic route planning by reciprocating method of cattle farming

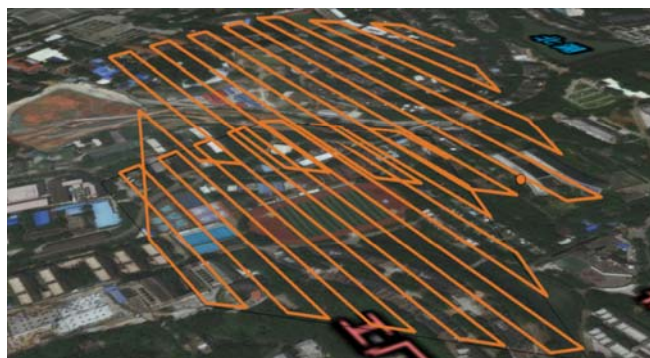


Figure 5 Flight route 3D planning map

4) Based on the method of cattle farming, the solid line drawn on the map from north to south is the automatically planned route, according to the acquired longitude and latitude information;

5) According to the 3D route interval set by the user, on the basis of the flat route, another flat route is drawn in the reverse order of the intersection coordinates, thereby completing the automatic planning of the entire 3D route.

### 3.2 Data exchange transmission link

After setting the 3D route planning on the ground, the platform outputs completed route planning data through the JavaScript framework. Using the communication mechanism between JavaScript and QT, QT can automatically obtain the route planning data. According to MavLink2.0<sup>[7]</sup> protocol, the data code is converted to the standard MavLink2.0 flight control data and sent to the UAV through 433 MHz wireless serial port transmitter. The data transmission format of the MavLink2.0 protocol<sup>[8]</sup> is shown in Table 1.

Table 1 Mavlink2.0 protocol format details

Format	Byte index	Content	Value
STX	0	Packet start marker	0xFD
LEN	1	Payload length	0 - 255
INC FLAGS	2	Incompatibility Flags	
CMP FLAGS	3	Compatibility Flags	
SEQ	4	Packet sequence number	0-255
SYS ID	5	System ID (sender)	1-255
COMP ID	6	Component ID (sender)	1-255
MSG ID	7-9	Message ID (low, middle, high bytes)	0-16777215
PAYLODE	10-(n+10)	Payload	
CHECKSUM	(n+10)-(n+11)	Checksum (low byte, high byte)	
SIGNATURE	(n+12)-(n+25)	Signature	

The system adds an onboard microcomputer Raspberry Pi to the UAV as a data management device, and four external serial ports are connected to UAV flight controller and multi-sensor. The data on the UAV includes sensor data and flight control data. The flight control data released by the ground station is received and analyzed by the Raspberry Pi on the UAV through the serial port and forwarded to the flight controller, which drives the flight power unit to perform corresponding action. The parsed flight control data includes the UAV's flight attitude information, gyroscope acceleration information, GPS location information, etc. Because of the small size of sensor data at a time, the system can adopt aggregation and packing method to reduce communication redundancy. However, due to the serial binary format, the system cannot directly aggregate the sensor data and the flight control data. Therefore, for data aggregation and packing, the system needs to

use the coding function of the MavLink protocol in the Python library to convert the sensor data type into a unified data type (standard MavLink Protocol). Then, through the shared wireless communication link, the data from the UAV is immediately transmitted back to the ground station to realize the real-time data reception, collection, transmission and storage.

### 3.3 Data 3D map display

In order to present the 3D map of the ground station<sup>[9]</sup>, the ground station constructs an HTML file which is developed using Arcgis API for Javascript, and uses Web EngineView and Web Channel to load and communicate with the file in Qt. The HTML file uses SceneView class to create a 3D scene and Map class to create a map loaded by the 3D scene. When instantiating the map, the ground property of the map is set to "world elevation" to display the elevation change, so that the points, lines and polygons created on the map have the height attribute. Among them, the point is used to represent each waypoint. The line is used to display the flight path and planned route, and the polygon is the target area of flight.

In the created 3D map, drawing various graphics with different colors can directly present the data collected by sensors in the target area, where the color of the graphics represents the size range of the data collected by the sensor. Therefore, after acquiring the UAV longitude and latitude, altitude and sensor data information collected from corresponding positions after decoding the MavLink2.0 data in real time, the ground station divides the data into multiple intervals according to the possible range of sensor data. As shown in Figure 6, taking 4 intervals and 3 heights as an example, if the sensor can measure a certain gas concentration in the range of 1-100ppm, then the four intervals are 1-25, 25-50, 50-75 and 75-100. The data of each range is displayed in the form of four different color blocks from small to large on the 3D map, and the size of color blocks can be adjusted adaptively according to the route spacing to ensure that the color blocks are relatively flat. Each color block contains the sensor data information and the longitude, latitude and height information of the acquisition point. When the UAV is flying at different altitudes layers, the 3D map interface at the ground station can also display the sensor data information at different altitudes in real time. Users can intuitively see the distribution of data collected at different altitudes in the target area in 3D space, so as to conduct targeted research.

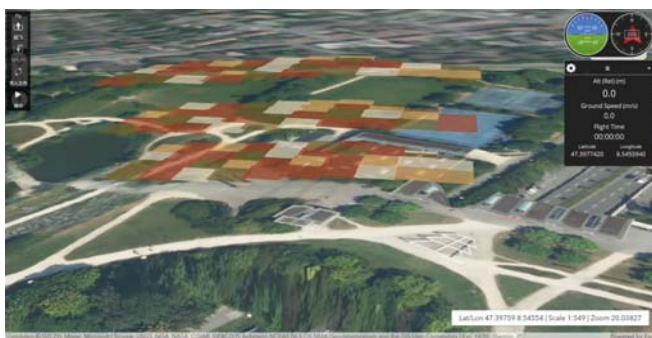


Figure 6 Real-time display of sensor data

Considering that the user needs to view the data collected in the target area in the past, the ground station stores the sensor data and position information of each flight of UAV. After each mission, the user can choose whether to export and save the mission information. To facilitate data processing on the ground, the flight information stored on the ground is stored in a simpler CSV file (suffix is .csv). When the user wants to view the data, the saved CSV file on the flight page can be imported for

visualization. Multiple layers can be imported for comparison at the same time and the information can be filtered out to obtain the user wants. A layer can also be imported separately to obtain more detailed single layer data information.

## 4 Platform function test

This paper uses jmafsim<sup>[10]</sup> quadrotor UAV simulation software to simulate the flight of the UAV for simulation experiments to test the effectiveness of the platform's functions. The specific steps of the simulation experiment are as follows:

1) Route planning. Before the UAV takes off, the user needs to plan the route of the test area on the user terminal and complete the route setting of the test area.

2) Complete the flight mission. After completing the route setting in the test area, the UAV will execute the flight mission according to the planned route and transmit data in real time during the flight. To achieve 3D map drawing, the UAV must complete a three-level flight mission.

3) Analyze the data. After all the UAV missions are completed, the collected data will be analyzed and compared to determine whether the data meets the indicators and then verify the reliability of the platform's functions.

### 4.1 Flight route monitoring test

The test is used to verify that the UAV can fly according to the pre-set planned route, and test whether the UAV flight route function is normal. After the user completes the route planning on the platform, the UAV executes the flight task according to the planned route. At this time, the UAV flight path can be observed on the user terminal map. By analyzing the flight path and the pre-set planned route, it is determined whether the flight path of the UAV on the user terminal map is displayed normally and whether it deviates from the planned route. The test results are shown in Figure 7a and Figure 7b below. Figure 7a is the pre-set planned route, and Figure 7b is the simulated environment flight path. Since the drawing of the flight path is affected by many factors, such as map terrain, drone flight speed, etc., there will be a certain error between the planned path and the actual flight path. Through comparative analysis, it can be showed that the simulated environment flight route is basically consistent with the planned route, so the UAV flight route function is normal.

### 4.2 UAV data link test

The test is used to check whether the UAV data link is working properly. Connecting the Raspberry Pi mounted on the UAV with the ground station, analyzing the data collected and saved by the sensor on the Raspberry Pi and the data sent back to the ground station, checking whether the data is consistent, and then detecting the packet loss rate. After the correct connection, the data received by the ground station and the data collected by the sensor are compared through multiple long-time tests (more than 30 minutes for a single test). It can be obtained that without other electromagnetic interference, the packet loss rate does not exceed 1%, and the UAV data link works normally.

### 4.3 Data storage and 3D display test

The real-time data transmitted by the UAV will be saved as a specific file in the form of a table, and the file is imported into the map to realize the 3D display of the data. The system checked whether there are saved files in the user interface to make sure the data is properly saved. Importing the file into the map to see if the 3D display of the data can be realized. The test results are shown in Figure 9. Analysis shows that the data storage and 3D display functions can be implemented normally.





Figure 7 (a) Pre-set planned route and (b) UAV simulation environment flight path

MAVLink Link Status (Current Vehicle)	
Total messages sent (computed)	276338
Total messages received:	274816
Total message loss:	1522
Loss rate:	1%

Figure 8 Data loss rate



Figure 9 3D map display of data

## 5 Conclusions

Based on the research of real-time common data transmission link technology, this paper proposes a planning method for flight area, develops the Raspberry Pi data acquisition and control hardware system installed on micro quadrotor UAV, and constructs a multi-interface real-time data acquisition and display visualization system for UAV flight monitoring. Simulation test

shows that the Raspberry Pi sensor platform in this system is easy to access multi-type sensors with interfaces such as I2C or UART, which enhances the portability and convenience of the system. The consistency of the data sent and received by the system is higher than 99%, and the packet loss rate is lower than 1%, which demonstrated the feasibility of the system. The system realizes the functions of multi-height flat route continuous planning, real-time data acquisition and transmission, and real-time 3D display in the target area, and verifies the real-time performance of data collection and the intuitiveness of data display.

Compared with the traditional UAV data acquisition system, this system can be extended to realize the synchronous data acquisition of multiple UAVs, and is widely used in a wide range of 3D area environmental monitoring and early warning, aerial mapping, mineral resources detection, emergency relief and other scenes.

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## [References]

- [1] Nie B W, Ma H X, Wang J, et al. Study on actualities and critical technologies of micro/mini quadrotor. *Electronics Optics & Control*, 2007; 14(6): 113–117. doi: 10.3969/j.issn.1671-637X.2007.06.028. (in Chinese)
- [2] Pei S Y, Wang S Z, Zhang H H, Zhu H. Methods for monitoring and controlling multi-rotor micro-UAVs position and orientation based on LabVIEW. *Int J Precis Agric Aviat*, 2018; 1(1): 51–58. doi: 10.33440/j.ijpaa.20180101.0009
- [3] Zhou L, Wang Y N, Yin F, et al. UAV Route Planning Using a Three-dimensional-like Map. *Computer Measurement & Control*, 2011; 19: 2788–2790. DOI: 10.16526/j.cnki.11-4762/tp.2011.11.013. (in Chinese)
- [4] Wang P, Luo X W, Zhou Z Y, et al. Key technology for remote sensing information acquisition based on micro UAV. *Transactions of the Chinese Society of Agricultural Engineering*, 2014; 30: 1–12. doi: 10.3969/j.issn.1002-6819.2014.18.001. (in Chinese)
- [5] Li S, Fan X Y. Design of Unmanned Aerial Vehicle Ground Control Station Software System Based on Qt Framework. *Radar Science and Technology*, 2017; 15(04): 410–414+420. doi: 10.3969/j.issn.1672-2337.2017.04.013. (in Chinese)
- [6] Cao G Q, Li Y B, Nan F, et al. Development and Analysis of Plant Protection UAV Flight Control System and Route Planning Research. *Transactions of the Chinese Society of Agricultural*, 2020; 51: 1–16. doi: 10.6041/j.issn.1000-1298.2020.08.001. (in Chinese)
- [7] Koubaa A , Allouch A , Alajlan M , et al. Micro Air Vehicle Link (MAVLink) in a Nutshell: A Survey. *IEEE Access*, 2019, PP(99): 1–1. doi: 10.1109/ACCESS.2019.2924410
- [8] MAVLink Developer Guide. Available online: <https://mavlink.io/en/#mavlink-developer-guide>(accessed on 6 12 2020)
- [9] Nex F, Remondino F. UAV for 3D mapping applications: a review. *Applied Geomatics*, 2014, 6(1): 1–15. doi: 10.1007/s12518-013-0120-x
- [10] Emad E, Martin S, Kristian H T, et al. A survey of Open-Source UAV flight controllers and flight simulators. *Microprocessors and Microsystems*, 2018; 61: 11–20. doi: 10.1016/j.micpro.2018.05.002.