# Ground Control Station Development for Autonomous UAV

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**Abstract.** Unmanned Aerial Vehicle (UAV) has typically been used in civil and military field all over the world. Based on the UAV mission of autonomous flight, the ground control station (GCS) including hardware and software become important equipment to be developed. This paper emphasizes three parts to build a well functioning ground control station: a portable ground station hardware system, a virtual instrument panel for the attitude information and flight path showing, all kinds of error alert. Through the whole test on the ground and in the sky, GCS can show the remote sensing information precisely and send the control command in time. The system can be also used to assist in the function of autonomous cruise task for UAV.

**Keywords:** Unmanned Aerial Vehicle (UAV), ground control station, man machine interface, autonomous task.

## 1 Introduction

Autonomous Unmanned Aerial Vehicle (UAV) has the potential to act as low cost tools in variety of applications such as traffic monitoring, border patrol, search, rescue and surveillance. As the central Part of the UAV, GCS (ground control station) also have a continuous development [1-3]. It is also called for "planning and control station". Planning means to plan tasks of UAV during flying, and then to control actuating mechanism. GCS is often consisted of planning facility, display equipment, telemetry schedule, computer processor, data terminal on ground, communication equipment and protection device.

In 2002, the Air Force Technical School had developed onboard system and ground station for UAV [4]. The whole computer system is developed in the present study to include such tasks as data collection, analysis and computation, and control/monitor the UAV in flight, while the ground station monitors in real time the status of UAV and uplink commands or waypoints. All the flight information is archived either onboard the vehicle or downlink to the ground station.

A new design for an immersive ground control station is presented by Bryan E. Walter in Iowa State University. This ground station utilizes a virtual reality based visualization of the operational space and the graphical representation of multiple information streams to create a comprehensive immersive environment [5].

The unmanned airship has a capability of autonomous flight, navigation and guidance based on a telemetry command of the ground control station [6,7]. GSC is

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comprised of propulsion system, communication system, electrical system and other airship sensors were realized as a software-based program and do the same function of the real hardware system. The Ground Integration Test is performed to check the operation with engine running.

There are two ways to achieve the UAV flight: remote controlling the UAV via instrument data/real-time video and autonomous flight by UAV itself. The latter one is adopted in current study. To accomplish the goal, in this paper the ground control station provides attitude information and track showing, hands remote control and other function, such as sending control command to UAV, all kinds of error alert and building its database which can query flight information offline.

## 2 GCS Design Requirement

In order to make the program open, we use the modular structure to express the process design. The Basic process chart is shown in Figure1.

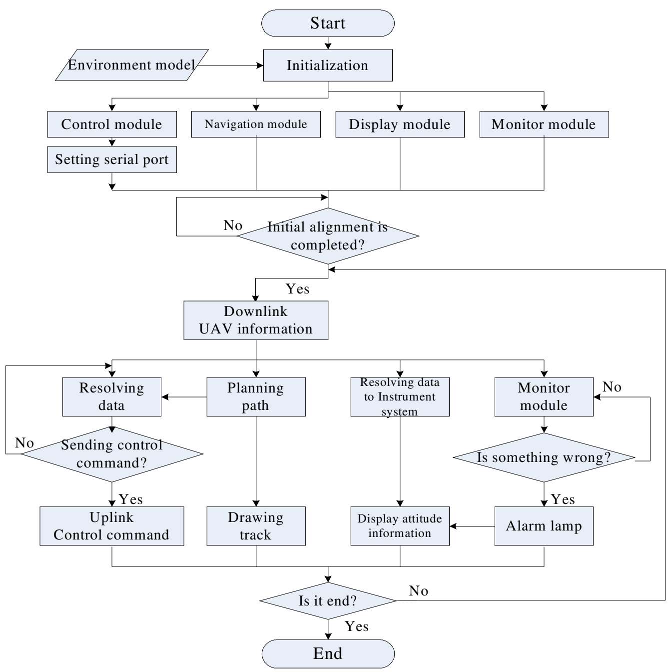



**Fig. 1.** Basic process chart

There are four modules to the whole system. Control modular is to resolve all information of UAV and send the control command to UAV. Navigation modular is to plan path before flight, and then draw the track. Display modular can show the attitude in the real time including the alarm lamps. Monitor modular is to take charge all kinds of error alert. The method has three merits: firstly, all modules have their own independence. We can add some new modules or bowdlerize old modules to complete other functions freely. Programming efficiency is high. Secondly, GCS should control any kinds of UAVs and can communicate any network. Finally, the software should be general for other user. The airborne system comprises an onboard system and a radio controlled aircraft. The GCS comprises a lab PC and a radio modern to communicate with onboard system. It can receive UAV flight information in real time, such as position, altitude, airspeed, heading, flight path, health condition of sensors and commands up-linking as well. On the other hand, it can send the control commands to on-board processor if necessary.

To achieve the basic communication link above all, the major design requirement of GCS should meet following function:

- planning the reasonable path according to current mission offline
- accepting down-link attitude information data from UAV
- carrying out the storage of the UAV data in time
- building up virtual instrument panel for the attitude information and tracking showing
- sending the up-link command data to UAV if necessary
- determining the position and the attitude with the data acquired from the navigation system
- monitoring the current status of systems and detecting the fault and failure on the platform
- coping with the emergency and performing all kinds of error alert

To be able to ensure a sufficient degree of confidence in performance during operations, both component and equipment of all hardware system should meet the physical and environmental conditions. Each part of systems of GCS must be able to withstand following temperature and humidity requirement:

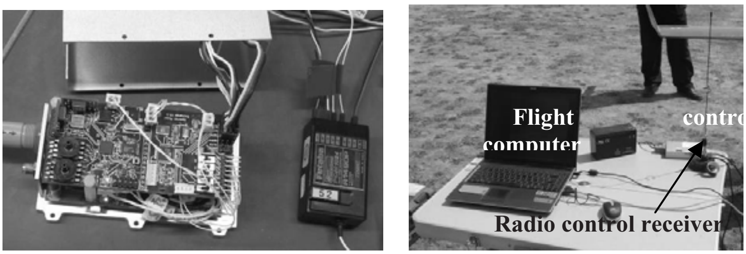
- temperature : -20 to +50 degrees Celsius
- humidity : not greater than 85%

## 3 Ground Control Station System

### 3.1 Station Hardware

The on-board system of UAV consists of single-point GPS receiver, three single-degree of freedom silicon MEMS gyroscopes and two-degrees of freedom silicon MEMS accelerometer which installed orthogonally. The analog signals from above sensors plus air pressure sensor are converted to digital signals by an Analog-to-Digital Convert which is controlled by C8051 microprocessor. AT91RM9200 microprocessor is used as a navigation computer, receiving GPS data through serial port, completing navigation resolving and flight control algorithm, finally driving PWM (Pulse-Width Modulation) to steering engine for deflection and communicating with ground control station. The experiment system shows in fig. 2(a).

To permit manual flight of the vehicle during flying, a radio control (RC) receiver is built into the land system. The final control signals, whether generated from the control loops or manually from the RC receiver, are sent from the microcontroller to the servo actuators on the UAV. The user interface is from a ground terminal and radio control transmitter. The terminal is for preflight parameter modification in the flight code on the microcontroller. The RC transmitter is for manual flight of the vehicle. The flight control computer was chosen to be a programmable microcontroller. Ground control system interface was designed for a RS-232 serial link. To allow for autopilot flight, a changer lever system was also designed. Figure.2 (b) illustrates the flight control system on board and ground support hardware.




(a) On-board system (b) ground support hardware

**Fig. 2.** On-board system and ground support hardware

### 3.2 Station Software

The development of ground control station is mainly based on Microsoft Visual C++ 6.0 that is useful to show all data as soon as possible. The communication protocol between UAV and GCS should be known before the data transmission by quest. The frame is led by the strings of '@@@', and then 35 groups data is flowing, such as position, altitude and attitude. All data will be saved as a text file including the wrong data. After checking the remaining data, they will all be converted into different sets of information and displayed on the instrument panel on the screen. If there is something wrong of the data, the system will immediately give a warning with red light and beeping sound to notify us. Fig.3 displays the panel of the ground control station.

The main function of the panel is to show the information of UAV during the flight, such as position, altitude, attitude, airspeed, and heading. All of this data will be written down the edit frame on the right of the panel. Moreover, the tracking will be drawn with red lines in the center. These flight paths are all in the relative coordinate system. The cross point of axis is the initial position of UAV, and then the next point is recorded for the next location. There are three icons on the toolbar; they are view-out, view-in and view-move. When the flight path of UAV is overflowing the coordinate, we can click the view-out, and then the scale ratio is smaller in order to show the full tracking lines. We can also choose the button named "Mission point setup" to input the next expected mission point. When it is down, there is a cross iron on the screen that is the position of the cursor in the current. Moving the cross and clicking it at the suitable position, the message of the numerical value will be sent to UAV. All of the steps can be also operated in the flight control.

On the right-bottom of the panel, it is the instrument board. Three attitude director indicators will be shown, that is roll angle, pitch angle and yaw angle. All of them are

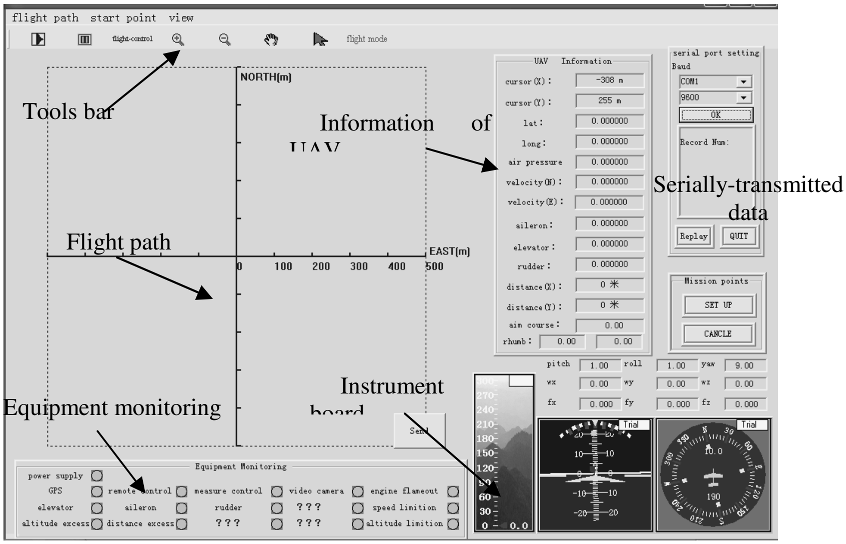



**Fig. 3.** Panel of the ground control station

refreshed with the downlink information 5 times a second. Height-position indicator is adjacent. We use the value of gas-pressure meter to remark the current height for UAV. All other important data will be written in the special edits.

For autonomous flight, the GCS interface also provides some flight states for users to choose, the entire function button is shown in the Fig.4. If you chose the “manual pilot”, the UAV will be controlled by the steering handle on ground. When you knob down the button “autopilot”, the UAV will run the autonomous mode. Other states will also be done, such as right-hover, climb, and slowdown. Now like a person UAV has its own decision making, but its information will be known by the instrument panel. It is also proved that the GCS is very important for early stage of autonomous flight.

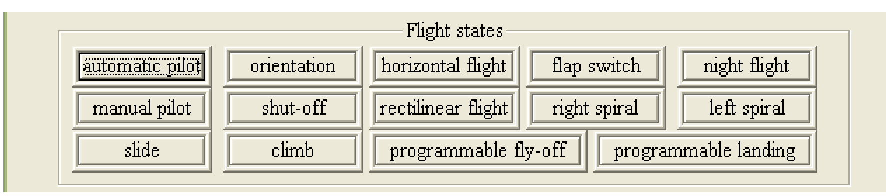



**Fig. 4.** Different flight states

During the program running, to accomplish sending the control command from GCS to UAV, three property pages named FLIGHT CONTROL is designed. Page one is to change the goal of the mission; the function can be realized in the program. Page two is to control actuator, and it is very important for sensitive adjustment of the steering engine. The order can be send to on-board system from radio-telegraphic transmitter wherever UAV on the ground or in the sky. Page three is the loops control. There are usually four loops to control and stabilize the attitude of UAV. Each loop has its own chain of command, but lateral direction and course have coupling. So the design of the loops must consider the relevance and dependence of each other. In this case, we use the PID method to stabilize and control the attitude angles and different state variables. To accomplish the attitude maintenance, constant height and turning control are the goal after all.

## 4 Test and Results

The overall system test can be divided into two important parts: ground phase and flight phase. UAV must be tested well on the ground before flight in the sky. The test on the ground is to detect the performance of the on-board system, and to test the liking of data. The integration test makes sure the entire system in regular status. The wireless data transmission test shows that the data delay in the ground station propagating with time increasing at the first beginning. The problem was solved soon, and the data can be synchronized both in airborne and ground system. The electromagnetic interference test is made to ensure that the electrical devices and wireless receiver do not influence with each other, and the communication between the onboard computer and the ground station will not be influenced by other factors. Finally, the dynamic ground test on a push car was implemented. Fig.5 is shown the flight path of the whole test.

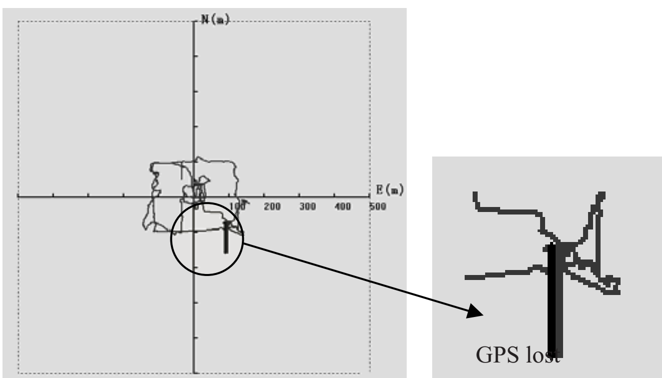



**Fig. 5.** Flight path of the whole test

Different from other ground control station, our system develops an algorithm to solve the problem of the global positioning system (GPS) lost. Some fight system only depends on the GPS receiver to get the position and attitude of UAV that is the system will be at a stand when GPS signal is lost. As the same with our system, it seems that the GPS lost track of signals for a while during the test in Fig.6. When the GPS receiver is wrong, the tracking of UAV will be disordered. In order to solve the problem, we develop a special compensation algorithm. The present navigation systems rely on Kalman filtering to fuse data from GPS and the inertial navigation system (INS). In general, INS/GPS integration provides reliable navigation solutions by overcoming each other shortcomings, including signal blockage for GPS and growth of position errors with time for INS.

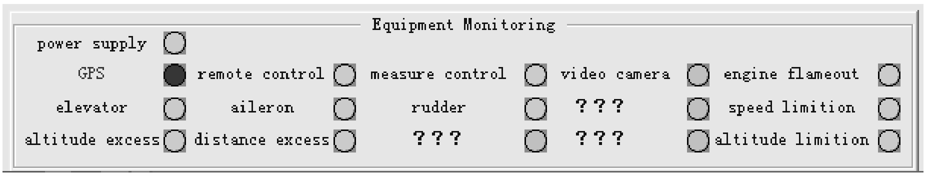



**Fig. 6.** Malfunction alarm panel

We can see in the right-bottom of the picture, there are some black-colored lines to express the no the GPS signal. Through the special compensation, the flight path looks like smooth. Fig.6 is shown that when the position data of the GPS receiver is wrong, there is the red light in the equipment monitoring. All other lights are green, and all of sensors are healthy. The malfunction alarm is finished, as soon as the GPS recuperate its heath.

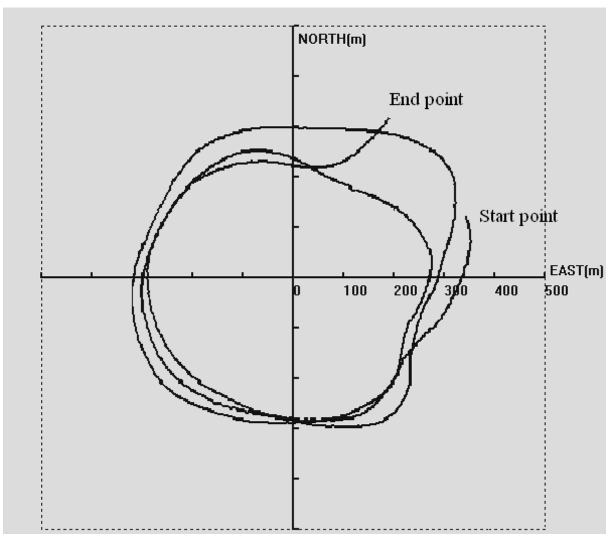



**Fig. 7.** The tracking of the cruise task

After the ground test, the flight test was put into practice. The major purpose is to validate the performance of the GCS above all, such as the real time data linking, the shown information of UAV and the function of equipment monitoring. After that, we also expect to accomplish the autopilot of UAV for an appointed task.

The whole fight test is 18 minutes long. The data of the ground control station is well displayed the condition during the flying for UAV in the sky including the manual flying and autopilot. To be assure the safe of the equipment on board, the cruise task command is sent up to UAV and then the autopilot system is run. UAV will enter the state to hover with 20m/s velocity. As shown as Fig.7, the purpose of the autonomous cruise task is to fly the circular area by a 300 meters radius. We can see the path tracking is smooth although the GPS signal is lost during 30 seconds. During the autonomous flight, the controller parameters are adjusted by UAV lateral controller to main the roll angle as constant. Fig.8 shows the roll angle and heading of the flight.

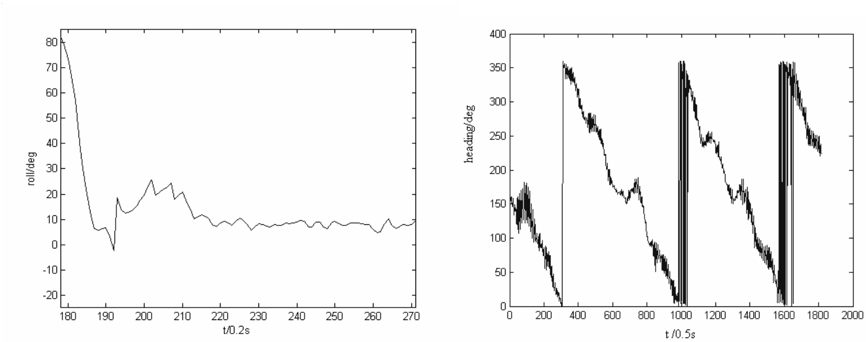



**Fig. 8.** Roll to level and heading track

## 5 Conclusion Remarks

The results of the tests show that the functions of the ground control station are verified in the both ground test and flight test. The ground control station has been developed successfully so that it can show data such as position, airspeed, altitude, heading, and health status for UAV. As the important function, the ground control station can send the autonomous control command to the system onboard. The information allows for implementation of basic ability for autonomous flight. But some significant problems can be conducted as following: Firstly, a portable graphical interface is not established. The electronic map can be used to display the position of UAV, and be moved and rotated to fix the position and heading of the UAV on the screen. It will be the next goal to realize in the future. Secondly, the power consumption is too large to maintain a long endurance flight. The method of power saving should to be given. Lastly, the complicated task can be designed for UAV to achieve the real autonomous flight.

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Ye Hong was born in Heilongjiang Province, P. R. of China, in 1979. Now she is a postdoctoral candidate of Beihang University of Instrument Science & Optoelectronic Engineering in China. Her main research interests are related to the theory of autonomous control and the path planning for micro UAV.

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