Software Design for Mini-type Ground Control Station of UAV

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Abstract *– The guiding ideology and principle of GCS (Ground Control Station) software design & development were proposed by analyzing the role of CGS in UAV (Unmanned Aerial Vehicle) systems. Firstly, established an abstract GCS software structure model of bi-directional information interaction; Secondly, analyzed the hardware system constraints caused by development of portable, mini-type GCS, as well as influences on GCS software design. Also, GCS software compatibility and interoperability standards and requirements were discussed. In the process of software design, at first, made a comprehensive analysis of the content of UAV data & information; Then finished the virtual instrument application design, put forward a multi-layer architecture model of 2D flight situation. The structure model analysis, data & information analysis provides a good guidance to the procedure of GCS software design & development, so as to avoid blindness and improve development efficiency. Virtual instrument interface design reflects the basic method of GUI (Graphical User Interface) design. The proposed multi-layer structure model of 2D flight situation shows the general scheme to solve the problem of navigation information output.*

Keywords*– software architecture; limitation factor; user interface; flight situation*

Ⅰ. INTRODUCTION

Ground control Station (GCS) is an indispensable part in UAV system [1]. Computer is the core of GCS, and the computer's application program, or GCS software, is the most critical element.

Presently, the software design and development of GCS gains insufficient attention. Researchers of UAV system generally considered it as a secondary affair. There is no unified, general approach of design. On the other hand, as the portable or mini-type GCS has its own features, the software design has particularities - the existing achievement of software design of large GCS should not be applied directly.

Thus, the design work should focus on following issues: the design of abstract software structure, the analysis of influence of the limitation factors, the main aspect of software design & development, such as Graphical User Interface and 2D flight situation.

Ⅱ. AN ABSTRACT STRUCTURE OF GCS SOFTWARE

UAV systems have been widely applied in military and civil fields. The root purpose of most UAV systems is: to extend or to replace human awareness, acquire useful information of external world. Thus, the essence of UAV system is: means to acquire useful information [2].

The acquisition of useful information utilizing UAV system is essentially a process of information interaction between human and UAV. This process includes two sides: a download process – human obtains, observes and utilizes UAV information; a upload process – human sends control command & information to UAV [2]-[3]. GCS is the media to perform this bi-directional process. And GCS software is the essential element of GCS functions.

As figure 1 shows below, an abstract structure of GCS software can be established according to the analysis mentioned above. This structure mainly focuses on the flow of data & information. Though functions may be complex and various, GCS software should always support the bi-directional process shown in figure 1.

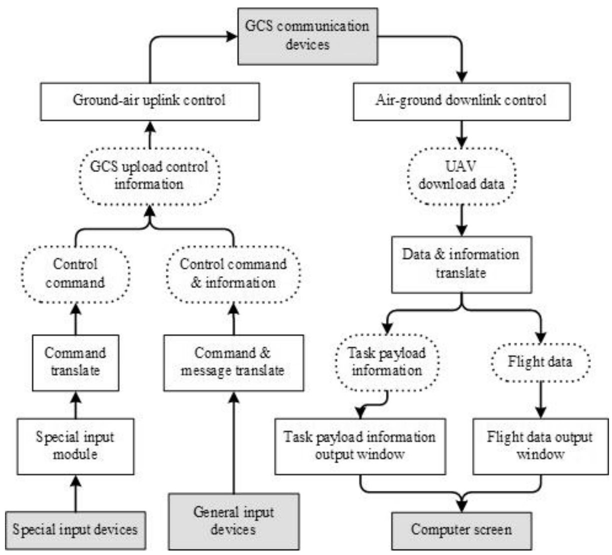

Fig.1. Typical structure of GCS software

Ⅲ. LIMITATION FACTORS AND DESIGN REQUIREMENTS OF SOFTWARE FOR MINI-TYPE GCS

A. Hardware related Limitations

"Hardware" mainly refers to GCS computer and its secondary devices (e.g. communication devices).

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Presently, the development of mini-type or portable GCS causes lack of hardware resource and decline of hardware capability, and influences software design.

1) *Air-ground data link:* The air-ground communication between UAV and GCS interchanges large volume of multi-type information. It requires high transferring speed and high reliability. But, restricted by the poor capacity of system hardware, mini-type GCS can only provide single, non-backup data link for data communication.

Therefore, GCS software should be capable of carrying out multi-type, large volume and momentary bi-direction communication, while using one and the same means of telecom. New generation of data interchange format, for example, XML (Extensible Markup Language) would help solving this problem [4]. In order to enhance the reliability of intercommunication, GCS software should also be capable of detecting errors and faults of data link, alarming properly, and fixing malfunctions automatically.

2) *Display device:* Compared with large-type GCS, due to the smallness and fewness of display devices, there's an obvious shortage of computer's available display area in mini-type GCS, which results in great difficulty of GUI(Graphical User Interface) design.

Thus, an overall planning in the process of GUI design is quite essential. According to different level of data & information importance, concern and real-time requirement, apply different, proper way of output to different data [5], so as to enhance the efficiency of information interaction.

B. GCS software design requirement

Currently, there is an obvious problem in UAV system design-a great lack of compatibility and interoperability. One kind of GCS software is only compatible with one kind of UAV system [1]; Information cannot be shared between different UAV and GCS. This situation greatly restricted UAV application efficiency, especially in military domain [6].

Aimed at this problem, NATO's standard protocol STANAG 4586, or "Standard Interface of the Unmanned Control System (UCS) for NATO UAV interoperability", is proposed [6]. Based on three standardized interface, it controls the interaction level, enables combination of multiple GCSs and UAVs.

Ⅳ. STUDY ON CLASSIFICATION OF UAV INFORMATION

The process of Obtaining & utilizing UAV information is the primary aspect of the information interaction process between human and UAV. The development of GCS software should emphasize on comprehensive analysis of downlink data & information, and make study on proper output methods [7].

According to different functions, UAV data & information can be divided into two aspects: flight data of UAV itself; useful information obtained by UAV task payload.

A. Flight data of UAV

Classified by the source and nature of flight data, there are three major aspects: parameters related to flight control; data related to navigation; status information of each UAV sub-systems. Some typical flight data included in GCS software, and their sources and properties are shown in table 1 below.

Table 1 UAV data & information

Aspect	Class	Source	Property	Examples
Flight control parameter	Space motion	Motion sensor	Para.	Air speed / Altitude / Climb rate / Attack angle
	Attitude	Attitude sensor		Pitch / Roll
Navigation data	Space localization	Navigation module	Para.	Latitude / Longitude / Absolute altitude / Yaw
	Task Information	Task control module	Status / Para.	Target direction / Current Task
	autonomous navigation	GCS software	2D Surface curve	Planned route / Planned route points / Flight Path
Sub-system information	Flight control system	Airborne computer	Status	Autonomous / Half autonomous / Manual
	Flight control device	Airborne sensor	Para.	Actuator output / Control law correction
	Navigation device	Airborne computer	Status / Para.	GPS parameter / Navigation status
	Engine & power	Airborne sensor	Status / Para.	Motor rotation speed / Temperature / Fuel volume / Voltage
	Com-munication device	GCS software	Status	Normal / Error / Disconnect
	Load & other device	Airborne sensor	Status	Payload state / Landing gear state

B. Task payload information of UAV

The UAV mission of acquiring useful information is performed by the task payloads, which are various kinds of sensors. Thus, the contents of information are determined by the type of task payloads.

Presently, image and video sensor is applied widely in most of the UAV systems [4]. The real-time video is an useful kind of information for human; On the other hand, it provides assistant to manual fight control.

Ⅴ. DESIGN PRACTICE OF GCS SOFTWARE

A. Flight parameter output by virtual instrument

1) *Virtual instrument technology:* The application of aircraft virtual instrument in GCS software has advantages below:

It imitates conventional instrument appearance in aeronautic domain, accords with the awareness of professional operator. For normal users, graphical way of output is more intuitive.

It is able to provide more abundant information output formats and contents.

However, the application of aircraft virtual instrument (component) has its disadvantages: the virtual instrument may occupies a quite large display area and considerable processing ability of computer. This causes difficulty of GUI design and multi-task parallel processing. Therefore, the usage of virtual instrument needs appropriate planning and selection.

2) *Virtual instrument interface in GCS software:* It is unable for an operator to control UAV as a pilot onboard. In order to give correct, in-time and necessary control command, the flight parameter output in GCS software should be accurate, real-time, distinct for reading, and accorded with conventional custom in aeronautic domain. Thus, aircraft virtual instrument (component) is a suitable choice for the design of flight parameter output interface [4][8].

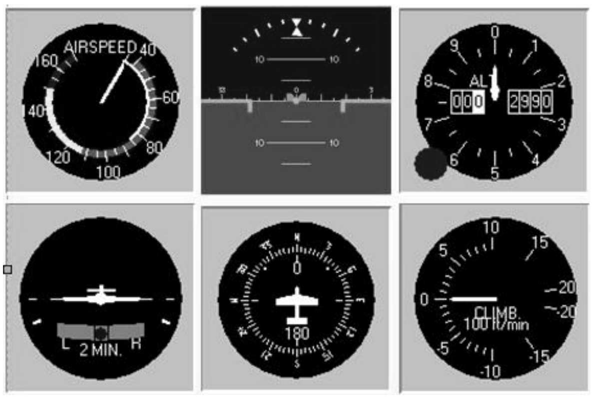

Fig.2. Virtual instrument output

Aircraft virtual instrument output interface is shown below in figure 2. Imitating Cessna 172R's instrument panel, this interface only consists of flight parameters which are the most important, the most concerned and the highest real-time performance required. In this way, software achieves a good balance between display efficiency and screen size restriction. From left to right in figure 2, first row: air speed, artificial horizon and altimeter. And the second row: turn coordinator, heading indicator and climb rate.

B. 2D flight situation for UAV

1) *UAV navigation:* The navigation information indicates the UAV 2D-surface position and motion situation, including: parameters (latitude, longitude, absolute altitude, etc), status of task navigation, 2D-surface curves (Planned route, flight path, etc).

The 2D flight situation is an advanced form of UAV navigation information. It is an integration of multi-type navigation information, which ensures a comprehensive and intuitive awareness for the operator [5].

2) *Multi-layer structure of 2D flight situation output:* 2D flight situation output consists of multiple layers. As shown in figure 3 below, from bottom to top:

(1) Geography environment layer, offers the coordinates reference and background display. This layer usually equals to "Electronic map".

(2) UAV layer, indicates the UAV current space position.

(3) Route & path layer, includes the 2D-surface curves: planned route and flight path.

(4) The other layer, includes secondary information such as restricted area, task targets, base stations, etc. May be divide into several more layers.

Finally, overlap these layers together to produce 2D flight situation output.

The design of multi-layer structure follows a software development principle - "divide and conquer". By treating different navigation information with different feature separately, the difficulty and complexity of the development of GCS software are considerably reduced.

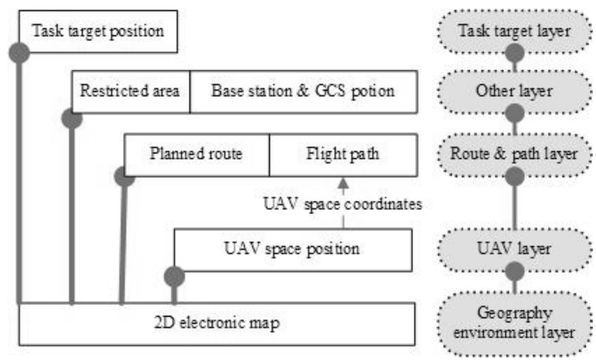

Fig.3. Multi-layer structure of 2D flight situation output

C. Design of Graphical User Interface

The design of GUI should take the software operation mode into account. In discussed UAV system, there could be two possible modes:

1) Normal flight mode: GUI mainly covers the graphical data & parameter outputs, including 2D flight situation, task navigation information, flight control parameters and conditions of each sub systems.

Under this mode, the outputs generally require vivacity or intuition, clearness, convenient operation and high real-time performance.

A typical normal flight mode GUI is shown below in figure 4.

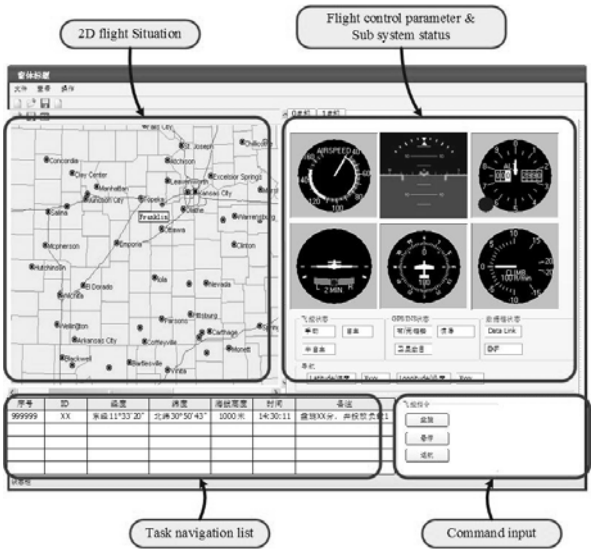

Fig.4. Normal flight mode GUI

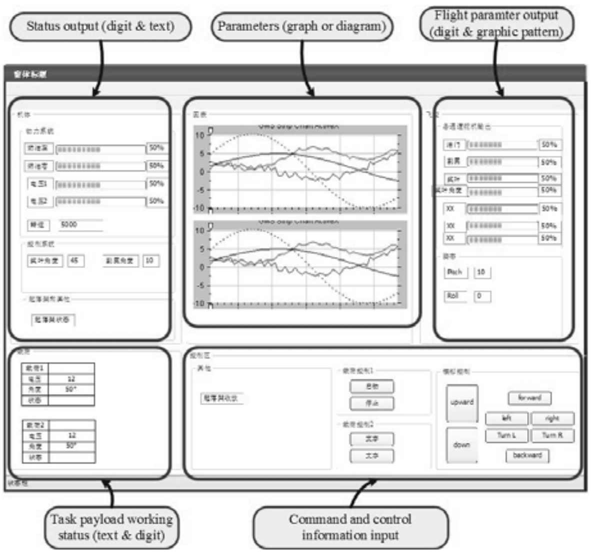

Fig .5. Diagnosis mode GUI

2) Diagnosis & experiment mode: Meanwhile, operator may need to focus on complete, detailed, accurate UAV information, for control algorithm experiment or fault treatment. GUI should cover textual, numerical data output and curve display. GUI also needs to cover multiple way of information inputs, including controlling command & task navigation data, etc.

Under this mode, the diversity of output methods is the major concern.

As shown below in figure 5, a typical diagnosis mode GUI, or a "vice interface" of GCS software provides multiple output and input sections.

Ⅵ. CONCLUSION

The analysis of abstract structure of GCS software, the comprehensive consideration of limitation factors and requirements, and the study on classification & feature of UAV information, can help to avoid blindness and improve development efficiency. The application of virtual instrument (component) technology reflects the method of GUI design; The multi-layer structure of 2D flight situation is a general solution for the problem of navigation information output.

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