Proceedings of the 26th Chinese Control Conference
July 26-31, 2007, Zhangjiajie, Hunan, China

Distributed Remote Control System of UAV Based on Man-in-loop Real-time Operation

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Abstract: Unmanned aerial vehicle (UAV) has been widely applied in reconnaissance, strategic bombing, discharging electromagnetic interference. Of paramount significance to completing tasks is control system; the UAV control system should have the ability of formate, revaluating the flight plan timely, making on-line decisions. Such requirements greatly challenge present control technology. A solution is presented to improve current UAV control system into a remote control system with network distributed computing, three dimensional dynamic display and man-in-loop real-time operation. This system aims to provide better functionality of real time, visualization, and intelligence in order to meet the above demands.. Besides, the application of forecasting display control technology in this system can not only mitigate delay problem—one usual problem in remote control system but also realize a high level of intuitive operability. Moreover, the application of .NET remoting lightens data dropout and makes this system meet the high data-rate communication requirement.
Key Words: UAV, remote control system, man-in-loop, .NET remoting, forecasting display control technology

1 INTRODUCTION

When compared with pilot aircraft, UAV has its unique advantages in that we do not need consider the safety guarantee system, the special design of passenger compartment and so forth any more. In the situation of fewer limitations, we can focus on maximizing pneumatic power and control efficiency. It, however, has its own fatal drawback——removing the human factor from the system so as to be lack of intelligent decision-making and agile flight control.

- Generally, there are three kinds of control methods:Independent control not only includes independent accomplishment of previous decided course and task but also includes making suitable decisions which are based both on previous task and on the analysis of present flight state, independently and timely. The high demand of making decision to deal with complicated problems independently even under some uncertain situations greatly challenges the control theory. Up to now, there are still many problems not solved.
- Telecontrol technology, from real-timely controlling the pneumatic rudder panel and the engine state to intermittently adjusting the flight course, need communications between remote control station and UAV. With timely flight state information, operators are responsible of surveilling and controlling UAV. However, without any independent control, it is sure that operators have large a mount of work.
- The third way is to combine independent control and telecontrol. Under many uncertain situations, it is a good choice to rely on the adaptive, analyzing and decision making capability of human being especially when the complexity of flight task and on-line decision-making exceeds the ability of UAV independent control system. Besides, adding human intelligence to UAV control system can also reduce the cost, lower the risk and improve the efficiency especially when distributing key task, identifying targets precisely or casting weapons. Moreover, adding independent control to telecontrol could reduce the workload of operators as well.

Up to now, distributed flight tasks for UAVS are more and more complicated and draw people's attentions mostly to the third control methods.

2 UAV CONTROL SYSTEM

2.1 Representation of current UAV control system

In view of efficiency, flight mode of UAV is often coordinated aviation. Fig.1 shows the process principle of a practical control structure.

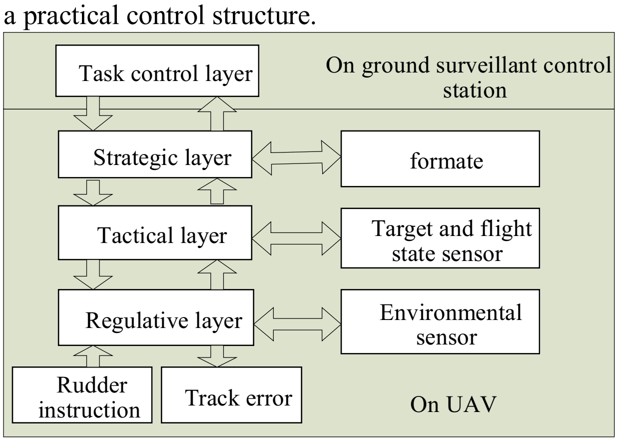


Fig.1 a practical control structure

The function of task control layer is to divide the whole task (such as reconnaissance, bombing and etc.) into detail aim for each UAV. The kernel function of this layer is to deploy resource and to rearrange the plan timely. For example it need to optimize the course of the air fleet when executing the task. The strategic layer takes charge of figuring out the detail limitations of executing the course after analyzing real-time information about appointed lane and target. Also, this layer could adjust coordinated flight plan to avoid collision and conflict among UAV. The tactical layer is responsible for controlling the change of flight modes and to make executable lane instructions. The function of regulative layer is to track the ideal trace by inner loop feedback controller. The first layer is on the ground surveillant control station and the next three layers are on the UAV. Therefore, this system is almost based on independent control with a little telecontrol in the task control layer.

2.2 Improved UAV control system

This paper discusses a way to improve the above control structure into a remote control system of UAV with network distributed computing, three dimensional dynamic display and man-in-loop real-time operation.

As Fig.2 shown, the operation table connects to instruction computer to offer control instruction for UAV in this system. Mode computer figures out flight mathematic model. Three dimensional dynamic display computer is to compute in time and display the flight scene.

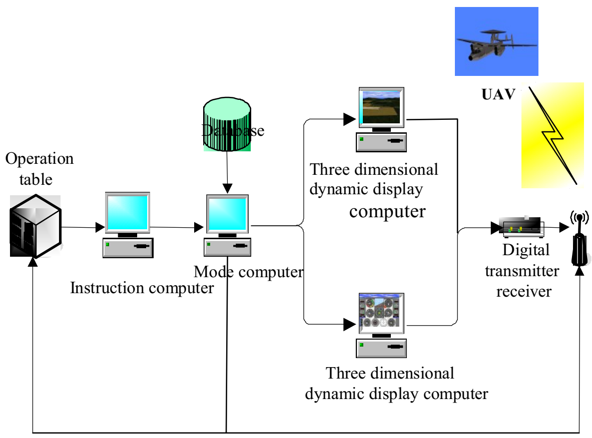
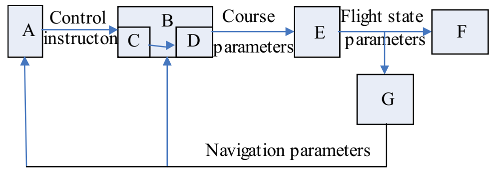


Fig.2 UAV remote control simulation system

To discuss the system further, instruction computer receives control instructions, which are sent by control panel and remote devices, transforms them into digital signals and then sends them to mode computer with promissory protocol on internet in order to control flight state and trace. Mode computer reads UAV parameters from database to work out real-time digital simulation. Moreover, after receiving information from instruction computer, this computer works out locomotory data of aircraft by control loop, rudder loop and the loop made up of UAV itself. Real-time three dimensional dynamic display computer gets data from mode computer periodically and displays real-time 3D dynamic flight scene including takeoff, climbing, wheeling, gliding, descending and etc. With virtual flight instruments, it supplies much real-time and visual flight information of UAV to the operators. Accordingly, the operators can easily control the UAV by sending the accordingly orders through this system. Fig.3 describes the data flow and logic relationship among different modules in this simulation system. These modules make up of a network distributed computing system so as to increase the running speed.



Arepresents a system control table.
Brepresents a flight control system simulation module.
Crepresents control loop.
Drepresents rudder loop.
Erepresents a flight model simulation module.
Frepresents a flight state and instrument 3D dynamic display module.
Grepresents a compositive sensor simulation module.

Fig.3 principle framework of UAV remote control system

2.3 Improvements between the former and the latter control system

Compared with the representation of current UAV control system, the improved UAV control system discussed above are more intelligent and agile with man-in-loop real-time operation. In other words, human factor is added not only to the task control layer but also to the other three layers.

The improvements can be seen clearly from the following example. In 20th century, the Air Force acquired the AQM-34V UAV to perform strategic bombing ahead of manned attack aircraft. When carrying out the appointed task, these UAV, mainly independent control with some telecontrol, bombed a wrong place. Since two-year-old map used for targeting did not show the numbers of buildings on that road, officers mistook the numbers of building on parallel roads as the arms agency of the enemy. Though officers had soon realized the error after sending UAV, it is impossible to prevent the task carrying out totally only by task control layer. If officers in the ground surveillant control station rearranged the plan entirely by task control layer, they would face many other problems for example whether the changed course of the air fleet, based on information from task control layer, would be better than bombing wrong buildings. However, the improved UAV control system add human factor not only to task control layer but also to the other three layers and thus can realize man-in-loop real-time operation. In this case, the timely changing plan could be much more reliable.

3 THREE MAIN PROBLEMS IN THE IMPROVED UAV CONTROL SYSTEM

3.1 Delay problem

The capability of wireless communication system is limited by wireless channel. In wireless communication, because of reflect and dispersion of electric wave, there are multi-transmission routes between sender and receiver. Moreover, both transmission delay and fading gene in each route are time-varying and accordingly make receiving signal fade. The delay between sending instructions and receiving feedback messages prevents operators observing the results of their actions timely, removes the actor from some of the consequences as well as reduces maneuverability seriously.

3.2 Problems brought by network itself

This remote control system of UAV with network distributed computing and man-in-loop real-time operation is a representative example of Networked Control System (NCS). In other words, each part of the feedback control system makes up of a closed loop by real-time network.

As Fig.4 shown, its essential is to exchange information among control components (reference input, object output, control parameter input and etc.) by network. Though this system has its unique advantages, it is obvious that the introduction of network into control system makes the analysis of control system much more complicate and some new problems such as data dropout, time confusion and time-varying delay.

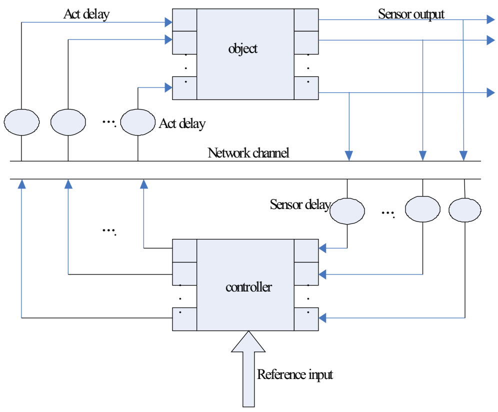


Fig.4 NCS framework

3.3 High demand of transmission rate

Data transmitted between UAV and the main station include telecontrol information, telemetry information and task sensor information. Telecontrol information is a kind of control information sent by the main station to UAV. Its main function is to control flight state, to lead UAV to required position and to manage various kinds of instruments. Telemetry information, from UAV to the main station, includes flight state, flight parameters, instruments' working condition and etc. Though the reliability, security and real-time demand of information transmission is high, the amount of telecontrol information and telemetry information is small and generally 12.8 kbps transmission rate is enough. Task sensor information is a kind of information obtained by task instruments such as television camera, infrared scanner, multi-spectrum sensor, compositive aperture radar and etc. The amount of task sensor information relate to the kind of task sensor, the size of image, resolving power, compression ratio and etc. Compared with telecontrol information and telemetry information, the amount of task sensor information is very large and demands high data-rate communication. For instance, task sensor information which is five-spectrum image, dimension 400 pixels × 600 pixels, 25 frames per second, 10 compression ratio, requires 24 Mbps transmission rate.

4 SOLUTIONS FOR ABOVE PROBLEMS

4.1 Forecasting display control technology

In view of delay problem, this paper discusses the forecasting display control technology in order to meet demands of the UAV control system. The developments of computer science, graphics and image technology, software engineering have pushed the research and application of system simulation technology into a new era of visualization, multimedia and VR (virtual reality). As Fig.5 shown, forecasting display control technology provides a scene in which entities move and behave believably and approximate the complexity of the real world.

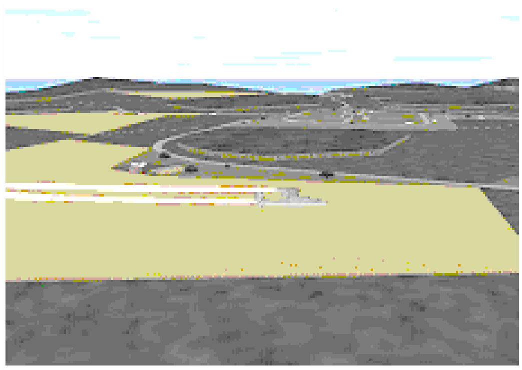


Fig.5 three dimension dynamic display of UAV flight

As Fig.6 shown, the idea behind this technology is to "project" actions that are carried out by users in the virtual world into the real world, like projective virtual reality in a sense. There is no delay between operators and the virtual world. Therefore, operators could work like they would in the physical world so as to this type of man machine interface reaches a high level of intuitive operability. The basic idea of applying forecasting display control technology in UAV control system is to build up virtual UAV to simulate real UAV with computer graphics, simulation technology and VR. Operators directly control virtual UAV to complete required task in virtual environment and then real UAV will follow what the virtual ones have done. With this forecasting display control technology, operators could control UAV more easily and precisely.

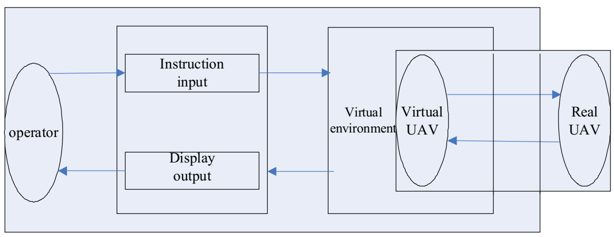


Fig.6 system framework

4.2 .NET remoting

Though forecasting display control technology has modified the improved UAV control system in order to mitigate the delay problem, there are still other problems in actual information transmission process. Considering the problems bought by network itself and high requirement of communication rate, .NET remoting, a framework for developing distributed applications, is a good choice. As the successor to DEC/RPC/DCOM, .NET remoting can help to solve the above problems in that it makes the communication system more reliable, applicable and compatible. This framework not only allows objects to interact with one another across application domains but also provides a mass of services. For example, .NET remoting provides object activation, lifetime support, communication channels for transporting messages to and from remote applications and etc. It enables objects in different application fields or processes to build up communication channels without limitation of transfer protocol. Before messages are transported by the channel, formatters are used for encoding and decoding. When interoperability with other remoting framework is critical, applications can use binary encoding or XML encoding which uses the SOAP protocol in transporting messages. Besides, .NET remoting provides abstract communication processing approach which can separate the remotable object from a specific client or server application domain and from a specific mechanism of communication. In this case, it greatly simplifies the accessing of distributed objects.

As Fig.7 shown, client side creates one instance of server classes and the remoting system creates a proxy object which represents this class and returns a reference of the proxy to the client. When a client calls a method, the processing structure of .NET remoting deals with the calling, verifies the message type and then sends the calling to the server process by channel. By listening to the channel, requests are forwarded to the server remoting system, which finds and calls the requested object. Then the procedure is reversed and the server remoting system transforms the response into messages that are sent to the client channel by server channel. Finally, the result of the call is returned to the client object through the proxy and any application can provide its services to any client on its network.

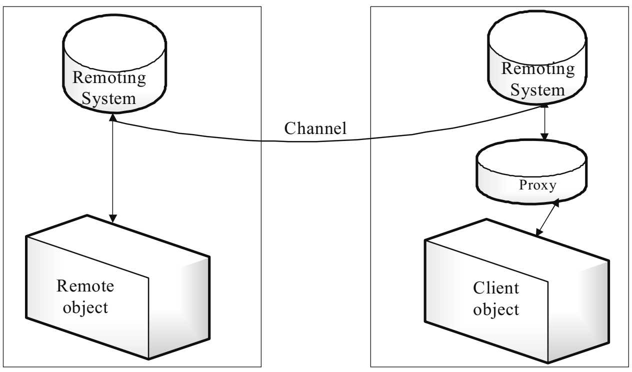


Fig.7 remote process

5 CONCLUSION

With wider and wider application and more and more complicated tasks for UAV, researchers focus on improving the UAV control system. In this paper, the improved UAV control system has the following advantages:

- The adaptive, analyzing and decision making capability of human being make this system more intelligent and agile. Abilities of revaluating the flight plan on line, making real-time decisions and managing malfunction are powerful.
- This system could lighten data dropout, transmit large amount of task sensor information and meet the high data-rate communication requirement.
- Forecasting display control technology not only mitigates delay problem—one usual problem in remote control system but also makes the system reach a high level of intuitive operability.

However, this control system still has space to be further improved. For example the reality of virtual flight instrument needs to be advanced and the delay between virtual UAV and real UAV still exists. Yet a remote control system with network distributed computing, three dimensional dynamic display and man-in-loop real-time operation will, of course, be an important research direction in future.

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