TERRAIN FOLLOWING FLIGHT REAL-TIME HIL SIMULATION PLATFORM RESEARCH

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Abstract

Terrain Following Flight is an effective method to penetrate enemy's airspace. So many aircrafts equip the low altitude navigation pods. But the development of the navigation pod is very dangerous, costly and time-consuming, because the low altitude flight test is very dangerous. To reduce the test risk and cost, a terrain following real-time HIL simulation platform are built. In this article the simulation platform's structure, working mechanism, simulation models, cabin instrument simulator and simulation method are introduced. Finally, Simulation data are compared with real flight test data demonstrating the simulation platform has strong validity and credibility.

1 Introduction

Terrain Following Flight is an effective method to penetrate enemy's airspace. Low Altitude Navigation Pod is the key navigation equipment for aircraft to reduce the risk of low altitude terrain following flight.

Low Altitude Navigation Pod integrated an Air to Ground Radar, a Navigation Computer and a Temperature Control System. Air to Ground Radar scans terrain outlines. Navigation Computer calculates the terrain following algorithm (TF Algorithm) and output terrain following command (TF Command) to the pilot.

Because the real flight-test of Low Altitude Navigation Pod is very dangerous, costly and time-consuming, terrain following flight real-time HIL simulation platform is constructed. It can effectively reduce the flight-test risk, cost and time.

In this article terrain following flight real-time HIL simulation platform's structure and theory are introduced firstly. And then some key technologies such as designing radar model algorithm, constructing simulation models based on Matlab/Simulink and generating real-time simulation codes with RTW (Real-Time Workshop) and VxWorks. Lastly, a terrain following flight real-time HIL simulation is completed and simulation data is compared with real flight test data.

2 Terrain Following Flight Real-Time HIL Simulation Platform

2.1 Structure

Terrain following flight real-time HIL simulation platform integrated 6-DOF dynamical aircraft model, radar model and emulational navigation instruments. It has five parts which are real navigation computer, real-time simulator, TF instruments simulator, simulation control computer and joy stick. Figure 1 shows its structure.
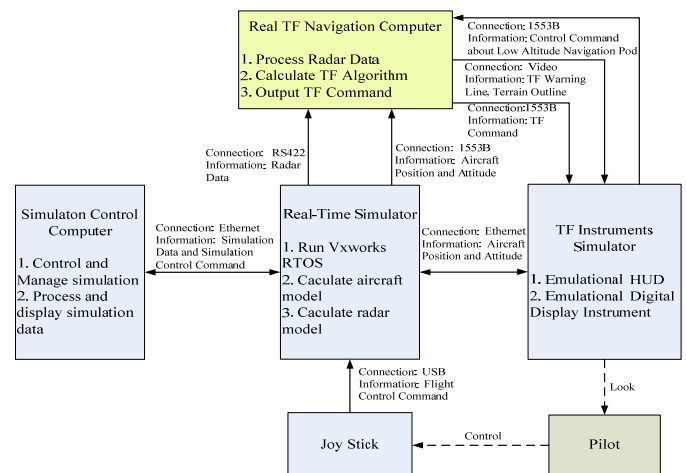

Fig. 1 *Terrain following flight real-time HIL simulation platform Structure*

2.2 How It Work

In figure 1, the real TF navigation computer is a real aircraft's equipment and it is the test object in this simulation platform. The TF navigation computer use it's high rate serial port obtain the radar data which include the angle and distance between the aircraft and the ground. Besides serial port, the navigation computer connects to the 1553B Bus. On this bus, there are flight control computer, INS and air computer. The TF navigation computer get aircraft's attitude data such as the plane's position, pitching angle, roll angle and so on. Using these radar's data and flight data, TF navigation computer calculates the TF algorithm and generates the TF command, warning line, terrain outline line and the zero-command line which are will display on the aircraft's monitors.

The real time simulator is the core of this simulation platform. It runs VxWorks OS, calculates plane model (including 6-DOF aerodynamic model, flight control laws, sensor models and actuator models) and compute the radar model (the model calculating the angle and distance between the aircraft and the ground). The simulator has serial port, 1553B port, USB port and Ethernet port. It use the serial port and 1553B port to communicate with the real TF navigation computer, sending radar data by serial port, sending aircraft's attitude data by 1553B and getting the TF command by 1553B. Through the Ethernet, the simulator sends the aircraft's flight data to the TF instruments simulator and gets the control command such as starting simulation, stopping simulation and so on. The joy stick is connected to the simulator by USB port and sends the control command to the flight control models which are running in the real time simulator.

The TF instruments simulator simulates the aircraft's meters in the cabin. The TF instruments simulator obtains the real TF navigation computer's commands and the command lines and displays this information on the monitor. Thus the pilot can see this navigation information to drive the aircraft.

3 Modeling and Code Generation

In this section, constructing simulation models by Simulink and generating real-time VxWorks simulation codes by RTW are introduced as below:

Firstly, develop the aircraft models which include sensor models, actuator models, 6-DOF dynamics model, radar models and control law models.

Secondly, develop the real-time simulator's VxWorks hardware drivers about 1553B card, Ethernet card and high-speed serial card and then wrapping these drivers into Simulink modules by using s-function.

Finally, generate the simulation models' C codes that can run in VxWorks operating system by using RTW.

3.1 A New Method of Modeling and Code Generation

In the real-time simulator there are radar models, aircraft models and IO card driver models. We use Matlab and Simulink to construct the simulation models because we can use RTW (Real Time Workshop) to generate the real-time C code automatically and run the real-time C code in the VxWorks OS.

RTW is an extension of capabilities found in Simulink and MATLAB to enable rapid prototyping of real-time software applications on a variety of systems. It provides a real-time development environment -- a direct path from system design to hardware implementation. User can streamline application development and reduce costs with RTW by testing design iterations with real-time hardware. Real-Time Workshop supports the execution of dynamic system models on hardware by automatically converting models to code. It not only supports x86, DSP and PowerPC hardware but also support Dos, VxWorks, Windows and xPC operating system.

A new real-time simulation method based on Matlab/RTW and VxWorks is introduced below.

Before real-time HIL simulation, digital simulation needs to be done. We should construct the aircraft's dynamical models, design control laws, construct the aircraft control system's digital close-loop models using

Simulink and do digital simulation until the control law satisfy the digital design requirement. In real-time HIL simulation phase, we should develop VxWorks drivers for simulation computer hardware, construct real-time HIL simulation platform, generate codes using RTW and then do real-time HIL simulation.

Besides we can use RTW extern mode to tune control parameters on-line to optimize the flight control law and testing all parts of the flight control system. Using this method we can realize a rapid translation from digital simulation in flight control system designing stage to real-time HIL simulation in control system testing stage. The whole simulation flow is described by Fig.2.
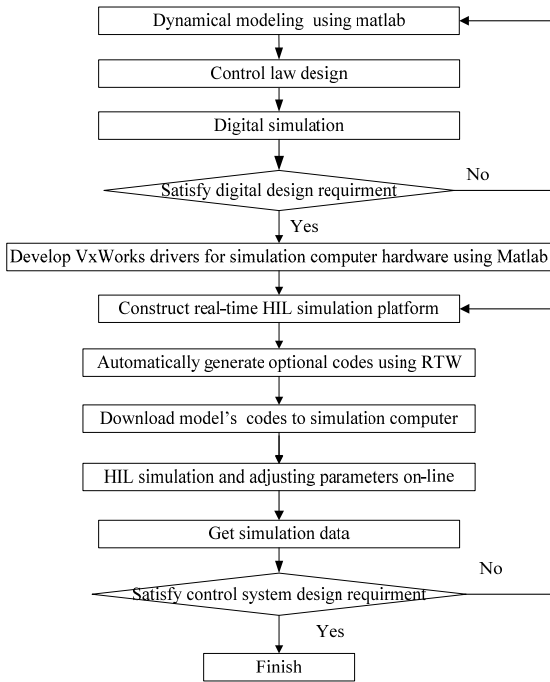
Fig. 2 *Real-time simulation method based RTW*

3.2 System Model

Terrain following system comprises TFR (Terrain Following Radar), TFNC (Terrain Following Navigation Computer), FCS (Flight Control System), INS (Inertial Navigation System) and RA (radio altimeter). TFR scans terrain outlines periodically and translate terrain data to the TFNC. TFNC receives terrain data, aircraft's pose and position data, calculates the terrain following algorithm according to maneuverability restrict and output TF Command to the FCS. FCS and pilot will control the aircraft's pitching angle to finish the terrain following flight.

Terrain following system models is constructed by Simulink showed by Figure 3.
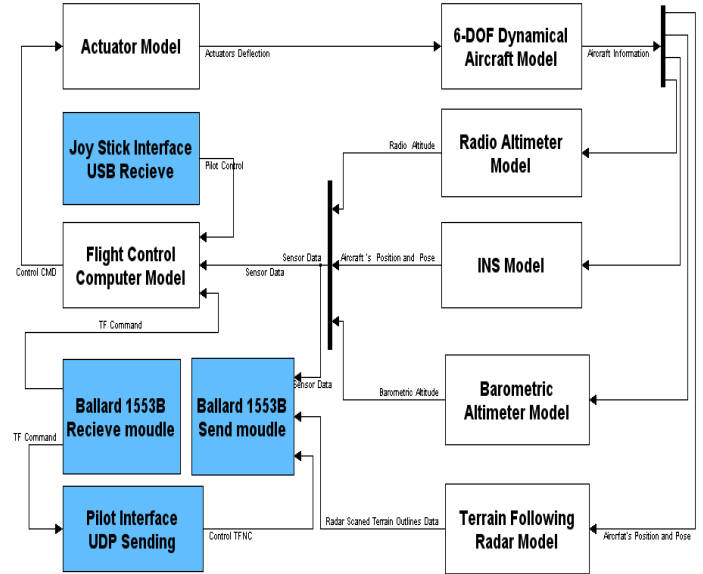

Fig. 3 *Terrain following flight real-time HIL simulation model*

In this model there are four IO driver models which realize the communication with the real TF Navigation computer, TF instruments simulator and the joystick.

3.3 Radar Models

The main theory of radar model is extending a virtual radar beam from the aircraft and then recording the beam's distance and angle when this beam reaches the raw terrain. The distance and angle will send to the real navigation computer to calculate scanned terrain outline.

In the terrain following model, the radar model is a key technique. In Figure 4, aircraft's position is P (x0, z0) and altitude is H2=z0; radar beam's angle is Beta; radar beam's length is L.
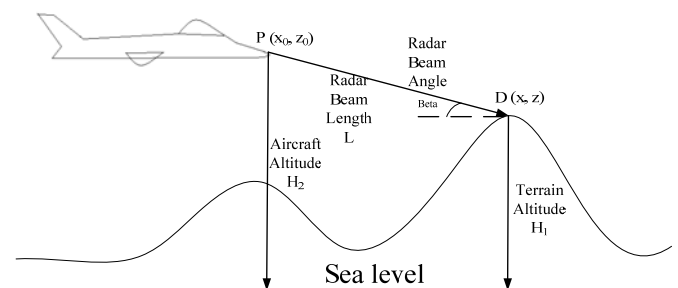

Fig. 4 *Radar Model Mechanism*

According to Figure 4, the radar model algorithm is showed by Figure 5.
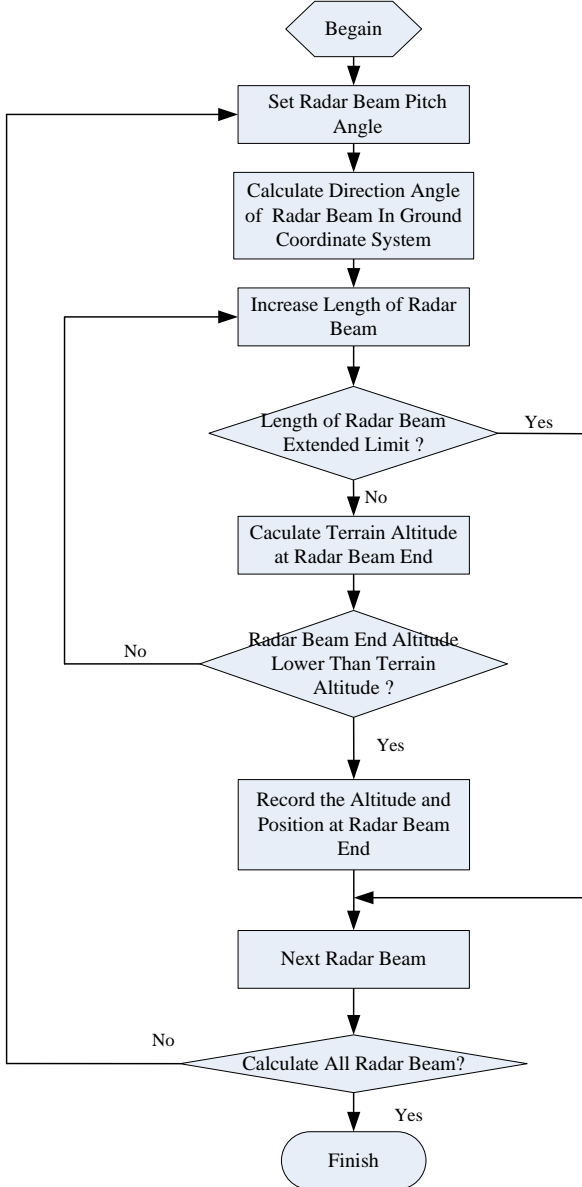

Fig. 5 *Radar Model Algorithm*

4 Cabin TF Aircraft Instrument Simulators

Based on GLStudio and CVI, the cabin TF instrument simulator was developed. TF Command and TF command line are displayed in the simulator. Following figures are flat display and below display.
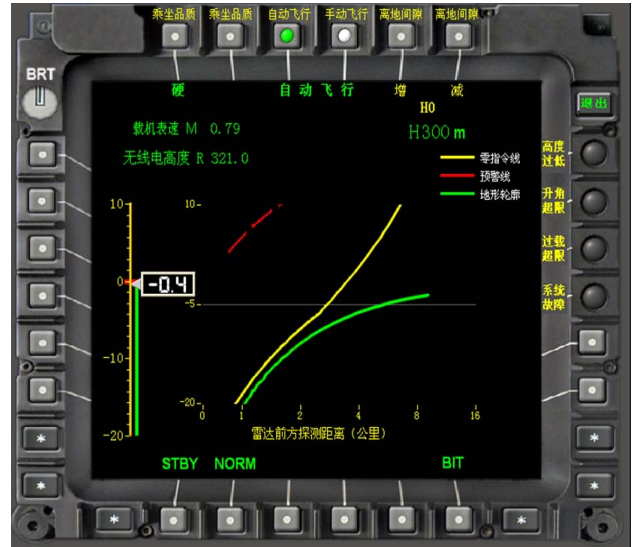


Fig. 6 *Below Display*

Fig. 7 *Flat Display*

5 Test and Data

A whole real-time HIL simulation for terrain following flight is completed and the simulation data is compared with a real flight test data.

In the simulation the real terrain outline data is used, which is recorded in the real flight-test. In figure 8, the blue line is aircraft's real track recorded in a flight test; the red line is the simulation track; and the green line is the real terrain outline.

This is an automatic flight. This comparison demonstrates the simulation platform has strong validity and credibility.
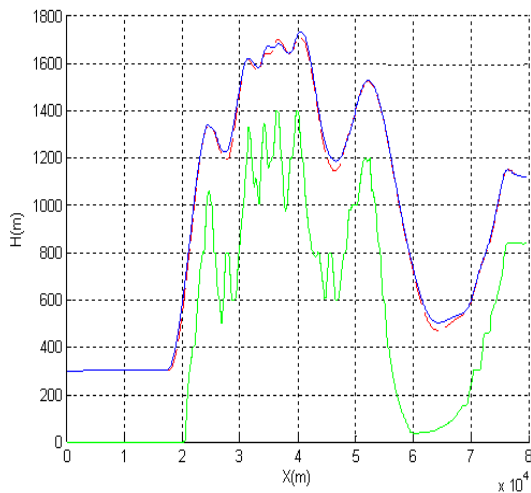
Fig. 8 *Terrain following Track*

6 Conclusion

In conclusion, profiting from the advantages of terrain following real-time HIL simulation platform, the TF algorithm and the terrain following navigation computer are improved. Especially, the risk and cost of real flight-test are reduced.

References

[1] Hallberg E，Kaminer I, Pascoal A. "Flight Test System for Unmanned Air Vehicles". *IEEE Control Systems Magazine* . 1999，2（1）：55～65.

[2] Menon P.et al. "Optimal Trajectory Synthesis for Terrain-Following Flight." *J. Guidance*, 1991, 14 (4): 807-813

[3] Erkkinen Tom. "Code Generation and High-integrity Embedded Systems". *Dr. Dobb's Journal*, vol. 6(6), pp. 68～70, 2004.

[4] The MathWorks, Inc. *Real-Time Workshop For Users With Simulink*. The MathWorks, Inc. 2003，3.

[5] The WindRiver Inc. *Tornado User Guide*, The WindRiver Inc. 2002.

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