Research on simulation technology of Shipborne Satellite Communication System

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Abstract. In this paper, aiming at the architecture, key technologies and member functions of the simulation of the onboard satellite system, a simulation federate model with good hierarchical structure is designed, and a satellite communication simulation system based on HLA is constructed. The key problems such as time unification, fault simulation and real-time visual display are solved. Through the functional simulation of the operation process of the Shipborne Satellite Communication System in the distributed virtual simulation environment, the results show that the system has good interactivity and scalability, and is an effective means to test the reliability of equipment and reduce the risk of scientific test.

1. Introduction
Shipborne satellite communication system, as the hub of ship data transmission, is composed of communication satellite capture and tracking equipment, information terminal equipment, radio frequency processing equipment, data receiving and transmitting equipment, control system and other equipment. Simulation technology is a comprehensive technology based on similar principles, information technology, system technology and its application field-related professional technology, using computers and various physical effect devices as tools, and using system models to conduct experimental research on actual or assumptions. The use of simulation technology to establish a simulation system for the operation process and operation of the shipboard communication system can provide data and virtual platform support for each stage of system operation and provide a basis for decision-making for real tasks.

2. System Overview

2.1. High-level architecture
HLA (High Level Architecture) is a high-level architecture of distributed interactive simulation proposed by the US Department of Defense. Its basic idea is to use object-oriented methods to design, develop, and implement object models of simulation systems to obtain high-level interactions. Operation and reuse. The HLA architecture model can not only manage and distribute simulation systems, but also manage and distribute simulation data in real time, emphasizing the reusability of simulation resources, the scalability of simulation models, and the interoperability of federal members. Structural simulation, virtual simulation and live simulation between systems.
HLA defines the architecture and mechanism of interoperability between federal members, and realizes interoperability through the Federal Runtime Support Environment (RTI: Run-time Infrastructure, also known as runtime infrastructure). HLA does not allow direct interaction between simulation components, but transfers the data to RTI for transfer. RTI is the specific implementation of the HLA interface specification. It is the core component based on HLA distributed simulation and the basis of HLA simulation program design and operation.

2.2. Simulation model
HLA builds a simulation system based on object-oriented ideas and methods. It is a technology that divides simulation members and builds a simulation federation based on object-oriented analysis and design. In HLA, the distributed simulation system used to achieve a specific simulation purpose is called Federation. It consists of several interacting federation members (Federate). The federated members are composed as a distributed interactive program entity. Federal simulation runs. When establishing an actual simulation system, specific federal members should be set up based on specific simulation scenarios and functional requirements.

The data interaction process is shown in Figure 1. After the shipboard data sending and receiving system acquires and processes the target satellite control data, it is transmitted to the satellite communication system through the data processing and network transmission platform. The satellite communication system sends the data through the data transmission link to the control center. At the same time, the control center sends control information and other data to the ship through the satellite communication system and transmits it to the target through the data sending and receiving system and the heaven and earth communication system, thereby completing the complete control process.

2.3. Key technology
(A). Time management technology
When controlling satellites, the time unified system enables all equipment in the control system to work under a unified time standard. The time unified system provides the time code (BDC) format and standard 10MHz frequency signal to the entire network equipment, so the time unified system is one of the most important standards of the control and communication system. For the communication simulation system, time synchronization is a key point solved problem.

Because HLA allows federal members to have their own time advancement methods, for simulation members with different functions and different time strategies, it is necessary to refer to the actual time unified system and establish time management services. HLA provides a time management service to solve this problem. By controlling the sending of timestamp events, it ensures that federation members will not receive events from other federation members whose simulation time is less than their own simulation time. In the design of this system, the time unified system members provide the reference time. When the remaining simulation members receive the reference time, the distributed simulation is completed independently according to their own simulation model, thereby avoiding the burden of the simulation members caused by repeated calls to the reference time process.
(B). Fault simulation technology

The focus of communication simulation system development is on the simulation of the satellite control implementation process. In order to meet the requirements of improving training levels and emergency response capabilities, the simulation of the actual operation failure of equipment has become an important part of the simulation system. In the actual communication system, there are many factors for the occurrence of faults. It is unrealistic to simulate all possible faults globally. Therefore, you can only refer to historical faults and design according to typical fault sources such as components, interfaces, parameters, etc. Fault rehearsal playbook, which designs scenes for fault phenomenon, fault influence and fault diagnosis. The fault playbook is displayed in the form of a fault tree.

When the system is running, the control personnel selects and sets specific fault types according to the fault script. According to the selected fault type, the fault diagnosis member will pass the fault code to the related equipment member involved in the fault through interactive operation. After receiving the fault codes of the fault diagnosis members, the relevant device members implement corresponding fault simulation. In the process of troubleshooting by the operator, each equipment member evaluates the standardization and correctness of the troubleshooting operation according to certain measurement criteria, and returns the final evaluation result to the fault diagnosis member. After all the faults have been correctly eliminated, the fault diagnosis member will again pass the information of successful troubleshooting to the relevant device members through interactive operations, so that the system enters the normal simulation process.

(C). Visual Simulation Technology

The visual simulation is divided into multiple federal members. The federal members are mainly used for kinematics simulation. Through the data-driven simulation program, the visual entity's trajectory is consistent with the position and attitude of the data. The federal members are used to implement in the hull coordinate system. Real-time visual attitude display of communication outer deck equipment (antenna).
3. Design of the system

3.1. Simulation member design

The simulation system consists of a simulation director control center, a network database server, a time unified system, a charge center, an observation member, and various simulation member machines, as shown in Figure 2. The observation platform is composed of ordinary network-connected microcomputers, and the high-performance database server instantly stores the required network communication data to support the system playback function, and realizes the post-observation and evaluation of the equipment operation and personnel training; the simulation director control center undertakes the exercise training director, Centralized monitoring of various systems and other functions, the control center completes the simulation of the higher-level mission center; the visual and ship visual simulators respectively complete the visual simulation of the target spacecraft and ship deck equipment; the unified time system uses RTI for all members Provide high-precision time, provide time and frequency reference for periodic data transmission with high synchronization requirements.

The status response and interface relationship of each subsystem in the simulation system are complex. It is necessary to divide the functional decomposition granularity reasonably according to the structural composition and characteristics of each subsystem, establish an HLA / RTI-based simulation system and federation members, and design and develop federation and simulation objects model.

(A). Design and Implementation of Simulation Director Control Center

The simulation director control center is mainly used by command and control personnel in the process of simulation implementation. Its main functions are:

① Director control function: according to the set state, generate control signals for each simulation member, and monitor the running status of each simulation member;

② Effectiveness evaluation: based on the prescribed operation timing, fault handling operations, etc., the operator's equipment operation is scored;

③ Fault simulation: It is used to set the fault location of the device, fault handling method, and control the status of the device;

④ Control simulation playback: By recording the status and parameters of each simulation member in real time, the operation data stored in the database can be played back afterwards to achieve system analysis and evaluation.

(B). Design and implementation of main simulation members

Servo and channel simulation members are mainly used to provide operation interfaces for post personnel to implement operation training during the simulation implementation process. The virtual instrument software generates an interactive interface that is completely consistent with the actual
device operation interface, and the post personnel interact with the simulation members through this interface. Its main realization content is: operation interface: mainly input of mouse and keyboard, and input of various switches and buttons, etc.; status display: mainly various indicator lights, instruments and displays on the operation panel.

3.2. System structure design
The communication simulation system adopts a hierarchical structure design. Good hierarchy can simplify the development process of the system and enhance the maintainability and robustness of the system. It is the premise and interoperability, scalability and resource reusability of the system basis. According to the realization process of the simulation plot, the system is divided into four implementation levels: communication interface layer, data layer, functional entity layer and human-computer interaction layer.

(A). Communication interface layer
According to the HLA / RTI architecture, the communication interface layer implements data exchange between federation members through a distributed network environment. The federation member interface module interacts with the RTI interface through the HLA standard. There is no need to design a separate communication protocol to directly interact with the underlying communication network, thereby achieving system reusability and federation scalability, and improving simulation efficiency.

(B). Data layer
The data layer is the basis of simulation implementation and system operation, and is the core layer of the simulation system. Through the actual modeling of data types, operations and processing algorithms in the system network, and at the same time, in response to the special requirements of the simulation plot, in the form of data services, data storage, data processing, data acquisition, and data retrieval are provided to provide the high-level needs information.

(C). Functional entity layer
The functional entity layer as the main body of the simulation application, based on the actual equipment operation process and the overall requirements of the simulation plot, based on the data services provided by the data layer, a series of functional entities independently carried by the federal members are designed, and the time required to simulate the system The requirements of unification, operation scheduling, etc. realize the synchronization of the simulation process within the federation members and the synchronization of the functions between the members.

(D). Human-computer interaction layer
The human-computer interaction layer provides the interface environment in which the system runs, and the simulation entity needs to provide an operating interface that is consistent with the real object; for the visual simulation, the real-time dynamic display of the simulation process needs to be realized in the three-dimensional visual window; Simulation members need to use charts, block diagrams, process display and other means to achieve a visual display of the simulation process and simulation results.

3.3. Object class and interaction class design
According to the actual function and operation process of the communication simulation system, the main object class and interaction class of the design include the following elements:

(A). Object class and its properties
Communication satellites: frequency, coordinates, antenna gain, antenna half-power beamwidth;
Receiver information category: receiver antenna gain, receiver antenna half-power beamwidth, Doppler frequency shift;
Servo information category: ship coordinates, antenna tracking each axis geographical angle, deck angle;

(B). Interaction class and its attributes
Control commands: control commands, including start, run, stop, fault status code, fault response, etc.
Operating status category: system name, current time, current status, etc.
Communication information: the content of interaction with other systems, mainly all kinds of data information actually transmitted;

4. Program implementation

4.1. Development environment
The simulation system chooses MAK RTI 2.2 of MAK Company to build HLA environment, and chooses VRLink for simulation development. It is a series of object-oriented C++ classes and function libraries provided by MAK Company. It designs distributed network simulation according to HLA rules.

VS C++ is used as the main program to develop the simulation program of the main federal members. The development environment is Visual studio.NET 2003.
The device simulation operation panel is developed with NI company's virtual instrument tool LabWindows, and the development environment is labwindows CVI 8.5.
The visual simulation tool chooses AGI's aerospace system simulation tool software STK (Satellite Tool Kit) to perform real-time simulation rendering and demonstration of members such as communication satellites and communication antennas. The development environment is STK8.0.

4.2. Program integration method
RTI provides a series of object-oriented C++ classes and function libraries, so the main program written based on C++ can directly call the interactive class to complete the simulation under the HLA framework. Because this system uses LabWindows to develop equipment simulation panels, and STK is used for partial visual simulation, the complete operation of the simulation system must be organically combined with different development environments to achieve the unity of data and operations.
The development of LabWindows / CVI virtual instrument program is generally to directly generate *.exe execution files in its development environment. This system uses the method of dynamic link library (DLL) calling. First compile the emulation panel program designed by LabWindows into DLL, and then call it in the main program written in Visual C++. Through the parameters of the output function provided by the DLL, you can call the LabWindows program panel in the C++ main program, and at the same time realize the data transmission from the Visual C++ program to the LabWindows / CVI program; This can be achieved by providing a callback function (callback) by Visual C++.
The data interaction between STK and RTI is realized through the connect function of STK. The main program of the simulation member written in Visual C++ constitutes middleware. The STK / Connect module is used to complete the communication between RTI and STK, display. The module calling relationship of two different calling methods is shown in Figure 3.
Simulation operation interface
Lab Windows Dynamic Link Library (DLL)

Figure 3. Schematic diagram of system development call

5. Conclusion
Through the analysis of the architecture, key technologies and member functions of the satellite communication simulation system, a shipboard satellite communication simulation system based on HLA is constructed, which can complete the function simulation of the communication system in a distributed virtual simulation environment. This system has been deployed and applied in ocean-going ships, and has become an effective means of testing equipment reliability and reducing mission risks. The communication system has a relatively complicated structure, and the simulation of the whole system and the whole process is the research direction of the simulation system. The follow-up needs to be carried out in terms of accuracy and effectiveness of data modeling, modularity and scalability of the system One step research work.

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