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An HLA based design of space system simulation environment

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Abstract

Space system simulation is involved in many application fields, such as space remote sensing and space communication, etc. A simulation environment which can be shared by different space system simulation is needed. Two rules, called object template towing and hierarchical reusability, are proposed. Based on these two rules, the architecture, the network structure and the function structure of the simulation environment are designed. Then, the mechanism of utilizing data resources, inheriting object models and running simulation systems are also constructed. These mechanisms make the simulation objects defined in advance be easily inherited by different HLA federates, the fundamental simulation models be shared by different simulation systems. Therefore, the simulation environment is highly universal and reusable.

Keywords: Space system simulation; Simulation environment; HLA; Reusability; Universal environment; Object library

1. Introduction

Along with the development of space technology, more and more people use simulation technologies to simulate space systems and establish simulation environments, such as STK (Satellite Toolkit) [1], SCT (Spacecraft Control Toolbox) [2], EuroSim [3] and Open-SSESSAME [4], aiding space system design and optimization.

Space systems are often simulated together with relative ground support systems and ground user terminals, for evaluating the overall performance or effectiveness of the system. The complex system consisting of these systems is called meta-system [5–8] or system of systems. The space system simulation dealing with a space meta-system is called space meta-system simulation. It is difficult to simulate these complex systems using hardware-in-loop simulation methods. The distributed mathematical simulation, for example, HLA (high level architecture) simulation [9–12], is needed to distribute objects reasonably into many computers and simulate the information flows of the whole space meta-system using information exchanges among the simulated objects.

Space system simulation is involved in many fields, such as space remote sensing, space communication, navigation and positioning, and deep space exploration, etc. Even though the HLA simulation technology is adopted, simulation systems for different fields may easily be chimneys and construction work may be repeated, if they are developed separately. So, a simulation environment which can be shared by different HLA simulation federations of space system is needed. In this paper, a new scheme of simulation environment is proposed, in which several mechanisms ensure that the simulation environment is highly universal and reusable.

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2. Principles of space system simulation environment design

As mentioned above, space system simulation is involved in many different application fields. However, for these fields, there are many common things, such as the definition of simulation objects, the fundamental simulation models and the simulation system structure, etc., which can be designed and constructed uniformly and then be shared by different application fields. It is the ultimate rule that the common things are shared as many as possible. Two material principles are raised.

2.1. The principle of object template towing

Using the Joint Warfare Simulation Object Library (JWSOL [13]) in the Joint Warfare System (JWARS) for reference, a uniform Space System Simulation Object Model Library (SSSOML) is established, which consists of an object template library and a fundamental model/algorithm library, see Fig. 2 in Section 3.1. The object template library provides the naming of object classes, the inheritance relationship of objects, the definition of object attributes and object methods. The implementation codes of all the object methods are deposited in the fundamental model/algorithm library. Every HLA federation of space system simulation is based on these object templates. This principle makes object behavior or performance models be easily inherited. For details, see Sections 3.3, 3.4 and 4.3.

2.2. The principle of hierarchical reusability

The reusability of the simulation environment is improved in many aspects and levels as follows.

- In the aspect of simulation technology system, HLA–RTI is adopted to support the reusability of *federate-level*.
- In the aspect of program structure, object-oriented methods are adopted for system modeling and program developing, to improve the reusability of *program-structure-and-code-level*.
- In the aspect of simulation objects, a uniform SSSOML is created to support the reusability of *object-level*.
- In the aspect of simulation resources, uniform databases are setup, in which the fundamental model/algorithm library supports the reusability of *program-function-level*, and the spacecraft database, the space environment database and the simulation scenario database support the reusability of *data-level*.
- In the aspect of application systems, every simulation application system uses a universal and consistent structure to support the reusability of *application-system-structure-level*.

3. The scheme of the space system simulation environment

3.1. The architecture

The space system simulation environment consists of a fundamental software and hardware environment and an application environment. See Fig. 1.

The fundamental software and hardware environment cannot directly support application research by itself, but can provide the basic software and hardware supports.

The application environment consists of data, models, tools and systems directly relevant to simulation applications. See Fig. 2.

(1) *Fundamental resources*: For details of the SSSOML, see Sections 3.3 and 3.4.

(2) *Experiment support tools and systems*: They are COTS (commercial off the shelf) software tools and experiment support systems developed by ourselves. Among them, the scenario management system is a universal editor of simulation objects. It can be run independently or integrated into any application system as a common module.

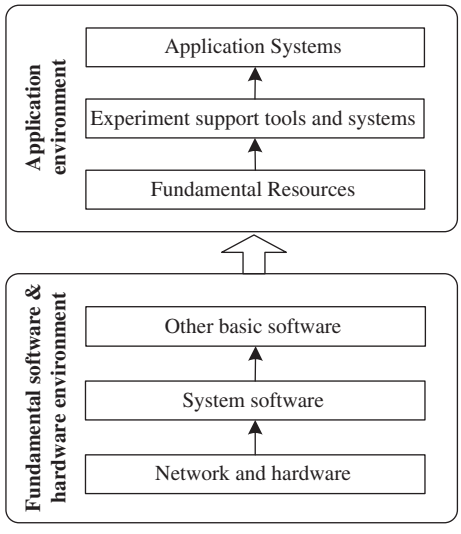

Fig. 1. The architecture of the space system simulation environment.