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Design and Implementation of a Joint Simulation Test Platform Based on LVC

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Abstract. Testing and appraisal are important links in evaluating the full lifecycle operation of unmanned systems, and are the last hurdle before entering the consumer market and military battlefield. They play a crucial role in improving the quality of unmanned systems. The performance assessment of traditional single system, single platform, and single equipment under standard conditions is no longer sufficient to meet the requirements of equipment development. Virtual experiments can make up for the shortcomings of physical experiments, improve the safety, efficiency, and effectiveness of testing and verification work, and have become a new form of experimentation that combines physical experiments. Firstly, an introduction is given to the real, virtual, and constructed LVC integrated simulation technology. Based on the requirement analysis of the LVC based weapon equipment joint simulation test platform, the basic composition and architecture of the platform are designed. Finally, the platform is implemented. The joint simulation test platform designed in this article can be used to combine resources of different scales according to the test purpose, thus achieving joint simulation tests at the unit level and system level of weapons and equipment.

Keywords. Testing and Appraisal, LVC(Live-Virtual-Constructive), Joint Simulation Test Platform

1. Introduction

With the rapid development of information technology and network technology, the form of modern warfare has also undergone significant changes. Network warfare is becoming an increasingly important combat style in high-tech warfare, moving towards joint combat modes such as air ground combat and air sea combat. Equipment testing and identification is an important part of the equipment development process. The transformation of equipment development concepts has brought about changes in equipment testing and identification, and the increasing level of equipment informatization, networking, and automation has put forward higher requirements for the testing ability of weapon equipment systems. The traditional experimental mode mainly based on physical experiments is difficult to meet the experimental requirements. Virtual experimentation can make up for the shortcomings of physical experimentation, support experimentation and evaluation work to improve safety, efficiency, and efficiency, and has become a new form of experimentation that combines physical experimentation.

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Faced with the testing requirements of "full system, full elements, full process, full profile, practicality, and integration", weapon equipment testing and identification should achieve a transformation from single equipment testing to equipment system testing, from testing in standard environments to testing in actual combat environments, and from performance testing to effectiveness testing. In the future, the traditional testing mode of range testing and identification will inevitably shift towards virtual and real integration A joint testing mode combining internal and external field experiments [1].

In response to the above analysis, this article proposes a weapon equipment joint simulation test platform based on LVC, which comprehensively utilizes computer technology, network technology, software technology, modeling and simulation technology, analyzes the advantages and characteristics of real simulation, virtual simulation, and structural simulation, and constructs a joint simulation test environment for multiple weapon equipment combat units, with the aim of promoting innovative development in the field of joint simulation test identification.

2. Overview

In the field of experimental appraisal, there is a demand for realistic and refined content, modes, and methods of weapon equipment experimental appraisal. The performance assessment of traditional single system, single platform, and single equipment under standard conditions is no longer sufficient to meet the requirements of equipment development. Therefore, the testing mode for weapons and equipment urgently needs to break through the limitations of traditional methods and achieve full system, full process, full profile, and integrated testing and evaluation [2]. LVC training provides appropriate interaction, consistency, and interoperability experiences for military personnel at different levels to organize and implement military adversarial exercises, designate operational plans, conduct training evaluations, and conduct technical testing and verification. Through modeling and simulation (M&S) technology, network technology, computer technology, etc., and on the basis of a unified and integrated architecture, a secure and confidential training environment is constructed to enhance the authenticity of training, thereby improving the level of military training and combat readiness [3]. LVC training mainly consists of three types of training:

- Real simulation experiments are conducted on real aircraft or vehicles, using real equipment to provide realistic visual effects, hostile military forces, and communication. For example, during actual flight formation training, pilots are trained on real aircraft.
- Training is conducted in a virtual environment, where the environment, vehicles, aircraft, and weapons are simulated, and the visual scene is generated by computers, such as pilots training on simulators. The strict requirement for virtual training is that people are on the loop.
- Usually combined with V, simulation experiments are constructed, where the combat forces, weapons and equipment, and combat environment are represented by computer models. Testers only participate in the formulation and deployment of combat decision points and import corresponding data into the model under the construction simulation test mode.

The joint testing of weapons and equipment will involve multiple types of resources such as weapons, platforms, instruments, simulators, actuators, computers, software modules, models, and data products. The joint simulation test platform, which integrates real, virtual, and composition, can effectively integrate the test resources of the aforementioned combat units and subsystems, integrate geographically distributed, interoperable, reusable, and composable test resources, achieve cross domain resource sharing, and build a joint simulation test environment where various target fields and facilities are interconnected [4-5].

3. Requirements Analysis of Joint Simulation Test Platform

3.1. Platform Functional Requirements Analysis

In order to interconnect, interworkt, and interoperate simulation test resources located in different geographical locations in the range, achieve flexible setting and restructuring of various test resources in the range, build a realistic synthetic test environment, and support two application modes: subsystem independent simulation test and whole system joint simulation test. The joint simulation test platform system needs to meet the following functional requirements:

- Before the experiment, it supports querying, adding, and modifying experimental resources; Support the analysis of experimental plans, achieve step-by-step decomposition and configuration of experimental tasks, and output standardized experimental task configuration files; Support reading the experimental object model modeling and QoS configuration in the experimental task configuration file, and output the object model configuration file; Support network connectivity detection of each unit in the network testing system, and complete the deployment of the testing model and data based on the object model configuration file.
- During the experiment, support time synchronization, task initialization, and synchronization simulation within the experimental system, and monitor the simulation status; Support visual simulation test monitoring; Support data synchronization and simulation status and warning.
- After the experiment, support the extraction and filtering of simulation test data; Support the integration of efficiency evaluation models for heterogeneous weapons and equipment to complete the calculation of efficiency evaluation indicators in experiments and provide objective evaluation methods for testers.

3.2. Analysis of Platform Resource Composition

During the joint testing process, the independent internal and external resources of the shooting range will be comprehensively considered and integrated into the system, forming a virtual real fusion, functional complementarity, real-time operation, and unified control internal and external joint testing system. The system will construct a realistic combat environment as much as possible, and fully evaluate the tactical and technical performance and operational performance of the weapon system according to the combat mode. Joint testing can fully leverage the characteristics of both external and internal field testing. Based on a joint testing environment of internal and external fusion and virtual real synthesis, comprehensive, scientific, and objective testing and identification of weapons and equipment can be achieved through conducting internal and external field joint testing, combined with real testing, virtual testing, and structural testing in LVC integrated simulation technology [6-7].

The resources that can be managed and configured by the joint simulation test platform include:

- Semi physical simulation system: such as equipment guidance and control semi physical simulation system.
- Digital simulation system: includes a mathematical simulation system for weapon units and a fully digital simulation system for weapon systems.
- Simulator: The simulator of the weapon unit can achieve seamless interconnection between the reconnaissance command process and actual installation by simulating the combat network system.
- Test object actual installation system: including weapon actual installation of reconnaissance system, command system, launch system, etc.

4. Design of a Joint Simulation Test Platform Based on LVC Integrated Simulation

4.1. Basic composition and structural design of the platform

Based on the above analysis, the composition and structure of the joint simulation test platform consists of the following three parts: the joint simulation test toolset, the common support system, and the interconnection agent system, as shown in Figure 1.

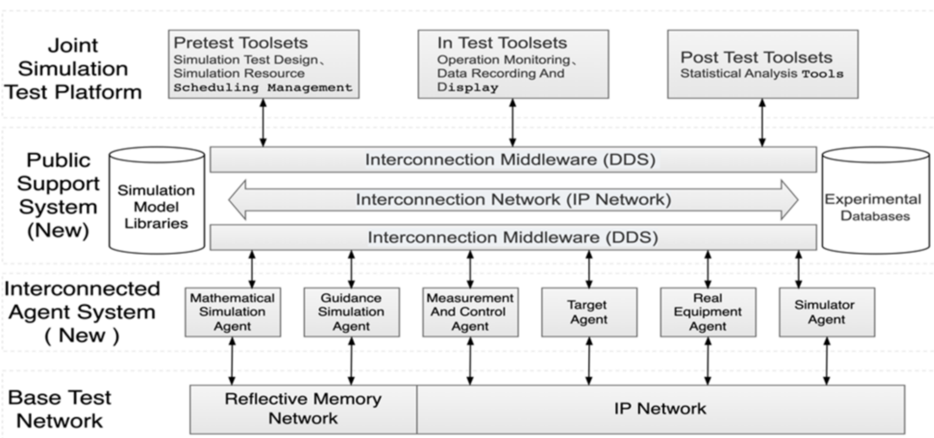

Figure 1. Structure diagram of the joint simulation test platform.

The joint simulation test toolset consists of pretest toolsets, in test toolsets, and post test toolsets that run throughout the entire life cycle of the joint test. It covers simulation test design, simulation resource management, simulation test configuration, operation scheduling control, operation monitoring, data recording and display, statistical analysis, resource management, and other tools, and can provide technical support for the testing process of joint simulation applications. The public support subsystem is composed of interconnected networks, interconnected middleware, simulation model libraries, and experimental databases, and is the foundation of the entire platform. The public support subsystem has a network support operating environment built with high-speed Ethernet and reflective memory network.

The interconnection agent system realizes the interconnection and interworking between the existing resources of the shooting range and the simulation platform. Modular design is required, with functions such as protocol conversion, data filtering, status monitoring, process control, adapters, etc; The interface has good scalability and supports real-time transmission and reception of network data, serial port data, CAN bus data, and reflected memory data.

4.2. Platform Architecture Design

The architecture of the joint simulation test platform is shown in Figure 2. The system is based on a distributed simulation real-time communication middleware based on Data Distribution Service (DDS), integrating simulation test design, test configuration, scheduling control, operation monitoring, data recording and display, test analysis, resource management, and other pretest, in test, and post test tool software to achieve full lifecycle joint simulation tests in the shooting range. It has the ability to combine Tailoring, reusability, and scalability provide convenience for further expansion and flexible applications.

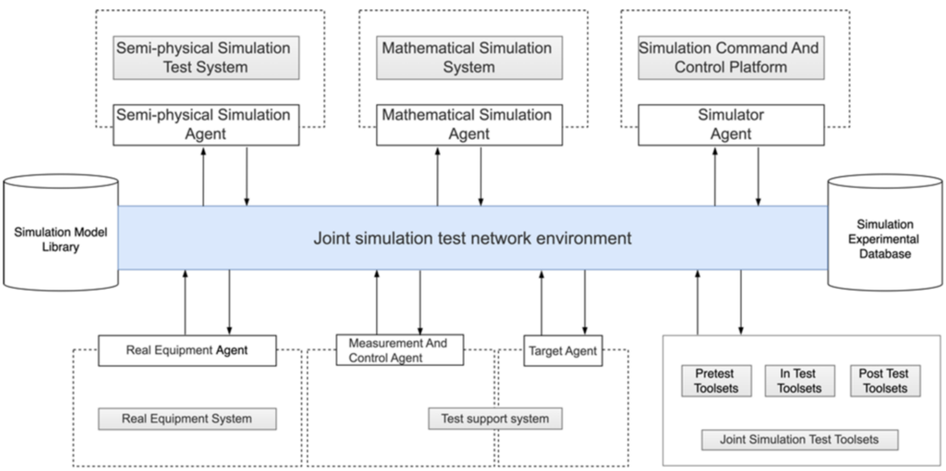

Figure 2. Architecture of the Joint Simulation Test Platform.

5. Implementation and Deployment of Joint Simulation Test Platform

5.1. Platform Implementation

The LVC based weapon equipment joint simulation test platform consists of a joint test toolset, a common support system, and an interconnected agent system. By defining the standards of model construction, interface development, data exchange, system use, etc., the compatibility and scalability of the joint simulation platform have been significantly improved. These standards not only make different modules and subsystems work more seamlessly, but also provide convenience for subsequent deepening and flexible application. On this basis, the platform can better adapt to the changing needs and provide a reliable infrastructure for simulation requirements.

The system uses the CGF (SinoStars CGF) software developed by Beijing sinostars Technology Company to construct the simulation model database, use Virtual Planet Builder (VPB) to build a three-dimensional large terrain database, and uses C++ to develop model convert tool (MCT) software to convert target models to establish visual situation display data, and uses a scripting language to complete the generation of configuration files. The simulation software uses OpenGL to develop the functions of each module in the VC environment. The Implementation Framework of Joint Simulation Test Platform is shown in in Figure 3.

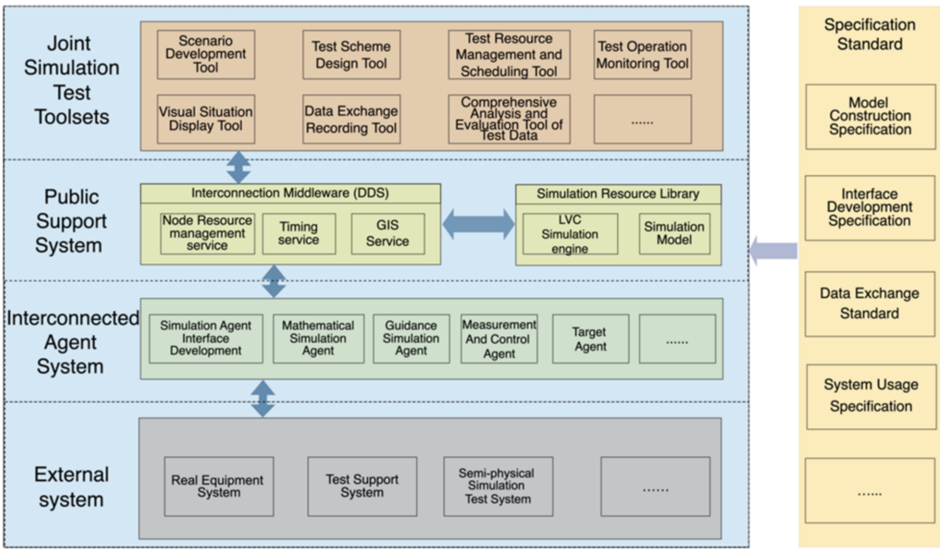

Figure 3. Implementation Framework of Joint Simulation Test Platform.

The joint simulation test toolsets are based on unified resource management, supporting test resource management and scheduling, test design, operation control and status monitoring, situation display, data collection, online and offline analysis functions. It connects multiple resources and comprehensively supports task command, technical development, participant training, analysis and evaluation, and system management personnel before, during, and after the test The business processes and activities in the last three stages.

The public support subsystem is composed of interconnected networks, simulation model libraries, experimental databases, and interconnected middleware, which is the foundation of the entire platform. The interconnection middleware is responsible for scheduling communication and interface messages between different simulation subsystems, controlling time consistency, and managing spatial consistency. Unified management and control of all simulation nodes and members in the simulation domain running in distributed simulation. The simulation resource library is a unified management of subsystem data for simulation models and simulation experiments, while providing a series of operations such as data query, addition, modification, extraction, and download to achieve effective data resource sharing.

The interconnection agent subsystem undertakes the bridging role between the simulation nodes of the joint simulation experiment and the comprehensive simulation platform. According to the actual situation of range resources and the requirements of joint testing tasks, the interconnection agent system achieves the interconnection and interworking between joint testing resources such as actual weapon systems, targets, simulators, semi physical simulation systems, digital simulation systems, and range measurement and control systems. It completes system level and subsystem level management and control in a combination of centralized and distributed methods.

When the platform is running, the scene data is called and rendered in real time through software and hardware, projected to the display system through six display devices, and the edge blend is corrected to generate a continuous visual scene image. Create a virtual environment for virtual image display, and its realization effect is shown in Figure 4.

Figure 4. Joint Simulation Test Platform effect.

5.2. Platform Deployment

Before the joint simulation experiment, the test personnel design and generate a matching joint test plan using the test plan design tool based on the range test task, including the selection of test simulation resources, simulation parameter settings, and simulation resource allocation. The joint test plan is stored in the test database for unified management. In the process of designing experimental plans, testers can also use experimental resource management and scheduling tools to query, add, extract, modify, and store experimental resources (models, equipment, simulators, etc.) within the range, achieving unified management and scheduling of experimental resources.

During the operation of joint simulation experiments, the testers extract joint simulation test plans from the test database through the monitoring tool and distribute them to the test nodes. Each test node loads the plan parameters to complete the initialization of simulation resources; Testers initiate joint simulation experiments and complete the simulation propulsion and data exchange work of each node under the drive of the joint simulation test engine. During the experiment, testers can monitor the experimental process and resource status through running monitoring tools and visual situation display tools, and intervene in the simulation operation according to the needs of the experiment; At the same time, the experimental personnel can listen to the experimental data published and ordered by each simulation node in the experimental communication network through data exchange and recording tools, and collect and upload the simulation data collected and stored internally by each simulation node to the experimental database for management.

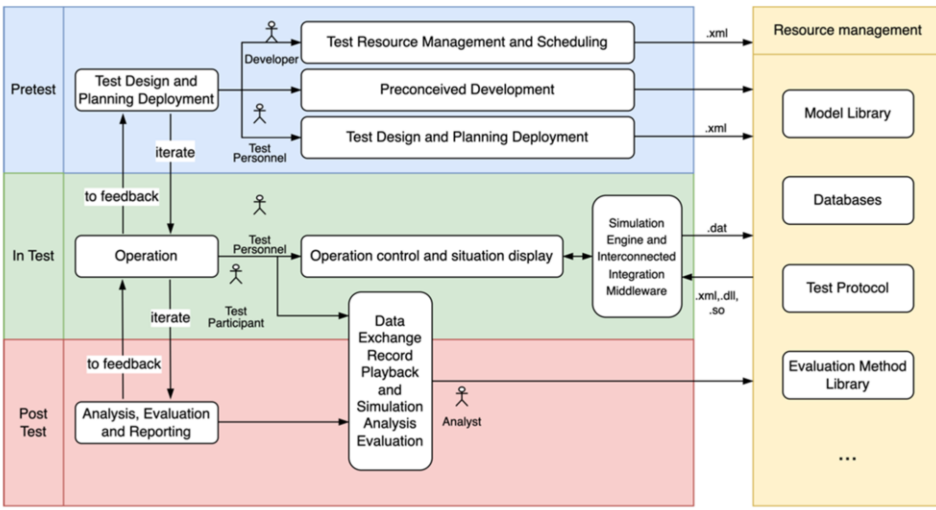

Figure 5. Deployment process diagram of joint simulation test platform.

After the joint simulation experiment is completed, the testers and analysts extract the joint test data from the test database through the test data exchange recording tool, input the test data comprehensive analysis and evaluation tool, use the integrated evaluation algorithm in the tool to analyze and evaluate the test data, and display the analysis results in curves, charts, and other forms. The deployment process and platform of the joint simulation test platform are shown in Figure 5.

6. Key Technology

6.1. High performance simulation engine driving technology

The simulation engine is the core of driving model operation [8]. Based on component-based modeling and discrete event simulation technology, the hybrid propulsion method based on time and discrete event is adopted, and the physical computer resources are fully utilized. It not only supports ultra-real-time automatic operation, but also supports human-in-the-loop real-time intervention. It provides centralized and distributed multiple simulation engine operation modes, which can support simulation from dozens to millions of entities.

6.2. LVC simulation agent and interface adaptation technology

The multi-level / multi-granularity / cross-domain joint agent and interface adaptation technology mainly solves the following problem : By implementing the mapping transformation of simulation expression and the simulation operation control agent, the existing simulation system is transformed to make it seamlessly integrated into the joint simulation test platform [9-10].

6.3. Interconnected communication middleware technology

Communication middleware is the basis of interconnection and interoperability. On the basis of fully drawing lessons from various communication middleware, interface-based programming technology is adopted to support the definition of object methods, attributes and messages, and to support remote asynchronous / synchronous method calls [11-12]. In the case of limited network resources and insufficient bandwidth, we provide a topic-based dynamic publishing and ordering mechanism to meet the different requirements of the data quality (such as transmission frequency, reliability, delay) of the publisher in different periods through dynamic QoS.Compared with OMG-DDS, dynamic QoS greatly reduces the overhead of the network, and can also choose to use different data transmission channels (such as RTPS, TCP, UDP, reflective memory network, etc.) according to actual needs, and different channels can be flexibly switched.

7. Conclusion

This article is based on the LVC integrated design and implementation of a weapon equipment joint simulation test platform. The platform combines mathematical simulation systems, semi physical simulation systems, test support systems, and tested weapon systems distributed in different regions of the test field to form a "physically distributed, logically unified, and spatiotemporal consistent" simulation test system, achieving joint simulation tests at the unit and system levels of weapon equipment.

The construction of a joint simulation test platform indicates that the platform can flexibly integrate and restructure resources such as digital simulation systems, semi physical systems, and practical systems distributed in the shooting range, establishing a realistic joint test environment; The designed platform has graphical management and control functions, friendly and beautiful interactive interface, convenient and flexible parameter settings, and simple and easy to operate; The platform has composability, tailorability, reusability, and scalability, providing great convenience for further expansion and flexible applications.

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