Research on Modeling Methods for Marine Test Environment

Biao Li [1, a], Jingping Wang [1, b], Tongkui Yu [1,2, c], Wanyu Liu[1, d], and Yunduan Lu [1, e]

[1]Dalian Scientific Test and Control Technology Institute, Dalian, 116023, P. R. China

[2] Hanjiang National Laboratory,Wuhan, 430060, P. R. China

[a] Libiao@163.com, [b] wangjingp@163.com, [c] ytk2222@163.com, [d] liuwanyu@163.com, [e] luyunduan@163.com

Abstract. In view of the needs of intelligent and unmanned development of marine equipment, not only the need to test its performance and intelligence level in the actual maritime environment, but also to test its intelligence and improve its intelligence level in the virtual environment, for this reason, it is very important to build a virtual environment under real test conditions, and the traditional simulation environment construction method is low in fidelity and large gap with the actual environment, which is not conducive to the intelligent system for experimental testing and training exercises, this paper is based on the physical parameters of the actual marine environment and the test ship platform data. With UE4 as the main development environment, a 3D digital twin of the maritime test environment with a more realistic and immersive sense is constructed, which provides basic environmental support for subsequent offshore related intelligent experiments.

Keywords: Digital twin; Modeling methods; Three-dimensional model.

1. Introduction

In order to discover the defects of the new intelligent unmanned system, improve the system performance, verify the intelligence of the system, and ensure the practical applicability and effectiveness of the system, it is necessary to carry out the test and verification of the intelligent system. At present, the real environment of the offshore system under the new situation shows many difficulties and defects, such as the need for a large number of manpower, material resources and support forces, long test cycle, many factors affecting sea state, climate, safety, etc., very limited test samples, low coverage of parameter change domains, etc., and the contradiction with the scientific test verification needs of intelligent systems is increasingly prominent. In this regard, with the rapid development of modern information, modeling and simulation, virtual prototyping and other technologies and their wide application in the field of maritime testing, the effective combination of modeling and simulation technology, virtual technology and testing and evaluation has been promoted, and a new test mode with great development prospects in the field of maritime testing and evaluation - virtual test has gradually formed, that is, the simulated tactical test environment is used to test the performance of real or digital platforms, systems and systems, with the advantages of repeatability, high cost-effectiveness ratio and low risk. Suitable for all stages of the life cycle of the platform system, virtual test as a supplementary verification method and new test mode of real aviation test, has become a wide consensus at home and abroad, therefore, the construction of a virtual scene of real environment mapping can provide technical support for virtual inspection of intelligent system performance, intelligence, practical applicability and effectiveness, which is of great significance[1] [2].

2. Basic theory

The core of the expression of physical scene to virtual scene lies in model construction, and the digital twin model of offshore test environment mainly covers geometry, physics, rules and behavior models, involving multiple disciplines and fields, and how to achieve the standardization and standardization of multiple models is one of the research focuses of this project， as shown in

Fig. 1. The twin model architecture is divided into four layers: requirements model, geometric model, functional model and performance model, in which the requirements model is used to describe the system itemized requirements and system architecture, the geometric model is used to describe the three-dimensional structure and geometric assembly relationship of the system, the functional model describes the system function for multidisciplinary comprehensive simulation verification, and the performance model is used to describe the process simulation such as finite element analysis and integration with physical real data[3].

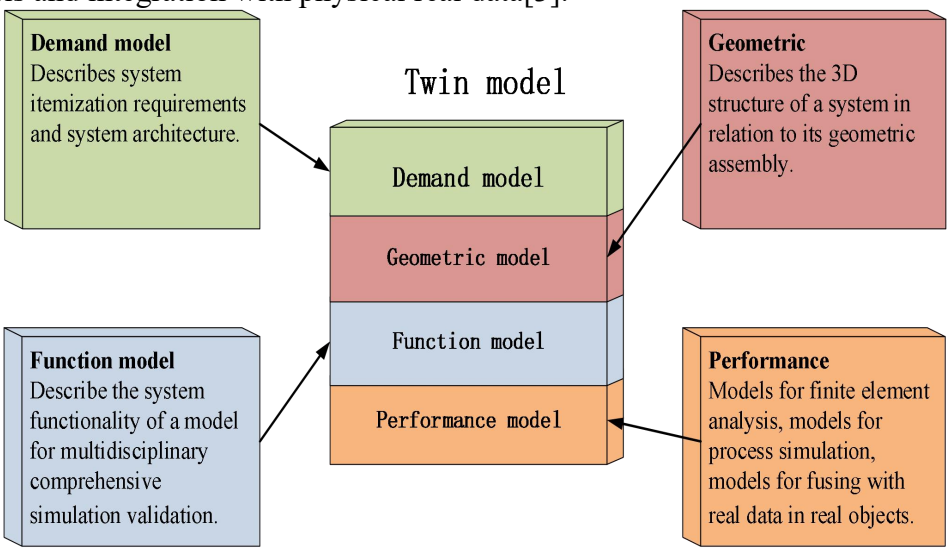

Fig. 1 Model architecture for offshore testing enviroment

When constructing the digital twin of the offshore test environment, the virtual mapping is carried out according to the physical entity characteristics of the offshore test environment, and the scene elements of the land-based test module, the sea-based test module and the ship-based test module are modeled respectively, and the geometric model, physical model, behavior model and rule model are used to describe and characterize from multiple time scales and multi-spatial scales, and through the assembly, integration and fusion of the model, a complete virtual twin corresponding to the physical entity is created, and the relevant model characteristics and modeling methods are analyzed as follows[4] [5].

(1) Geometric model

The geometric model mainly refers to the three-dimensional model and two-dimensional plan used to describe the geometric parameters and relationships of physical entities in the offshore test environment, including shape, size, position and other parameters, and has good temporal and spatial consistency with physical entities. By rendering the level of detail, the geometry is visually closer to the physical entity, meeting the basic requirement of similar appearance.

(2) Physical model

The physical model adds information such as materials, loads, and other information about the properties, constraints, and characteristics of the physical entity of the offshore test environment on the basis of the geometric model. Through dynamic mathematical approximation simulation and characterization, such as structure, fluid, electromagnetic field and other simulation analysis.

(3) Behavioral model

The behavior model describes the external environment and interference of physical entities in the sea test environment at different time scales under different granularities and spatial scales, as well as the real-time response and behavior generated by the internal operation mechanism, such as evolutionary behavior, dynamic functional behavior, and performance degradation behavior over time.

(4) Rule model

The rule model includes regular rules based on historical correlation data, experience based on tacit knowledge, and standards and guidelines in related fields. These rules have grown, learned, and evolved over time, enabling virtual entities to have real-time judgment, evaluation, optimization

and prediction capabilities, so as not only to control and operate the physical entities in the offshore test environment, but also to correct and analyze the virtual entities.

3. Scheme design and modeling of marine test environment model

Data, models, and software are the three technical components of a digital twin system. The essence of digital twin is to optimize the resources of the physical world with data flow, so data is the foundation of technology; The core of digital twin is to establish a mechanism model or data-driven model for physical entities to logical objects, and realize the virtual and real interaction from physical space to virtual space, so the model is the core of technology; The key to digital twin is model coding, standardization, dynamic simulation or detection of the real state, behavior and rules of physical objects in the form of software, so software is a technical carrier. Combined with the three major technical components, the digital twin model of the offshore test site is pre-constructed, relying on the actual test data of the North Sea Test Site, driving the model, realizing real-time display of test data, real-time simulation of ship tracks, real-time monitoring of test environment and other functions， as shown in Fig. 2, and finally displayed in the form of software[6].

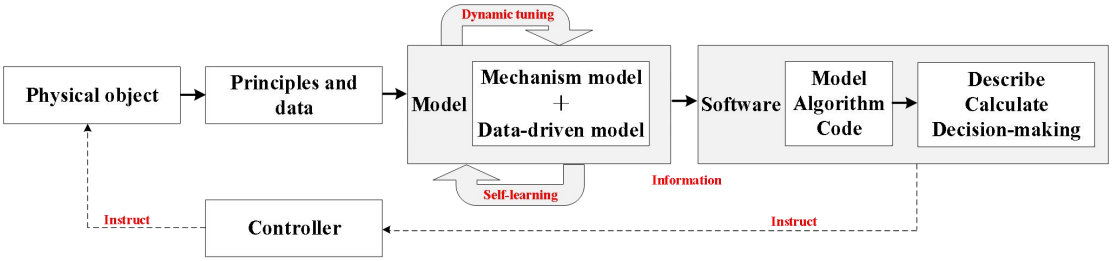

Fig. 2 Environment modeling framework

The sea is derived from the actual test data of the sea trial test in the exclusive test area, which has an exclusive test dock and related support facilities, and the open sea area can ensure that the test vessel has a good maneuvering range; At the same time, taking the ship of dalian institute of measurement and control technology as the offshore test platform, the test ship has basic equipment conditions, combined with the parameter requirements required for software function verification, and has completed energy efficiency, automatic rudder, 360° panoramic monitoring, bridge and other system modifications in key parts such as wheelhouse, communication system, engine room, centralized control room, etc. At present, the offshore test site has opened up the ship-shore sea information transmission link, which can obtain the data information of the offshore test site in real scenarios, which can provide a real and reliable data source for the digital twin of the offshore test site.

The digital twin model of the offshore test site is based on the five-dimensional model of the digital twin, which includes five parts: physical entity, virtual entity, twin data, system service, and connection. First of all, it is necessary to clarify the physical entities involved in the sea test, the so-called physical entity is the object entity that objectively exists in the physical space, which is the basis of digital twin technology, as far as the offshore test site is concerned, it mainly includes test ships, buoys, sensing equipment to measure the test environment and the operating state of the ship; Virtual entity refers to the real depiction of physical entities from multiple dimensions of geometry, physics, behavior and rules, so as to determine the components of virtual entities, that is, when building a panoramic virtual model of the sea test site, it is necessary to build: test sea terrain model, test ship three-dimensional model, buoy three-dimensional model; Twin data refers to the data set applied to the construction of the digital twin system, considering the reality of the sea test, some important data affecting the navigation of the ship and the test are presented on the main interface, the relevant data to be displayed include: the operation direction, speed, location of the test ship, that is, latitude and longitude information, etc., relevant environmental information includes: wind speed, wind power, temperature, etc., in order to store relevant digital twin data, you

need to build a relevant database; System services refer to "functional services" that can support the operation and implementation of internal functions of digital twins, and "business services" that encapsulate the data, models, algorithms, etc. required in the application process into application software, mobile APP and other forms to meet user needs. Connectivity is the interconnection of the various components of a digital twin.

The offshore virtual test scene mainly adopts Unreal Engine 4, combined with 3D Max, World Machine and other modeling and terrain editing software for development and packaging, and the main functions realized include ship navigation simulation and test environment display. Ship navigation simulation needs to first realize the positioning of the ship model in the virtual test scene, combine the latitude and longitude data collected by the ship's positioning and navigation equipment, apply the map projection method and UE4 coordinate system, realize the real-time positioning of the ship and realize the navigation simulation function， as shown in Fig. 3. The test environment display function relies on a large number of real-time data collected by environmental perception and condition monitoring equipment, combined with multi-sensor data fusion theoretical knowledge and UE4 development environment, to realize the real-time presentation of ship operation status data and environmental information[7] [8].

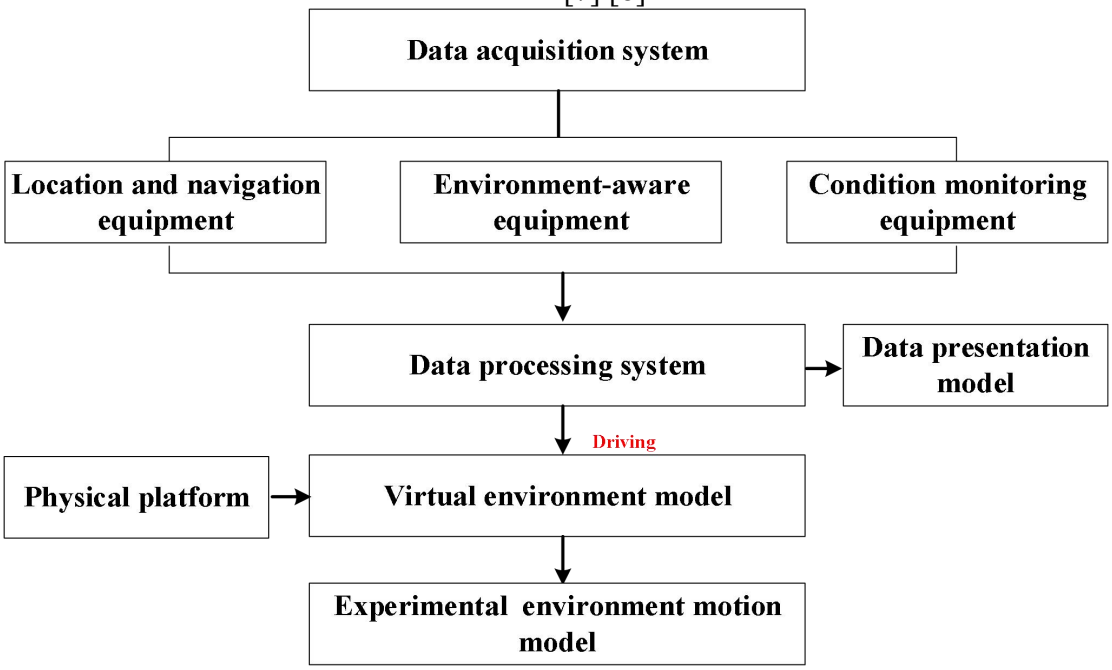

Fig. 3 Modeling scheme for marine test environment

(1) Data acquisition system

Relying on the existing ship navigation information collection system, through the data acquisition equipment deployed in each key position of the ship, the key state information of the ship during navigation is collected: GPS, electric compass, sounder, AIS, taximeter, etc., and the measured latitude and longitude, draft, heading angle, pitch angle and roll angle constitute the dynamic model of the ship's six degrees of freedom. Relying on the existing marine environmental information collection system, shore-based information is obtained through the marine environmental parameter monitoring buoys deployed at sea: weather conditions (sunny and rain), wind, wind direction, temperature, humidity, time, etc., which constitute the external environment of the sea test. The data collection work is planned to be carried out in the exclusive test area of dalian institute of measurement and control technology, which also has an exclusive test dock and related support facilities, the open water can ensure that the test vessel has a good maneuvering range, the ship is used as the offshore test platform, based on the existing basic equipment conditions of the test ship for data collection work, the ship is sailing at a given speed, there is no motor vessel interference within 2 nautical miles during the test, and the test sea state is not more than 3 levels.

(2) Data processing system

Classify and store the information collected by the data acquisition system into a relevant database and unify the data format for platform calling. The database management system used here is MySQL, which saves different data in different tables, which increases the speed of data calls and improves flexibility. Like UE4, MySQL is open source, reduces the development cost of the system, and is low in complexity and easy to learn. At the same time, MySQL also has: good portability, can work on many different system platforms, such as Windows, Linux, Mac, etc.; Rich interfaces, providing APIs for C, C++, Java and other languages[9].

(3) Virtual test scene and ship motion model

Refer to the actual terrain information of the test scene and the real scene of the South Pier to build a panoramic 3D model of the sea test environment, including the pier, sea area, hull, etc., import it into UE4 to build blueprints separately, and apply blueprint components to build the interaction relationship between each part to realize the function of buoys placed in designated positions and ship navigation. The problem to be solved is the conversion relationship between latitude and longitude to UE4 world coordinates and the data import and reading on demand, and the main realization function of the ship's motion model is trajectory reproduction, referring to the ship dynamics model of six degrees of freedom, ignoring draft, pitch angle and roll angle.

(4) Data display model

It is mainly to design and organize a data display interface, present the external environment information of the test in real time, realize the visualization of data, and make the test results more intuitive. UE4 as the main development environment, relying on its rich interface to implement data reading and calling, combined with its visual UI design tool UMG design data display interface, the main tools also include Echarts chart library, the advantage of Echarts chart library is that it has a high degree of adjustability, can adjust the visual performance according to actual needs, and has a rich interactive scheme, good data display effect, suitable for data visualization interface, its disadvantage is that the data throughput is small, But enough for our needs.

Taking the ship as the test platform, the test scene under typical navigation conditions is designed, and according to the actual physical scene parameters and related data of the offshore test environment, the ship, marine and other models in the virtual test environment are constructed， as shown in Fig. 4, in which the ship platform covers the internal models such as wheelhouse and engine room, and realizes the twin modeling and dynamic drive of the offshore test environment，as shown in Fig. 5 [10].

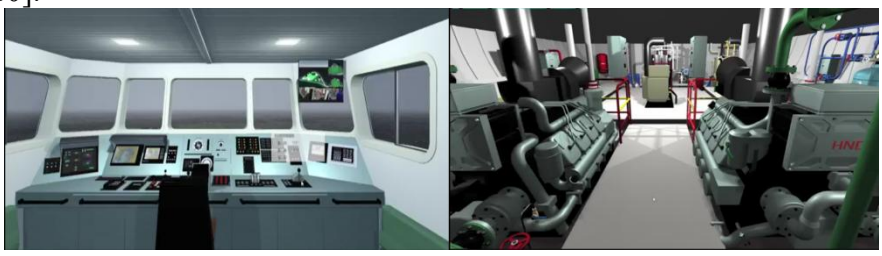

Fig4 Ship platform cab and engine room models

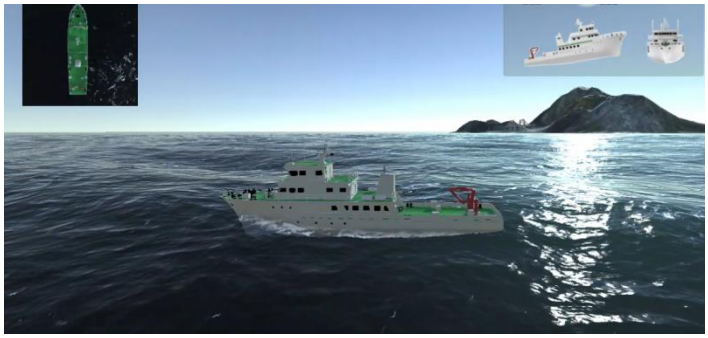

Fig5 Model of the sea test scenario

4. Summary

This paper analyzes the elements of physical to virtual scene modeling, combined with the method of related model construction, this paper discusses the feasibility of using Unreal Engine to model the digital twin system, determines the development environment of the digital twin environment of the offshore test scene, designs the modeling scheme and the driving data required for the model, establishes a five-dimensional model of the typical maritime test scene with the ship as the test platform, realizes the construction and dynamic drive of the maritime test environment model driven by the measured data, and develops the subsequent offshore physical system. Virtual simulation tests in the performance inspection and other stages laid the technical foundation.

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