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Development and Application Mode Design of Complex Ship Numerical Simulation System Based on SaaS

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***Abstract*—The current numerical simulation system is developing in the direction of large-scale, complex and service-oriented because of the high integration of numerical simulation technology development and equipment research. However, the numerical simulation research of the three important links of prediction, evaluation and optimization for the ship general performance is highly dependent on foreign commercial software. It is urgent to integrate multidisciplinary fusion methods and data knowledge engineering to implement independent research and development of numerical simulation systems. In order to remodel the research and development mode of ship general performance, the experience and lessons in the development of industrial software are summarized in this paper. The research and development concept of numerical simulation system for ship general performance including "crowd-innovation and sharing", knowledge collaborative application, and intelligent are proposed to improve ship R & D capability.**

Keywords- numerical simulation system ;industrial software; ship general performance; crowd-innovation and sharing;SaaS

I. INTRODUCTION

The development of many computer-aided technologies such as CAD, CAE and CAM have contributed to the birth of large and complex numerical simulation systems. It has become a common view of the global industry that during the whole life cycle of equipment research and development, design, manufacture, maintenance, etc. the application of large-scale complex numerical simulation system for system modeling, simulation, calculation, evaluation, optimization can significantly improve the performance level of equipment, shorten the development cycle as well as ensure the reliability.

The general performance of ships, represented by hydrodynamics, structural safety and comprehensive stealth performance, is related to the safety, economy and comfort of ships. Its design and research have always been the basis of the shipbuilding industry. There are many problems in the traditional general performance research and development mode, such as relying on experience and mother type, loose process connection, insufficient data mining and so on. It is urgent to apply information technology and deeply integrate the general performance research system and simulation system technology of ships, which activate massive test data and knowledge resources to realize the reform of R&D mode driven by optimal performance. The world's maritime powers have been promoting the research and development of numerical simulation systems related to the overall performance of ships. The "virtual pool"[1] program launched by the European Union in 2006 plans to develop a reliable numerical simulation system for ship hydrodynamic performance. In 2006, the U.S. Department of defense launched the Computing Research and Engineering Acquisition Tools and Environment (CREATE) project under the High Performance Computing Modernization Program (HPCMP), which includes a ship oriented subproject (CREATE-Ships)[2-3]. This sub project aims to create an integrated design environment with rapid design and integration capabilities, ship impact and damage assessment capabilities, and ship hydrodynamic design, assessment, and optimization capabilities. Foreign classification societies have also been constantly improving and iterating their ship performance numerical simulation systems, such as SESAM, HydroSTAR, etc., which have gradually integrated hydrodynamic and structural safety numerical simulation. In 2016, China launched the "numerical pool"[1][4] program aimed to develop a numerical simulation system for the evaluation of ship hydrodynamic performance. In recent years, the China Shipbuilding Research Center has also developed the 3D Hydroelastic Analysis Program (THAFTS) software for large floating structures, which is mainly used for wave load calculation and response prediction; ship noise control design evaluation software (CABINNOISE); marine structural analysis general software (SAM) and second-generation integrated software for complete stability assessment, etc. These softwares are all simulation systems that focus on a single performance forecast of ships, and are not widely commercialized at present [5].

Based on the development history of foreign industrial software, its development trend and successful experience are systematically reviewed and summarized in this paper which analyzes the current situation of domestic numerical simulation system of ship general performance and sorts out the existing problems. Combined with the latest software R&D ideas and the development direction of information technology, a new model of developing and applying large-scale complex numerical simulation systems based on the SaaS of ship general performance is proposed.

II. DEVELOPMENT TREND AND COUNTERMEASURES OF NUMERICAL SIMULATION SYSTEM FOR SHIP GENERAL PERFORMANCE

The numerical simulation system of the overall performance of ships is a kind of industrial software. The

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essence of industrial software is to use information technology to abstract the industrial mechanism model, then the knowledge formed by running the rule is packaged into the software[6].

A. Development Trend of Foreign Industrial Software

Due to the early start and long-term accumulation in the field of industry and information technology, foreign developed countries have occupied a leading position in industrial software. Driven by Internet technology and applications, industrial software is gradually developing towards platformization, modularization and ecologization, that is, from products to platforms and from technological competition to systematic ecological competition[7]. The main development trends are as follows:

1) From the perspective of software function design, industrial software has evolved from a large system with complex architecture and functional coupling to many small applications with simple architecture and function decoupling. These small applications can be easily combined into powerful comprehensive software as shown in Fig.1.

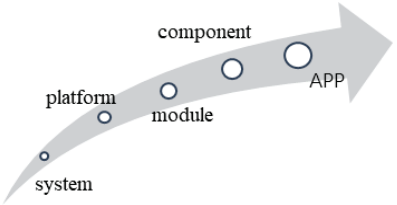


Figure 1. Transformation of industrial software

2) From the perspective of the software service model, industrial software is developing towards the cloud. Software and hardware resources are deployed in the cloud, making users choose software services according to their needs. The application mode of industrial software has changed from stand-alone mode to client/server (C/S) and then to browser/server (B/S) mode. At present, it is moving towards cloud deployment and edge deployment mode. With the rise of the Internet, more and more industrial software has turned to B/S mode. There is no longer necessary to install software on the client, which makes software upgrades and migration more convenient. At the same time, cloud technologies such as server virtualization can make better use of server resources. Software as a service (SaaS) has become a service mode increasingly adopted by industrial software.

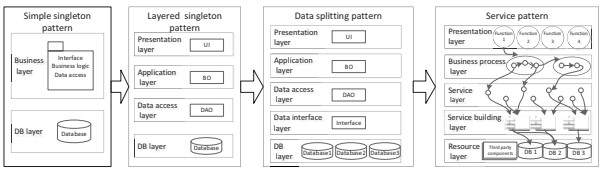


Figure 2. Software Architecture Evolution

3) From the perspective of software architecture design, on the one hand, the software architecture has changed from the original single architecture to service-oriented and micro service architecture, which is developing towards componentization and service as shown in Fig. 2. On the other hand, industrial software has transformed to an integrated software platform, especially the infrastructure platform at the technical level.

B. Limitations of foreign industrial software development

Although foreign industrial software enterprises have first started and are leading the transformation and development of industrial software design and application, there are also huge difficulties in the transformation process which are listed as below.

1) As foreign mature products have completed the development and design of core functions at a fairly early stage, the old development language and software architecture have become a huge obstacle in the front of current new technologies and applications. The huge workload of completely reconstructing these softwares will also drag down the speed of their transformation. For example, Dassault is redesigning its series of products in the form of APP on the overall platform [8]. While developing the cloud native CAD system named Onshape, PTC also retains the original desktop CAD tool Creo [8].

With the rapid development of technologies related to big data and artificial intelligence, the value of data is also increasing, and data has gradually become the key for industrial software to further mine industrial knowledge and provide intelligent services to customers. However, the original foreign software, such as Abaqus, NX, Hyperworks, Ansys, etc., are basically stand-alone operation models and have no advantages in data accumulation and utilization.

2) Although foreign companies strive to innovate and develop software service models and ecological construction, due to the different software used by various units in the ship system, there are still great problems in data interconnection [8], so it is impossible to establish a unified ecological standard and security system in China, resulting in very slow development.

For our country's independent industrial software, the best way to quickly improve the level of China's industrial software is to adopt a loosely coupled software architecture and pluggable component integration methods, build a software application environment with mutual trust and win-win results, and unite various forces in the domestic industry to make rapid transformation together.

C. Countermeasures for the independent R&D of ship general performance numerical simulation system

Since the ship general performance numerical simulation system is a complex giant system including prediction, evaluation and optimization functions in multiple fields, disciplines, majors and various methods/approaches, its functions cannot be fully developed at one time. Compared with the waterfall development model, the agile development model has the characteristics of a loosely coupled system architecture (a typical agile development model shown in Figure 3)., which can continuously improve the system functions in the process of continuous development iteration. It is an inevitable choice for the development mode of the numerical simulation system for the general performance of ships. In the first version (v1.0) released, a batch of fast calculation and widely used prediction modules can be developed to verify the overall architecture design of the system. The second version (V2.0) will be released to

supplement a batch of prediction modules with high requirements for graphics processing, high resource support and long-time calculation to verify the system's resource scheduling, graphics display and other functions. Then, the self-developed pre- and post-processing functions and solvers will be used to gradually replace foreign products (V3.0), continue to improve the system functions and iteratively upgrade the system version.

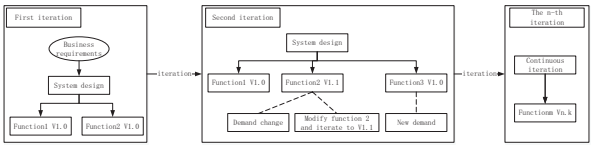


Figure 3. Typical flow of an agile development model

In addition, the complexity of the overall performance of the ship with the professionalism determine that it cannot be completed by a single unit or enterprise independently. Under the intellectual property protection environment of mutual trust, the most mature achievements of each unit in the field of expertise must be converged to provide services in a modular manner with the concept of "crowd-innovation and sharing". Furthermore, the platform needs to provide a low-cost innovative R & D environment, allowing users to easily implement service innovation so that the services provided by the platform have more and more content and the solutions become more and more complete. At the same time, it is necessary to establish the application ecosystem of the system, find the deficiencies of the system in the application, and quickly iterate to form a sustainable and benign development atmosphere.

III. APPLICATION AND DEVELOPMENT MODE DESIGN FOR THE INDEPENDENT R&D OF SHIP GENERAL PERFORMANCE NUMERICAL SIMULATION SYSTEM

Relying on the two foundations of big data analysis based on physical experiments and complex accurate simulation technology, the APP software for ship general performance prediction, evaluation and optimization is independently developed [9-10] to realize the accumulation and mining of knowledge and data, and construct a new ecosystem of "crowd-innovation and sharing" of collaborative development of demand generation/overall design/research/application. This will bring into full play to the technological advantages of cloud computing, big data, artificial intelligence and blockchain, as well as the ecological advantages of the combination of industry-university-research cooperation. It is the development path of independently developing the numerical simulation system for the general performance of ships.

A. "Crowd-Innovation" and "Crowd-Utilization" Based on Cloud Service Model

Based on information technology such as hyper convergence and cloud computing, the numerical simulation system for ship general performance will adopt SaaS mode to provide external services. The overall architecture design is shown in Figure 4. The SaaS service model can provide convenient conditions for "Crowd-Innovation" and "Crowd-Utilization":1) The basic platform and APP can be deployed rapidly. Users can quickly get the latest software versions and APPs that reflect the newest knowledge and achievements. 2) Software/hardware resources can be fully shared. Users can get the required CAE tool software, various computing resources, storage resources, network resources, high-performance graphic display resources, and the computing bottleneck can be effectively solved. At the same time, these IT resources have also been fully utilized for the company.3) Data can be stored and managed safely and uniformly. Cloud infrastructure provides a complete data security storage solution, which is more secure than local storage. The unified management of data based on the system greatly reduces the data management cost for users. 4) Service requests can be quickly responded to. The problems and demands of users can be tracked and reproduced quickly, which can be repaired, improved and released in time.

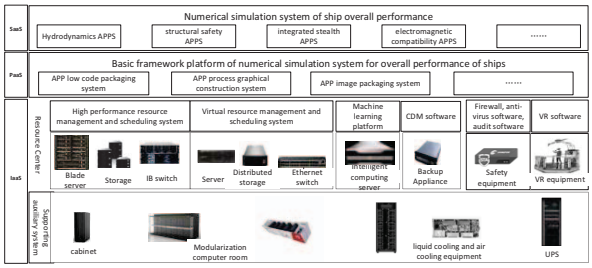
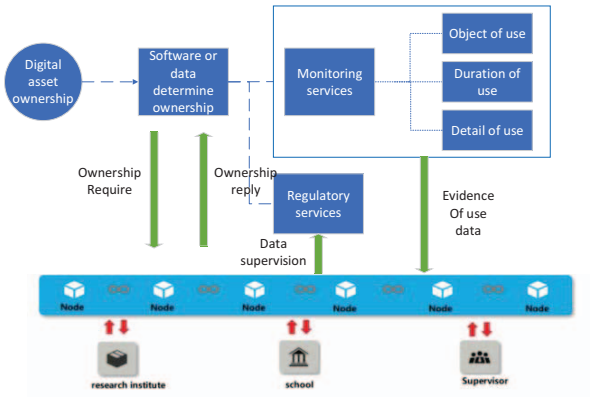


Figure 4. Architecture design of numerical simulation system for ship general performance

The numerical simulation system for the overall performance of ships will bring together various APPs developed by different fields and units, including fast calculation APPs based on empirical formula, fast calculation APPs based on physical data training, and accurate calculation APPs based on commercial software and self-developed solvers etc. According to the individual requirements of various APPs for resources, a resource pool composed of high-performance computing resources, intelligent computing resources and ordinary computing resources is constructed. The computing scheduling system automatically allocates and recycles the corresponding computing resources for APPs, which can greatly improve the computing speed of APPs and maximize the utilization of computing resources, that is, building infrastructure services (IAAs). By developing an APP low-code packaging system, system developers can easily package various types of APPs as a service. System developers and users can build the application process of APP collaborative work simply and carry out innovative research by developing the APP process graphical construction system. By developing an APP image packaging system, system administrators can quickly generate APP container images to facilitate the release and operation scheduling of APP, namely, to build a basic platform service (PaaS). Through the development of end-user-oriented portals, users can easily query and use various APPs to achieve numerical simulation of the overall performance of ships, that is, to build application software services (SaaS).

B. *Unify system access standards and establish a secure and trusted system*

In order to ensure the plug-and-play with high robustness of the APPs developed by "crowed-innovation" units, and solve the serious problems of information or data fragmentation, discontinuity and "data island" caused by the "separate efforts" of all forces, it is necessary to establish standards for system development, testing, distribution and management based on the complete system, clear classification, strong guidance and rolling revision.



(a)Blockchain accounting and right confirmation design

(b)Blockchain basic platform

Figure 5. Using blockchain to confirm rights and account for digital assets

During the construction of the numerical simulation system for ship general performance, a knowledge-based application basis for data can be established by formulating unified physical test data and simulation data standards, as well as standardizing data names, symbols and other information. By referring to the popular development standards of different development languages in the industry, unify the coding format and interface form of all kinds of APP development, so as to improve the readability and maintainability of APP. Establish a fair feedback mechanism for "self-development", "other verification" and "third-party testing" of APPs, unify "metrics" through functional testing and multi-level verification of APPs, the quality of APPs developed by different units is strictly controlled to ensure robustness. Strengthen the reliability of the basic framework platform through various testing methods. The security and stability of the system are guaranteed by using test-driven development.

High requirements for "protecting intellectual property rights and ensuring data security" are put forwarded because of the "crowd-innovation" mechanism and the "cloud" storage method. Blockchain technology is an effective way to solve this problem. Based on the internal network of the shipbuilding industry, the open-source alliance chain HyperLedger Fabric is used to confirm the rights and account for the APP and data assets independently developed by each unit which use smart contracts to count and analyze the accounting data. By deploying the blockchain supervision node and operation node in different places, the "trust" problem can be effectively solved to ensure the rights of "crowd-innovation" and "crowd-utilizer" personnel and the security of digital assets, as shown in Figure 5

C. *Adopt service-oriented and component-based design to facilitate the continuous accumulation of knowledge*

The ship general performance numerical simulation system is designed by the method of "basic framework platform + various APPs [5]", and adopts the ideas of modularization, componentization and servitization to split the huge system into multiple modules and components with low coupling and high cohesion and subdivide the modules and components into services. The advantages of this design are listed as below: 1) The risk of interaction between a large number of developers and business modules can be minimized; 2) It is possible to quickly respond to demand changes with minimal impact on the system through service orchestration, which is convenient for system upgrades and maintenance; 3) The distributed micro-service architecture can quickly expand the hardware for service bottlenecks and quickly meet the concurrent requests of users across the industry; 4) The system functions are easy to deploy and expand that meet the needs of "step-by-step implementation and sustainable development" of the system; 5) The prediction, evaluation and optimization functions of various ship performance are designed in the form of APP [9] as an independent component of the system. On the one hand, "attribute segmentation and knowledge encapsulation" can be better realized for specific problems, as shown in Figure 6. On the other hand, it can realize plug-and-play apps. At the same time, with the continuous improvement of fields and disciplines, the development of various methods/approaches and various APPs will continue to be integrated into the system.

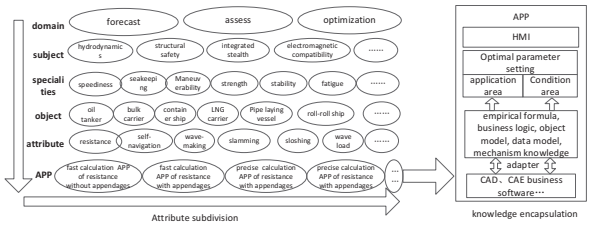


Figure 6. APP-style development of various performance prediction, evaluation and optimization functions

D. *Create a "drag and drop" low-code integration environment to realize collaborative knowledge services*

A single APP is a knowledge package for specific objects and problems, while the ship general performance is a multidisciplinary and multi-domain issue. Therefore, in addition to bringing together industrial APPs in various

fields and disciplines to provide external services independently, the numerical simulation system for the ship general performance should also provide a graphical and light-code "drag-and-drop" integrated design environment to realize the data exchange between APPs, so that multiple APPs can cooperate to provide services as shown in Fig.7.

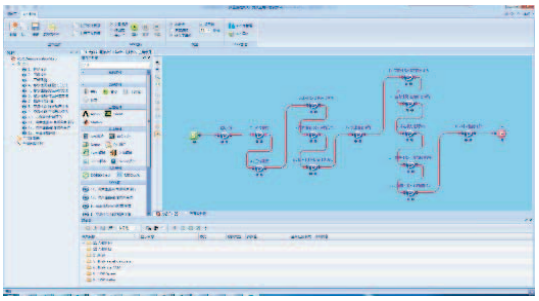


Figure 7. "Drag-and-drop" integrated environment

Under the constraints of unified development standards, data standards and interface standards, the ship genera performance numerical simulation system realizes the cooperation between two aspects of APPs through the integration framework. 1) In terms of execution control of multiple APPs, it is possible to control the running modes of APPs such as sequential execution, parallel execution, conditional execution and circular execution to realize the process integration of APPs.2) In the respect of data collaboration of multiple APPs, data integration between APPs is achieved through the analysis, transformation, transmission and loading of APP input/output data. As shown in Fig. 8, after APP A is executed, its execution result is judged. If the judgment condition one is met, branch one is executed, that is, execute APP B then execute APP D. After that cycle condition one is judged. If the loop stop condition is met, the APP collaboration process ends, else, APP B is executed cyclically. If the judgment condition one is not met, APP C is implemented, and then the APPs collaborate until the end. After the operation of APP A is completed, its input data and calculation result data can be transferred to APP B or APP C for use. The input data and calculation result data of APP B can be transferred to APP D.

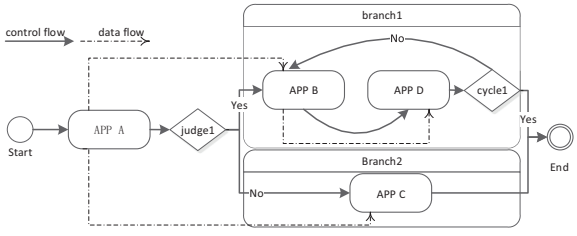


Figure 8. Collaboration of APP and data

IV. CONCLUSION

With the enhancement of numerical simulation methods, the research on the overall performance of ships has ushered in new development opportunities. The demand for building a complex numerical simulation system that is independent R D and “crowd-innovation and share” is increasing. At present, there are still many problems, such as the core software is controlled by others, highly dependent on expert experience, the application of simulation technology is scattered, and the information/data flow is discontinuous. Through the innovation of application mode and development mode, this paper proposes to establish a loosely coupled system architecture and a “crowd-innovation and share " development mode to realize the convergence of industrial knowledge (APP) and data of the dominant forces in the domestic shipbuilding industry and create a scheme for the overall performance numerical simulation service system for intelligent applications. A useful exploration has been made in order to gradually solve the bottleneck problem in the design of simulation software in China's shipbuilding industry, and then effectively support the transformation of China's shipbuilding industry.

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