Methods for complex simulators development for complex technical objects control

Методы организации комплексных тренажеров управления сложными техническими объектами

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Development of complex simulators for training crews in control of complex technical objects has several aspects. They focus on the achievement of the main goal - the development of collective skills to respond to standard and non-standard situations in complex technical object control. The article discusses the problem of hardware-software implementation of various scenarios for joint training of crew teams. It is proposed to use the concept of a virtual private supercomputer for the effective use of the hardware resources of complex simulator.

Создание комплексных тренажеров для обучения экипажей управлению сложными техническими объектами имеет несколько аспектов. Они отражают достижение основной цели – отработка коллективных навыков реагирования на стандартные и нестандартные ситуации по управлению сложным техническим объектом. В статье обсуждается проблема аппаратно-программной реализации различных сценариев совместной тренировки команд экипажа. Предлагается использование концепции виртуального персонального суперкомпьютера для эффективного использования аппаратных ресурсов комплексного тренажера.

INTRODUCTION

The training of teams and crews for the control and operation of complex technical objects implies the training of a big number of people at once, who must jointly solve the assigned tasks. Unlike a simple training system, such simulators are built on the basis of a distributed computing environment, consisting of the workplaces of the training crew members and the control server. In the case of organizing simulators for individual subsystems under normal operating conditions, there are no problems with the design of the computing environment. Experience shows that in this case, simplified mathematical models are sufficient for training purposes. Standard bandwidth of network channels copes with the amount of data transmitted between the server and workstations. The situation changes in the case of organizing complex simulators. In this case, multifunctional modeling of technological processes takes place. Both an increase in jobs and synchronization of the work of various subsystems are required. At the same time, the demand for this type of complex simulators becomes real. Coordinated work of various subsystems and their teams in case of extreme situations is especially important.

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Such situations require the full commitment of the entire crew. Traditional schemes for training simulators organization are no longer effective. The reasons lie both in the complication of the mathematical models and their heterogeneity, and in the increase of data transmitted between the nodes, which ensures the operation of a big number of mathematical models [1].

PROBLEMS OF COMPLEX SIMULATOR

Let us consider problems arising in a process of complex marine simulators development. Thus, when training operators of manned submersibles, there is a problem of developing skills for their actions in extreme situations. It is impossible to develop such skills on a real object because of the threat to the life of the crew and the submersible itself. Therefore, it is required to use a simulator of an underwater object, which allows to simulate various extreme situations. This provides an opportunity to practice the crew's skills in performing primary measures when organizing the fight for the survivability of an object. In this case, however, it is not sufficient to simulate only certain aspects of the underwater vehicle. For example, if the rudders are jammed, the crew has about forty seconds to detect the problem, react and take the necessary action. In reality, the crew is not ready for such situations. Therefore, it is required not only to simulate an extreme situation, but also the possibility of this situation occurring at any moment, including during other extreme situations. Another example: a fault in the electrical power system can lead to control problems, failure of remote control systems or failure of elements of other systems. The crew must be able to use the manual controls correctly and in time.

Thus, there is a need for a complex underwater object simulator that simulates simultaneously the motion and control of an underwater object, flooding and movement of media in compartments and tanks, various systems, system failures, emergency flooding and fires.

In this case, it is important balance between the complexity (accuracy) of the mathematical models for each complex under consideration and the goals of the simulator, including training level, cost-effectiveness, operational complexity, and more. All mathematical models of individual components should be coordinated with each other and provide reproduction of the modeled processes in time. The object of application of the marine simulators is, in general, a dynamic object whose behavior is described by the classical equations of motion of a solid body with six degrees of freedom (three linear and three rotational):

$$\begin{cases} \vec{a} = \dfrac{\delta\vec{V}}{\delta t} = \dfrac{\delta^2\vec{x}}{\delta t^2} = \dfrac{\vec{F}}{m} \\ \vec{\omega} = \dfrac{\delta\vec{\varphi}}{\delta t} = \dfrac{\delta^2 R}{\delta t^2} = \dfrac{\vec{M}}{\vec{J}} \end{cases} \quad (1)$$

where in addition to standard notations $\frac{\vec{M}}{\vec{J}}$ is term-by-term division of the vector of the moment of force by the vector of the moment of inertia, R is rotation operator.

The forces and moments that make up the right side of the equations reflect the effects of hydrodynamic interaction between the object under consideration and the environment. At the same time, many forces arise at the controls, which makes it possible to provide a given mode of motion or response to emerging situations, including extreme ones. The rudders themselves are controlled by a hydraulic system. Mass and inertia characteristics depend on the water in the compartments and tanks and change when the fluid flows. Fluid transfer is accomplished by means of diving system. Elements of diving system receives power from ship's electrical power system and compressed air system. The compressed air system, like the hydraulic system, is usually controlled remotely, which is only possible with power. A separate team is responsible for ensuring the normal operation of each of the subsystems, but malfunctions or emergencies in one of the subsystems adversely affect all others. Individual training requires running a big number of independent simulators on different workstations, which is not resource-intensive. However, when implementing group sessions, you need to run different elements of the simulation model at the same time. These elements are closely coupled, as well as interact with graphical simulators deployed on the trainees' workplaces. In sum, such a complex simulator puts forward high demands for both computational and network performance.

HARDWARE AND SOFTWARE ORGANIZATION OF COMPLEX SIMULATOR

Increased computing performance requirements can be solved in several ways. A simple but ineffective way is to increase the complexity of the computing environment: more powerful computing nodes, network infrastructure, etc. We have two principle ways. The first one is using of single powerful multiprocessor system. This solution is extremely expensive and inefficient due to weak load and downtime in normal operation modes. The second solution is to increase the power of each workstation and network infrastructure and organize MPP system on this basis. This option, although more economical, has the same disadvantages as the first option. In addition, any MPP system has an acceleration limit when solving a specific problem, especially in the case of strong node connectivity [2]. The solution in distributed computer environment of complex simulator, which integrates separate functional simulators, could be using virtual private supercomputer approach [3]. In this case, dedicated virtual computing environment is dynamically created for each resource-intensive application. Computing infrastructure is configured to optimize application performance and optimally allocate virtualized physical resources between applications. For this purpose, virtual clusters are created for each possible scenario (Fig.1), corresponding to the application profiles (CPU, memory, network).

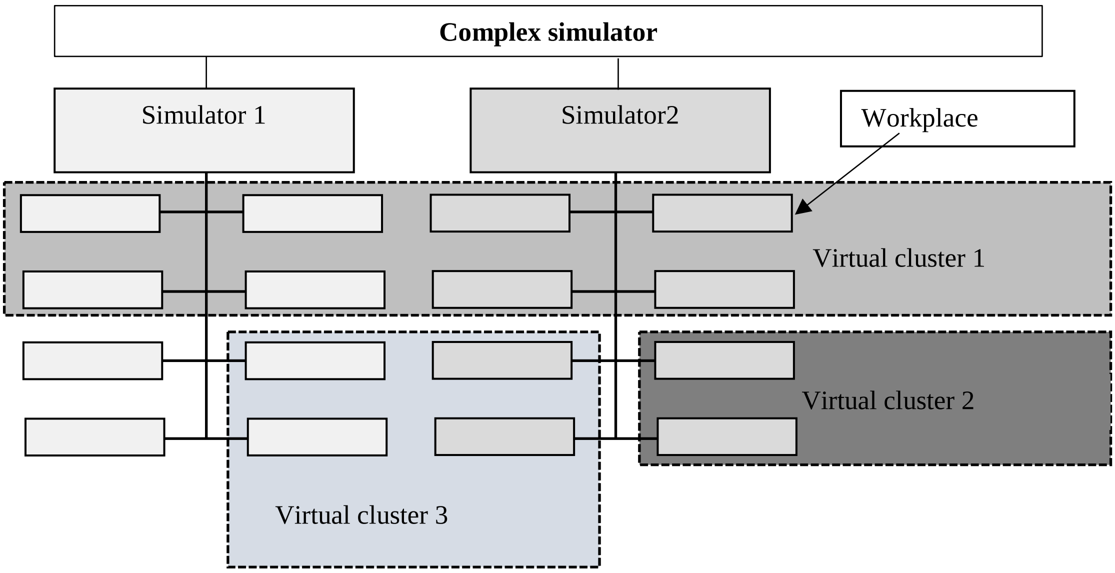

Fig. 1 Hardware architecture of complex simulator

In this case, only the resources that are required now are brought together. In this case, idle resources are efficiently utilized. As a result, a virtual SMP system is organized to solve a specific task. Light virtualization is used to reduce costs [4].

CONCLUSIONS

Simulator complexes have the function of description and representation of complex technical object in terms of crew training for effective control, developing skills and correct reaction in non-standard situations. In is necessary to note, that other goals of digital description are aimed in the case of virtual testbed [1], CAD systems, etc. It gives the right to conclude that the appeared term "digital twin" can also be considered in various forms of realization. Complex simulator can be considered as one of the forms of digital twin.

The presented approach of complex simulator organization is effective in terms of balance of resources and simulation quality within the aimed training goals.

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