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Using Virtual Reality Technology in the Design of Complex Systems[1]

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This article provides a concrete example for using and creating a virtual environment for computer-aided design of complex systems. The subject area is design, and the object of research is an aircraft. CAD creates a parameterized 3D model, which is demonstrated and processed on a virtual stage using special equipment. Special equipment such as the HTC Vive Pro virtual reality helmet and the included controllers. The virtual assistant of the designer allows you to create detailed parameterized models of an aircraft, in particular, a transport aircraft based on the An-124 Ruslan, and virtual reality helps the user to learn more about the created project and make the necessary optimization edits directly in VR space. By changing the model in VR space, it will change in the main project. The work is a continuation of the development of a decision-making system, a virtual assistant to the designer: "Robot designer", whose application interface has been defined. The main control menu for the user in virtual space is shown, and the aircraft with the fuselage skin and cockpit removed is also shown. Plans for further use of virtual reality technology in the design of complex systems and training of specialists with the profile of aircraft engineers are presented.

Keywords: *virtual reality, robot designer, 3D model, finite element model, thesaurus, aircraft*

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Использование технологии виртуальной реальности при проектировании сложных систем

Приведен конкретный пример использования и создания виртуальной среды для автоматизированного проектирования сложных систем. Предметной областью является проектирование, а объектом исследования — летательный аппарат. САПР создает параметризованную 3D-модель, которая демонстрируется и обрабатывается на виртуальной сцене с помощью

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специального оборудования. Специальное оборудование — шлем виртуальной реальности HTC Vive Pro и прилагаемые контроллеры. Виртуальный помощник дизайнера позволяет создавать подробные параметризованные модели воздушного судна, в частности, транспортного самолета на базе Ан-124 "Руслан", а виртуальная реальность помогает пользователю узнать больше о созданном проекте и внести необходимые оптимизационные правки непосредственно в VR-пространстве. При изменении модели в VR-пространстве, она изменится и в основном проекте. Работа является продолжением разработки системы принятия решений, виртуального помощника проектанта "Робот-проектант", интерфейс приложения которого был определен. Показано главное меню управления для пользователя в виртуальном пространстве, а также показан самолет со снятой обшивкой фюзеляжа и кабиной пилота. Представлены планы дальнейшего использования технологии виртуальной реальности при проектировании сложных систем и подготовке специалистов по профилю авиационных инженеров.

Ключевые слова: *виртуальная реальность, робот-проектант, 3D-модель, конечно-элементная модель, тезаурус, самолет*

Introduction

The design processes have become more specialized and intensive, but still they are performed by human designers. The designers specialize in their own fields, and in order to solve challenging problems and implement larger projects, they have to cooperate with other designers. When comparing different design processes, one can notice a variety of forms that reflect the richness of product options and how said products are developed and further sold to many different people [1]. Now computer-aided design (CAD) systems are recognized as the basic systems in the design process. 3D models created in CAD systems provide a natural way to exchange project information between the designer and other participants of the production process. However, to share a CAD model between different people, each person should have access to a CAD workstation. This is reasonable if the involved participants work in the same company, preferably if they work in the same or related departments, and of course, they also need to know how to use the CAD system. In practice, the situation is often very different. Model data must be transferred from one system to another, often using the Internet as a data transfer medium. Due to the continuous development of CAD systems, they have become sophisticated tools for modelling 3D objects as well as highly parameterized and powerful tools in presentations, analysis and modelling. However, many problems still remain unresolved. For example, CAD does not provide support at the early design stage, although this stage is recognized as the most important for product development and it has a large impact on development and production costs. In addition, the old paradigm of using 2D design interfaces for modelling 3D objects is still applied, etc. [2].

Virtual reality (VR) is rapidly developing and offers interactive immersion into a different reality, in which both science and industry, medicine [3], and tourism [4] are interested. From pilots to surgeons [5], VR has a strong impact on learning through embodied cognition, psychomotor abilities, and a high level of retention [6].

1. Related work

The main goal of this work is to develop and implement a computer system to assist in decision-making and studying parameterized 3D models in CAD as well as to manipulate them with the addition of parts and enable simultaneous data exchange. For effective aircraft design, it is necessary to move to the maximum possible modular structure that allows data exchange and automates the production process.

Due to the possibility of exchanging models through the Internet and taking other limitations into account, the system shown in fig. 1 has been developed. During the study the following tools have been used: CAD system CATIA [7] for the creation of parameterized models, a plugin written for UNITY [8] for representation of geometric data models in VR, XML as a carrier of configuration data, and C# as programming language [9]. The diagram of the work of the project manager is shown in fig. 1.

The VR project involves the introduction of this technology in the design of the aircraft, showing all the individual features of the aircraft design. It provides disassembling the aircraft by one click of the manipulator and the possibility of seeing all the individual parts [10].

In one of the latest versions of the "Robot designer" project [11], an application interface was developed that allows you to create a parameterized three-dimensional model of a transport aircraft. To build it, the user needs to enter basic data on the aircraft, the so-called technical task. The interface of the classic version is shown in fig. 2, see the 2nd side of cover.

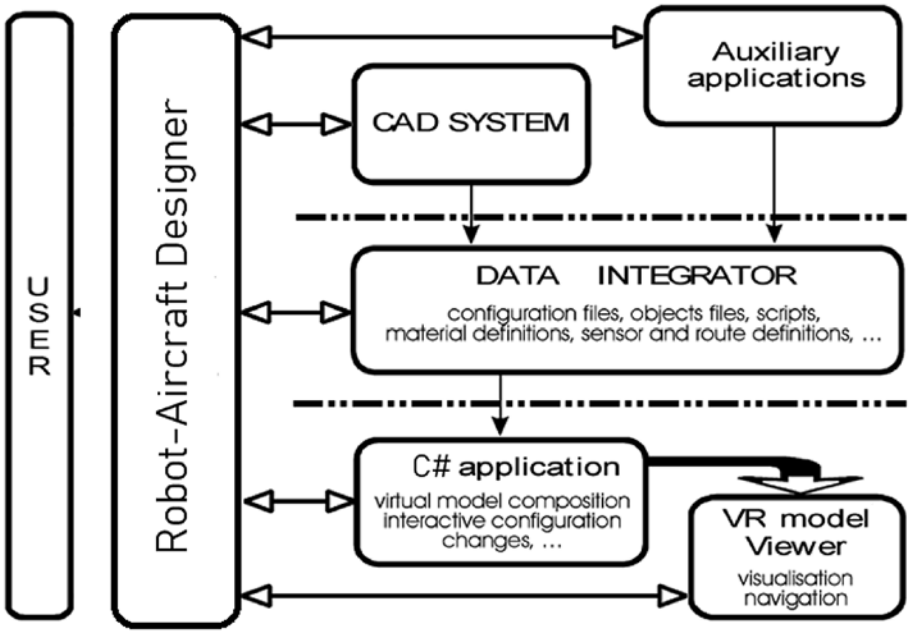

Fig. 1. Diagram of the work of the project manager

The interface of the "Robot designer" consists of several main parts: the project timeline (1), the interactive screen for changing the design parameters (2), the project matrix (3), the model preview window (4), the button for switching the application to virtual reality (5).

The interface is directly connected to the CATIA CAD system [12]. The user can move the model in space as it suits them, scale and rotate the model. Also, for convenience, the user can change the type of the model with one click [13]. There are four options for standard model positions in space: front view, side view, top view and isometry.

In addition to displaying the model in the classic interface [14], it is necessary to provide a more visual comparison image and an intuitive way to interact. This task is effectively handled by visualization using a virtual reality headset, which allows you to deepen the perception of the demonstrated model both from the point of view of development and from the point of scale relative to the user [15, 16].

This project was developed on the Unity platform [17] and tested on the HTC VIVE Pro eye equipment [18] during classes aimed at teaching students of the aviation industry. Currently, there is only one aircraft model built in CAD CATIA [19]. This is a model of the An-124 Ruslan transport aircraft. In a VR helmet, the user is transferred to a virtual hangar with an aircraft model. One of the joysticks allows you to move around the scene with the model shown in fig. 3, see the 2nd side of cover.

First of all, the design of the aircraft is the main point of interest. Taking into account said condition, the cockpit, the cargo compartment, and the locations of passengers and crew are omitted.

To provide comfort while working with the model, an interface with a special user menu is developed, see fig. 4, the 2nd side of cover. The interface has all the necessary functions. The user can move the entire aircraft around the virtual space, replace it around the model, measure the model using the joystick, disassemble the model in parts (remove the fuselage skin of the aircraft).

While the model is controlled in standard mode using a conventional computer mouse, it is controlled in virtual space using special joysticks. These joysticks are complemented by a virtual reality helmet. Using the joystick, user can move around the virtual space and perform manipulations with the model.

The cockpit is not empty and the user can see the location of the crew as a simple visual demonstration example, see fig. 5, the 2nd side of cover. Figure 5 also shows the location of the cabin floor, the room for accompanying cargo, the location and number of frames.

For a detailed analysis of the structure of the aircraft, the user can see the fuselage frame, the location of the frames, stringers and other power elements of the aircraft. By interacting with the menu bar, it is possible to select the appropriate "hide/show" function. Figure 6 (see the 3rd side of cover) provides the demonstration of said function.

The robot-designer is intended for visual demonstration of the aircraft design process [20]. A set of built-in methods and procedures allows to reduce the time for decision-making. In view of the above it is possible to move on to a detailed studying of the model quickly [21]. Therefore, the virtual reality technology allows one to see the model of the aircraft as close as possible and study the structure of the aircraft in detail. With a pair of controllers in hands, the user can use virtual hands to disassemble, measure, change, repaint, and rebuild the model of the aircraft. This technology is aimed primarily at young engineers, students and schoolchildren [22]. Figure 7 (see the 3rd side of cover) shows the process of working with the design robot in the VR mode. The parameterized model is built, the data is added by the user, namely: the range, the cruising speed, the number of seats for the crew, the commercial load.

The effectiveness of immersive design, conducted in VR, has been tested by the first-year students, specializing in aircraft engineering. The young engineers gave a positive feedback on the work with the "Virtual Assistant" system. The use of virtual aircraft design with the HTC VIVE helmet allows one to present the design of the aircraft in a more interactive way [23].

2. Working with other parts of the aircraft

In the design of an aircraft, there is a stage of selecting an engine for it. The choice of an engine for a projected aircraft consists of several stages.

- Preliminary selection of several real engines (or projects of promising engines). The choice is made by the amount of take-off thrust or power. When choosing these parameters, you should pay attention to the prototypes that are installed on similar aircraft.
- Take into account the capabilities of the engine, in the specified flight modes and operational requirements.
- The choice of the most suitable prototype engine.
- Preliminary selection of engines (or projects of promising engines) is carried out according to the scientific and technical characteristics, depending on their dimension (their thrust class or power). Each of the engines is considered as a possible prototype engine, the thrust or power of which will be specified based on the results of subsequent design calculations performed in the course work.

The analysis of the obtained engine variants should include a comparative quantitative assessment of their specific characteristics among themselves in the conditions of a determined technical specification. At the same time, the method of quantifying engines can be similar to the method described above for comparing the layout options of engines on an airplane.

The intelligent assistant "Robot designer" uses a selection engine according to the prototype of the projected transport aircraft. The user can select the appropriate type of engine and view its model, both in standard mode and in VR mode, as shown in fig. 8, see the 3rd side of cover.

3. Working with other parts of the aircraft

In the future, it is planned to create additional functions for working with the model within the present work [24]. Such as the development of a new model of the passenger aircraft based on the MC-21 aircraft with the option to access the cabin of the aircraft from within. This addition will require considerable time to recalculate basic parameters, create a new database since the calculation methods and the design of the passenger aircraft and the transport one are very different from each other.

It should be noted that there are also the plans to create multiplayer options in this application [25]. This will allow multiple users to be in the virtual space and work on the same model simultaneously. One person will be able to deal with the fuselage, another one — with the wing, the third — study the structure of the horizontal tail or model the landing gear and etc.

Another advantage of the present work is a remote usage. From anywhere in the world, the user will be able to connect to the server of the "Virtual Assistant" [26] and create 3D models or simply study the structure of complex systems, such as an aircraft, without leaving home just wearing a virtual reality helmet [27].

The project "Robot designer" has a great future, at least within the walls of Samara University. The project has acquired the appearance of an interface, parameterized 3D models of aircraft, a thesaurus [28], an integrated module for calculating aerodynamic parameters and a module for working with a model in virtual reality. Let the VR functionality now have only basic parameters (twist, rotate, measure, move). In future publications, it is planned to add a more detailed user interaction with the 3D model being created in the virtual environment itself. A detailed interaction is understood as a change in the size of the model and its geometry, these changes will take into account the limitations imposed when designing the aircraft. It is also planned to support this system with augmented reality technology [29].

It is also planned to develop a basic model of interaction with the system, which will take place in several stages. This connection will allow linking the "Virtual Assistant" with other disciplines of the aircraft engineering course and will help teachers integrate VR at any stage of training. This scheme can be seen in fig. 9 (see the 4th side of cover) [30].

Conclusion

In conclusion, the preliminary results of the study provide a positive incentive to continue exploring the use of virtual reality as a tool to support aircraft design concepts that may be difficult for design students to present, and to develop these applications using authentic design learning elements that can provide a solution to bridge the gap between theoretical knowledge and practical application. Further analysis is needed to better understand the expectations of students and their attitude to learning using these new technologies [31].

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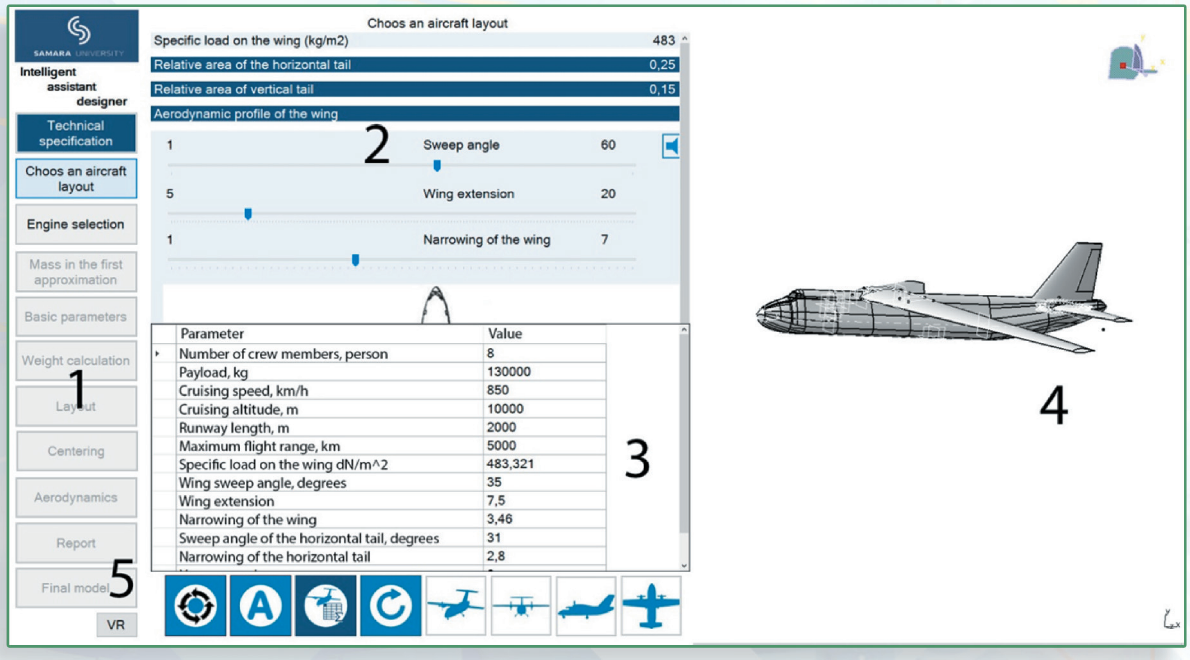

Fig. 2. Interface of the «Robot Designer»

Fig. 3. Model AN-124, VR

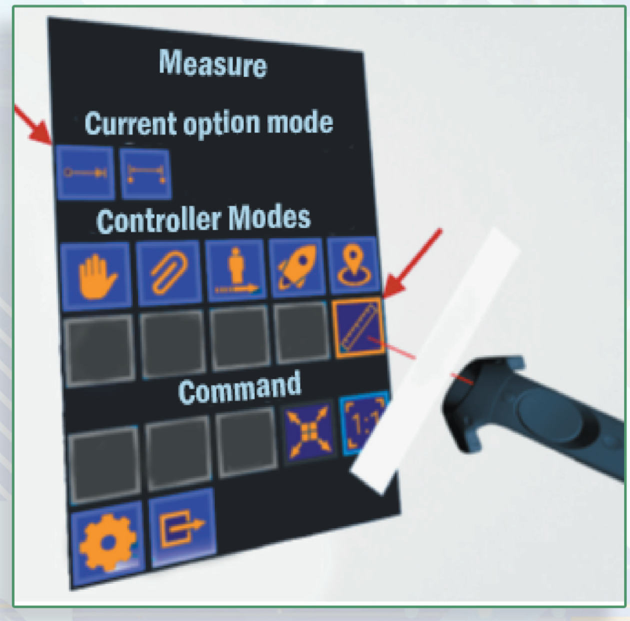

Fig. 4. Interface of the user menu

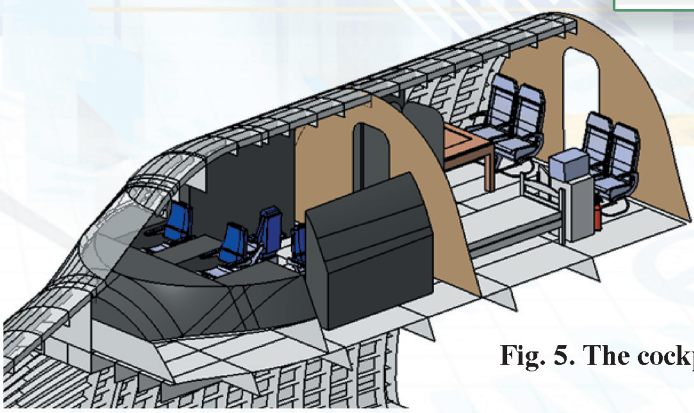

Fig. 5. The cockpit

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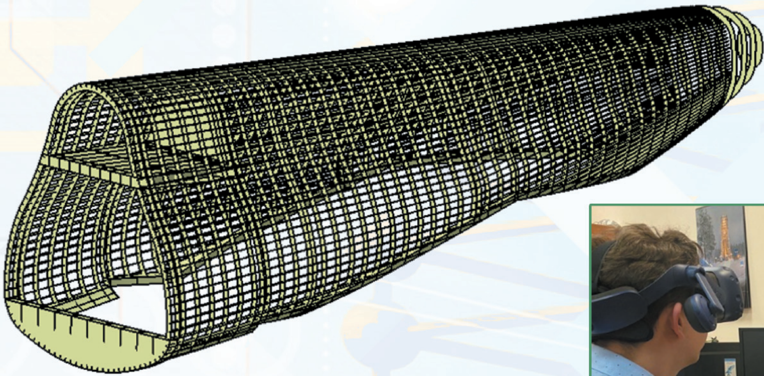
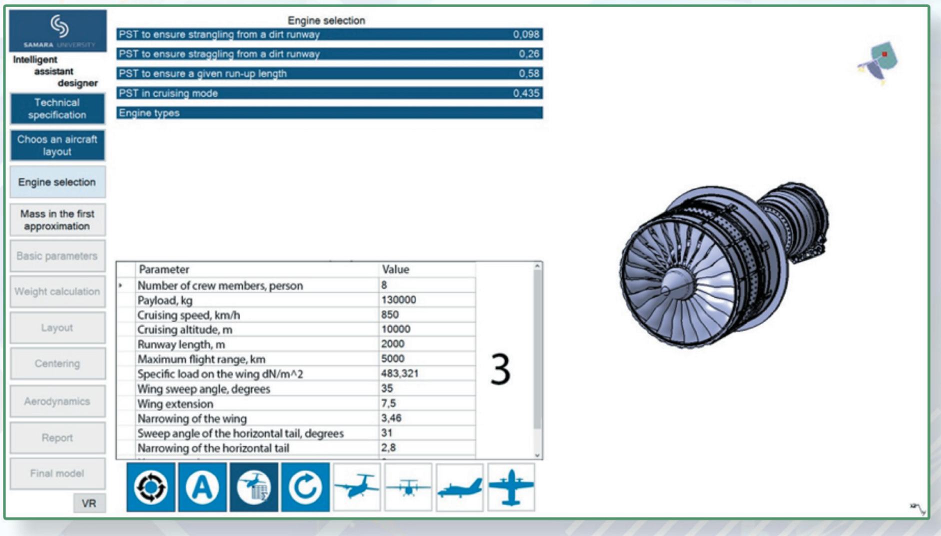


Fig. 6. Fuselage frame

Fig. 7. Working with the robot designer in VR



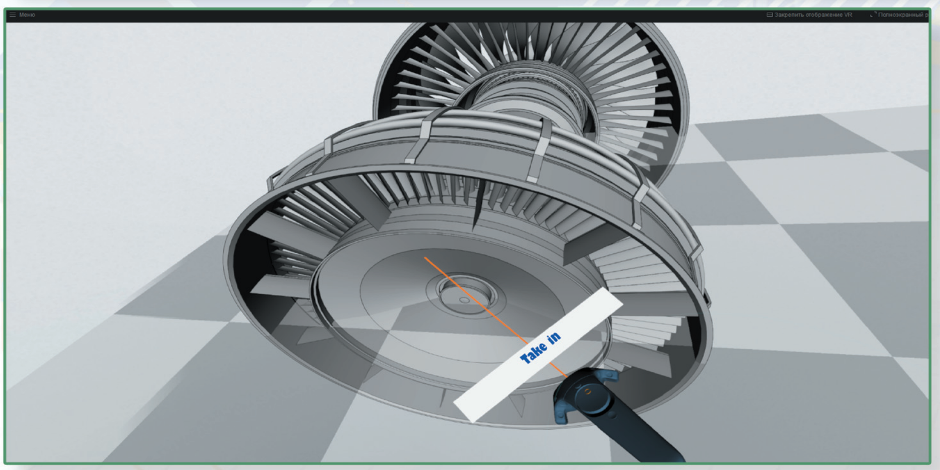


Fig. 8. Working with the robot designer in VR, engine model

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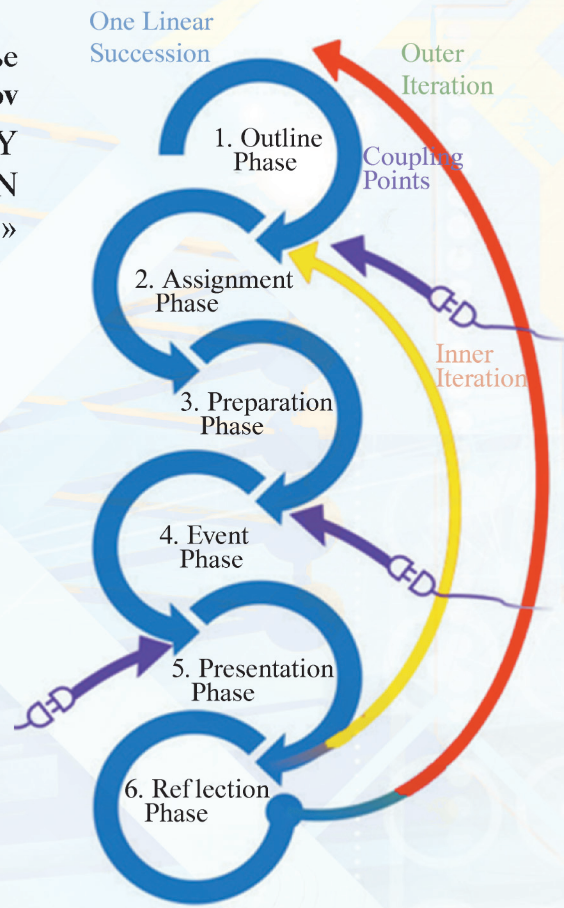

Fig. 9. A phase model for VR and AR training

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