References

1. Jackson S.E., Joshi A. and Erhardt N.L., "Recent Research on Team and Organizational Diversity: SWOT Analysis and Implications," Journal of Management, vol. 29, pp. 801-830, 2003.

2. Marana J., "HOW A GENERAL AVIATION AIRPORT CAN BENEFIT YOUR BUSINESS," Business People, vol. 27, pp. 26, June, 2014.

3. Hill T., "Westbrook R. SWOT analysis: It's time for a product recall," Long Range Planning, vol. 30, pp. 46-52, Jaunary, 1997.

4. Dyson R.G., "Strategic development and SWOT analysis at the University of Warwick," European Journal of Operational Research, vol. 152, pp. 631-640, March, 2004.

5. Paiva. R.C.D., Dur M.T. and Faisal H., "Spatiotemporal interpolation of discharge across a river network by using synthetic SWOT satellite data," Water Resources Research, vol. 51, pp. 430-449, Jaunary, 2015.

6. Thurber M., "Resource sharing comes to small general aviation aircraft," Allevatore Di Ovini E Caprini, vol. 147, pp. 519-536, May, 2014.

7. Zhai H., Hao Y. and Guan X., "State-of-the-arts and prospects of manufacturing and application of titanium alloy tube in aviation industry," Journal of Plasticity Engineering, vol. 16, pp. 44-46, April, 2009.

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FEATURES OF THE DEVELOPMENT OF VIRTUAL REALITY APPLICATIONS FOR TRAINING AVIATION INDUSTRY SPECIALISTS

ОСОБЕННОСТИ РАЗРАБОТКИ ПРИЛОЖЕНИЙ ВИРТУАЛЬНОЙ РЕАЛЬНОСТИ ДЛЯ ОБУЧЕНИЯ СПЕЦИАЛИСТОВ АВИАЦИОННОЙ ОТРАСЛИ

АВИАЦИЯ САЛАСЫНДАҒЫ МАМАНДАРДЫ ОҚЫТУҒА АРНАЛҒАН ВИРТУАЛДЫ ШЫНДЫҚ ҚОСЫМШАЛАРЫН ӘЗІРЛЕУ ЕРЕКШЕЛІКТЕРІ

Abstract. In this paper, the methods of developing virtual reality applications designed for the training and retraining of aviation industry specialists are considered. The analysis of the stages of development of software tools for VR applications is carried out.

Key words: virtual reality (VR), augmented reality, programming, modeling, visualization, assembly.

Аннотация. В данной работе рассмотрены методы разработки приложений виртуальной реальности, предназначенных для подготовки и переподготовки специалистов авиационной отрасли. Проведен анализ этапов разработки программных средств VR-приложений.

Ключевые слова: виртуальная реальность (VR), дополненная реальность, программирование, моделирование, визуализация, сборка.

Аңдатпа. Бұл жұмыста авиация саласының мамандарын даярлауға және қайта даярлауға арналған Виртуалды шындық қосымшаларын әзірлеу әдістері қарастырылған. VR-қосымшалардың бағдарламалық құралдарын әзірлеу кезеңдеріне талдау жүргізілді.

Түйін сөздер: виртуалды шындық (VR), кеңейтілген шындық, бағдарламалау, модельдеу, визуализация, құрастыру.

Effective engineering education, especially in the field of civil aviation, is an important problem. Traditional methods are complex and expensive. That is why it is necessary to introduce new educational tools and technologies for this purpose. We suggest using the possibilities of virtual reality. Naturally, additional time and costs will be required for the development of such systems, immersive virtual reality (VR), since each virtual reality system used for educational purposes is unique - there is no standardization.

The modern learning process, which takes place in the era of informatization of mass communication in the spheres of public life, requires a significant expansion of the arsenal of teaching tools. Improving the quality of education in the aviation field is dictated by increased safety requirements regulated in Kazakhstan by the law "on the Use of the Airspace of the Republic of Kazakhstan and aviation activities", international requirements for the standards and recommended practices of the International Civil Aviation Organization (ICAO), as well as the safety requirements of the European Aviation Safety Agency (European Aviation Safety Agency - EASA), whose members are the Republic of Kazakhstan.

This paper presents a methodology that can be used to create immersive virtual reality (VR) applications designed for learning. Conceptual modeling in the field of virtual reality (VR) and VR applications are becoming more accessible thanks to better and faster equipment, and thanks to new technologies and faster network connections, they are also starting to appear on the Internet. The development of such applications is still a specialized, time-consuming and expensive process.

During the conceptual modeling stage and during the development of virtual reality applications, a number of obstacles that prevent the rapid spread of this type of application can be eliminated. However, the existing conceptual modeling methods are too limited to model a VR application appropriately. The work shows the successive stages of the methodology and the tools used for its implementation. The proposed innovative approach can improve the effectiveness of the preparation of educational VR solutions in aviation, as well as in other branches of engineering.

Characteristics of the stages of software development. Immersive virtual reality (VR) has been known for decades, but at the beginning of this century it was widely recognized and found a wide range of professional applications. The main concept of VR is the creation of a digital world (or environment) in which a human user is located and can interact with him in real time. Virtual reality differs from other methods of human-computer interaction in that three-dimensional graphics strive for realism, intuitive interaction and user immersion in the digital scene [1-2]. Immersion is a sense of presence in an artificial environment, despite a physical presence in the real world [3], which is achieved mainly through the use of various stereoscopic projection devices, such as head-mounted displays (HMD) or CAVE systems, have joined user tracking solutions to improve the sense of presence in the virtual world. In recent years, new inexpensive devices have appeared on the market. Computing power is also steadily increasing, allowing for more demanding real-time visualizations and simulations. In addition, access to cheap or free software for creating interactive virtual worlds is constantly increasing. Thus, we can say that creating VR solutions is becoming easier and easier.

The virtual reality environment can strongly influence the user's behavior and feelings and can be used to teach knowledge and skills. The positive educational effect of VR was observed and described in the literature back in the 90s [4] and proved in further studies [5]. Today, virtual reality is widely used in engineering education, as well as in many other engineering activities, including modeling the operation and assembly of machines, visualization of knowledge and configuration of various products in the automotive industry. Virtual reality has many applications and is often used for educational purposes [6]. Different implementations may have different degrees of immersion:

– Cockpit simulators, used mainly to recreate and simulate a real cockpit, such as the cockpit of an airplane, a car, or the bridge of a ship.

– Projected reality consisting of a moving avatar of the user in real time, which is displayed on a wide screen.

– Augmented reality, which requires special immersive glasses or a mobile device to visualize augmented objects that overlap the real environment.

– A remote presence that can be used to influence and control something real, but in a different place, for example, in a laboratory, at a nuclear power plant, etc.

– Desktop virtual reality, which requires a regular computer display. Interaction with the virtual world is limited by the capabilities of a desktop mouse or joystick, but does not require expensive hardware or software, so it is relatively easy to develop.

– Visually related systems that are mainly used in military aviation. The system places the screens at the user's eye level and connects the user's head movement with the displayed image. The system includes sensors to track the user's eye movement and is able to determine what he or she is looking at.

Virtual reality in education has the advantage of lower costs compared to real models and laboratories. However, this technology is still not widely used. The first reason for this is that the equipment is expensive, although the situation is currently changing thanks to cheap virtual reality solutions such as HTC Vive [7] or Oculus Rift [8]. The second and most important reason is that creating a VR application for engineering education requires, on the one hand, high qualifications in programming, and on the other - a large amount of specialized engineering knowledge. The development of effective virtual reality learning tools requires time and investment, as well as full-fledged cooperation between subject specialists and software developers.

The main obstacle to the widespread use of VR is that most solutions are "point-based", created only for the purpose defined in the current context, without regard to any methodology. Since every decision is immediate, the time and costs are high, with frequent errors and corrections. We need a methodology that could speed up the development process and get more effective results.

The authors of the article suggest using a methodology for creating educational VR applications, the main stages of which are shown in Figure 1.

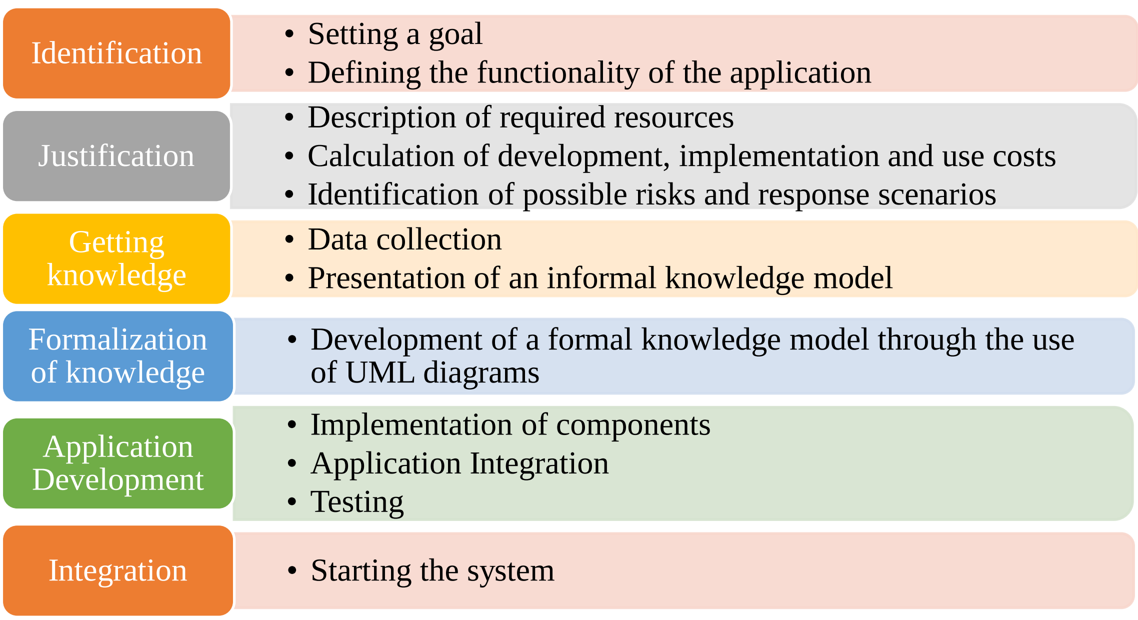

Fig. 1. The main stages of creating a VR application

The purpose of this methodology is to accelerate the implementation of virtual reality solutions by presenting a set of common procedures.

The development of any VR application begins with the conceptual stage of identification and justification, at which the goal and expectations of the software product are determined. Based on a certain concept, a VR application can be classified. In [6], a three-level classification of VR applications is proposed, depending on the established conceptual requirements. Each application layer has its own set of functions and requirements, such as the necessary data types, means of interaction and the expected behavior of the virtual objects presented. These functions correspond to certain software and hardware components of the VR system. In summary table 1, the authors provide an optimized version of the classification.

Таблица 1. Classification of VR applications, depending on the established conceptual requirements

Requirements	**Degree of implementation**		
	Level 1	**Level 2**	**Level 3**
Visualization	Static - pre-rendering	Kinematics - real-time rendering (3D engine, live animation)	Dynamic - real-time rendering with object deformations
Animations	Simple, pre-processed	Rigid bodies - in real time, deformations - pre-rendered	Both rigid and deformable bodies in real time
Methods of object manipulation and interaction	Mouse, keyboard, graphical user interface, gestures	Graphical user interface, gestures, tracking	Graphical user interface, gestures, tracking, tactile manipulation with force feedback
Collisions and user feedback	absent	preferably	Necessarily
Required tracking accuracy and strength	a low degree of measurement is not necessary or acceptable	medium or low degree of measurement	high degree of measurement
Required computing power	low or medium	medium or high	high

The practical significance of the presented classification lies in the fact that, based on the presented table, it is possible to determine which classes of components should be included in a VR application. After determining the type of application, its main characteristics and requirements, it is necessary to determine the sources of knowledge and conduct a risk analysis.

Effective use of knowledge in the design process requires their appropriate acquisition and correct entry in the knowledge base [9]. Methods of collecting knowledge also depend on sources, which can be of various quantities and forms (for example, personal notes, drawings, diagrams). The representation of knowledge is understood as its formal record. The presentation method should be as simple, complete, understandable and unambiguous as possible, not only for those who are engaged in its description, but, above all, for those who will use it. The authors propose for these purposes UML (Unified Modeling Language [10]), an open standard that uses graphical notation to create an abstract model of the system.

The stages of developing a VR application after collecting and formalizing knowledge should be as follows:

- planning;
- visualization;
- programming;
- User interface;
- testing.

At the planning stage, selection criteria are determined using analytical methods for selecting components. For this purpose, decision-making tools are used, such as analytical hierarchy process, fuzzy logic, cluster analysis. The result of this stage is the specification of the selected and received software and hardware. There are many hardware and software components for creating VR systems, with better or worse capabilities [10-17].

At the visualization stage, 3D and 2D models are prepared, export-import procedures, hierarchy and navigation are carried out. For this purpose, 3D modeling tools, 2D graphics tools, and the VR software engine are used. At the end of this stage, an interactive 3D visualization with navigation was obtained.

The programming stage involves planning actions on objects triggered by certain sensors. The VR software engine selected at the planning stage is used for implementation. The programming method depends on the chosen VR engine, as some engines use classical object-oriented programming and/or scripts, while some use visual programming methods into which Unified Modeling Language diagrams can be directly transferred. Interactive visualization is considered the result of this stage.

The user interface stage solves the issues of using the graphical user interface, connecting all hardware components. At this stage, tools such as the VR software engine and programming software are used. This stage provides a complete VR application.

The testing phase should consist of two stages - internal verification with the participation of the entire development team and external verification, where the first version of the application should be evaluated by a sample of end users. This stage is performed using the VR software engine and analytical research methods. The result of the testing phase is a list of recommendations for improving the application.

The stages of programming and user interface in the development of a VR application are the most labor-intensive and time-consuming, they can be considered separately, but they are often carried out simultaneously. The overall goal here is to get a fully interactive application with all the intended functions related to object manipulation, animation, interaction using both virtual reality devices and a classic interface. There are many ways to program virtual reality systems, ranging from simple visual programming to scripting and object programming in high-level languages.

Virtual reality is already an effective tool for education and, thanks to its inexpensive solutions, will become increasingly popular all over the world, improving or even replacing traditional teaching methods. The virtual learning experience should not be aimed only at gaining knowledge; therefore, it is necessary to design these learning environments based on a constructivist approach in order to get all the benefits of learning. The presented construction methodology is designed to accelerate the process of planning, acquisition and formalization of knowledge, as well as to increase the effectiveness of VR solutions. The methodology uses basic knowledge engineering tools in the processes of planning, creating and verifying interactive educational solutions.

References

1. Burdea, G. C., Coiffet, P. Virtual Reality Technology // NY: John Wiley & Sons, Inc. 2003. – P. 464.

2. Scherman, W. R., Craig, A. B. Understanding Virtual Reality: Interface, Application, and Design, 2nd Edition // Burlington: Morgan Kaufmann. 2003. – P.660.

3. Bowman, D. A., McMahan, R. P. Virtual Reality: How Much Immersion Is Enough? // Computer. 2007. 40(7). P. 36-43. doi:10.1109/MC.2007.257.

4. Bell, J. T., Fogler, H. S. The Investigation and Application of Virtual Reality as an Educational Tool. Proceedings of the American Society for Engineering Education 1995 Annual Conference. 1995. https://vrupl.evl.uic.edu/vrichel/Papers/ aseepap2.pdf.

5. Getchell, K., Miller, A., Nicoll, J. R., Sweetman, R. J., Allison, C. Games Methodologies and Immersive Environments for Virtual Fieldwork // IEEE Transactions on Learning Technologies, 2010. 3(4). P. 281-293. doi:10.1109/TLT.2010.25.

6. Gorski F., Bun P., Wichniarek R., Zawadzki P., Hamrol A. Effective Design of Educational Virtual Reality Applications for Medicine using Knowledge-Engineering Techniques // EURASIA Journal of Mathematics Science and Technology Education. 2017. 13(2). P.395-416.

7. Ainakulov Zh.Zh., Kurmankulova G.E., Ainakulova Zh.K. Modeling of 3D objects in applied intelligent virtual reality systems / Electronic periodical peer-reviewed scientific journal "SCI-ARTICLE.RU " http://sci-article.ru , – Russia. – No.31 (March) 2016, – pp. 118-125.

8. Butch G., Jacobson A., Rambo J. UML. St. Petersburg, 2006, – 736s.

9. Virtual reality. https://www.tadviser.ru /.

10.What is virtual reality: properties, classification, equipment. https://tproger.ru/translations/vr-explained/.Shetty V., Patil M. Study of hardware and software used in: virtual and augmented reality device // National Conference on Technological advancement and automatization in engineering. 2016. - pp. - 177-179.

11. K.T., Koshekov K.T., Astapenko N.V., Anayatova R.K., Seidakhmetov B.K., Fedorov I.O., Zuev D.V. (2021) Effective development of educational virtual reality applications. Information telecommunication networks: magazine professional telecommunications magazine, Almaty, 2021. P.33-36.

12. Ainakulov, Zh., Zuev, D., Sejdahmetov, B., Fedorov, I. i Koshekov, K. (2021) VIRTUAL"NOE MODELIROVANIE I MONITORING DETALEJ AVIACIONNOJ TEHNIKI. Vestnik «Fiziko-matematicheskie nauki», 75, 3 (okt. 2021), 35–43. DOI: https://doi.org/10.51889/2021-3.1728-7901.04. (In Russian).

13. Zuev D.V., Fedorov I.O., Astapenko N.V., Koshekov K.T., Ainakulov Zh.Zh. (2021) Mathematical model of nut rotation using a wrench in a virtual reality environment. Scientific Collection «InterConf», (78): with the Proceedings of the 1st International Scientific and Practical Conference «Scientific Goals and Purposes in XXI Century» (October 7-8, 2021). Seattle, USA: ProQuest LLS, 2021. P.384-392. https://doi.org/10.51582/interconf.7-8.10.2021.042.