Modern virtual laboratory for aggregate and assembly works using VR technologies

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Abstract. Today in the production sector all industries are trying to reduce costs while improving product quality. This is a quite ambitious purpose. However, current advances in technology provide such a necessary step towards making significant improvements in the standardization and general practice of complex processes. Making steps simpler, using different visual cues and a quality assurance system, a virtual reality system can provide greater flexibility in production without any additional risk of making mistakes. Its unique feature is the ability to simplify the diverse complex tasks associated with modern assembly and production processes, reduce risks and bring to life products that are part of the new 21st century.

1. Introduction

The management system in virtual reality can move and integrate with equipment that is in operation in production, in addition it can be mobile. Such production tools as laser trackers, spinning guns, robots and programmable machine vision cameras can be smoothly introduced to ensure the accuracy of any task, for example, during the sequential assembly of a device, tightening bolts, or aligning pipes. Directly on the desktop, the projection-based management system can have instructional videos, projects, drawings and virtual instrumentation for basic steps. Moreover, all this is located right in front of an operator.

In this article we study the possibility of using end-to-end digital technology of virtual and augmented reality in order to increase the efficiency of studying the installation of standard assembly devices and practicing the skills of the assembly of typical aircraft units (panel). The concept of the creation of an interactive 3D model with a demonstration of the main elements of assembly device (frame, brackets, supports, switch, latch) and elements of a typical airframe assembly is also described using the example of a panel (skin, stringer, frame rim, knit, etc.).

The paper describes the functions implemented in the virtual laboratory of aggregate and assembly works (AAW) (simulator using AR / VR technologies) for the core disciplines implemented in the Master's program “Automated Assembly Technology” - the training program for specialists in the assembly of modern civil aircraft MS-21 for Irkutsk Aviation Plant. The authors propose to develop a virtual 3D model of the assembly area and assembly devices of the aggregate assembly of MS-21 aircraft typical units. Using them it is possible to practice the skills of performing special technological
operations, such as launching in an assembly device, fixing, drilling, sealing, connecting packages (riveted, screw and bolted connection) and control.

This research is based on the idea of using AR / VR technologies in the educational process when performing laboratory work and practical exercises during the course of specialized disciplines “Assembly technology in aircraft construction” and “Design of assembly devices”. Since it is impossible to provide students with access to the real units of MS-21 aircraft to practice the performance of standard assembly operations, the virtual laboratory will show them the real technologies and equipment used in the production of this aircraft.

During the development of the project, we can see that the share of virtual and augmented reality technologies increases and companies show their superiority not only in the quality of their product, but also in financial indicators. Moreover, it is necessary to note that the introduction of these technologies is possible not only in education, but also in personnel advanced training, after-sales service, repair, marketing and other important areas.

2. Materials and Methods

2.1 Product Structure

The virtual laboratory of aggregate and assembly works, developed in the Unity 3D system, includes:

1) A 3D model of the assembly areas of MS-21 aircraft units (two assembly devices);
2) Digital models of technological operations (launching, fixing, drilling, sealing, riveting, countersinking, control, etc.);
3) The instruction for the use of developed educational product in educational process.

An educational product and a virtual reality system will be included in the work programs of such disciplines “Assembly technology in aircraft construction” and “Design of assembly devices”.

It is planned to realize some of the following processes in virtual format.

2.2 Trial Mode of Assembly Device

3D model of the assembly device separately shows all the elements that make up the joint venture with comments and highlighting of elements:

1) Structure/ frame;
2) Supporting element;
3) Brackets (for mounting switches);
4) Basic fixing elements:
   a) Basic switchers;
   b) Fixing switchers;
   c) Supporting element;
   d) Screw holders (which press the knees and are located on the fixing switches).

2.3 Trial Mode of Assembly Unit

The unit is assembled; during training students are shown a list of parts in the assembly in the form of a comment and highlighting of parts:

1) Skin;
2) Stringers;
3) Knees;
4) Rims of frames.

2.4 Trial Mode of Technological Process of Unit Assembly

This mode presupposes a visual reflection of the list of technological operations that are used when assembling a unit, with their definition. It is also possible to display and explain the tool, equipment, etc.
3. Results and Discussion

3.1 Drilling Technological Process
Drilling — the term is used for processes that create through and blind holes. The purpose of this operation is to make technological holes for placing fasteners, anchor bolts, electrical cables, etc. Equipment - pneumatic drill. Tool – drill, countersink.

Installation of elements of assembly device assumes the active VR laboratory mode using, for example, the HTC VIVE Pro Full Kit system and interaction with objects using the Leap Motion controller.

Trial mode of installation of elements of assembly device includes a list and sequence of basic actions that must be performed when installing the assembly device.

3.2 Assembly Unit
The studied unit is a typical fuselage panel, which consists of the following elements: skin, stringers, frame rims, Knees.

Design bases in this unit are:
- theoretical surface;
- plane of frames;
- stringer planes;
- building horizontal of fuselage.

![Image of fuselage panel](image_url)

**Figure 1.** Airplane panel

3.3 Assembly Device
Assembly device is a frame structure for the assembly of conditionally flat units. It consists of a structure / frame and brackets fixed to it. The switchers (basic fixing elements) are mounted on the brackets. The operating scenarios on programmed in training mode and tested in exam mode.
3.4 Installation of Assembly Device
1. To install the frame of the assembly device: frame + supporting elements
2. To install brackets on reference pads, which are placed on the frame of the assembly device:
   a) To take the bracket from the rack;
   b) To install it on the site;
   c) To fix temporarily it with bolts;
   d) To measure the coordinates of the target mark, it is temporarily placed on the bracket using the API Treker3 laser tracker;
   e) To tighten the bolts;
   f) To repeat all steps for all brackets;
   g) To install the circuit breakers on the brackets installed earlier.
4. To check all moving parts.
5. To fix circuit breakers using locks.

3.5 Panel’s Assembly Process
1. To open the locking switches and turn the locks.
2. To turn up the fixing switches.
3. To take the "skin" part from the rack.
4. To install it in assembly device, press it against the basic switchers and stops.
5. To take the stringer.
6. To press the stringer to the skin and fix it using normal lines (repeat 6 times for each stringer).
7. To lower the fixing switches and press the skin against the basic switchers.
8. To lock the fixing switches.
9. To take the knee from the rack.
10. To press the knee to the locking switcher and skin.
11. To fix the knee with a screw clamp, which is located on the switcher (repeat the steps for all knees).
12. To take the pneumatic drill from the rack.
13. To perform hole preparation (visual movement of the pneumatic drill and simulation of drilling).
14. To replace the drill with a countersink and cut holes for countersink rivets from the outer surface.
15. To install the rivets.
16. To rivet with a pneumatic hammer and support.
17. To unlock the fixing switchers.
18. To turn up the fixing switcher.
19. To perform the removal of the unit from the assembly device.
20. To take the rim of the frame.
21. To install it to the knees with the CO clamps (repeat for all frame rims).
22. To drill holes in the package “knee + frame rim”.
23. To install regular rivets into the package.
24. To rivet with a pneumoscope (1 person).
25. To control visually the unit, with a description of the name of the parts included in it.

3.6 Practical Value
The virtual laboratory of aggregate and assembly works will make the technological assembly processes more illustrative before their practical implementation. As a result it will lead to the decrease in possible mistakes in practice. During the introduction of the project into the educational process, it is expected to improve the quality of training for undergraduates in the development of theoretical knowledge and knowledge consolidation in practice immersing students in the technological process of aviation units’ assembly. It is also expected to increase the development of core competencies among students in the field of MS-21 aircraft assembly.

The use of digital technologies in educational activities will increase the involvement of students in the process, as well as provide the university graduates with modern competencies which are in demand in labor market, namely digital skills. For a university, the introduction of modern technologies in educational activities will allow attracting a larger number of applicants to engineering fields, and will also contribute to increasing digital literacy among students and teaching staff.

The novelty of the research project is reasoned by the integration of AR / VR technologies into the special disciplines of educational process, which will allow training high-level assembly specialists.

4. Conclusion
The relevance of the described project is in the training of highly qualified specialists for the production of modern Russian MS-21 aircraft at a high innovative level. The process of assembly technological operations take up to 55-60% of the entire aircraft production cycle and operations performed in assembly devices - up to 40%. The graduates of the Master's program “Automated Assembly Technology” must possess modern specialized and digital competencies. This is the main purpose of this project.

The result of the use of a virtual assembly laboratory in production is that it reduces errors and improves process efficiency. Unlike many CAD systems, in a virtual laboratory the integration of human intelligence with software is carried out using VR / AR technologies. The VR / AR-technology system can reduce the use of printed instructions and will provide information in the form of visual 3D animation. This approach will reduce the time for the study of work instructions and technological processes, as well as reduce the requirements for the qualifications of specialists.

Thus, the role of virtual reality in everyday life is increasing. Its implementation will increase the speed of the production process, reduce production downtime, help easily and quickly access the required data, reduce the number of employee errors to a minimum and help to quickly identify them. Augmented reality technologies have great potential for the application in the field of corporate training. In addition, augmented reality can provide exceptional properties of a product: instead of boring and complex instructions, commodity producers can release applications that will present information about the product in an accessible, precise and visual mode.

References
[1] Krastyaninov P M and Khusainov R M 2016 Selection of equipment for machining
processing of parts using NX and TEAMCENTER programs IOP Conf. Series: Materials Science and Engineering 134 012041

[2] Khusainov R M and Sharafutdinov I F 2016 Methods of assessing the dynamic stability of the cutting process using UNIGRAPHICS NX IOP Conf. Series: Materials Science and Engineering 134 012042

[3] Dolgovesov B S, Debelov V A, Morozov B B, Zhmulevskaya D R 2003 The System for Interactive Virtual Teaching Based on “Focus” Virtual Studio. 3rd Intern. Conf. “VEonPC2003”, Russia, Yugra Research Inst. of Inform. Technologies (in Russ.).

[4] Huang M P, Alessi N E 1999 Presence as an emotional experience In J D Westwood, H M Hoffman, R A Robb, D Stredney (eds). Medicine Meets Virtual Reality: The Convergence of Physical and Informational Technologies Options for a New Era in Healthcare, pp. 148-153. (Amsterdam: IOS Press).

[5] Insko B E 2003 Measuring presence: subjective, behavioral and physiological methods. In G Riva, F Davide, W A Isselstein (eds.). Being There: Concepts, Effects and Measurement of User Presence in Synthetic Environments (Amsterdam: IOS Press)

[6] McLellan H 1996 Virtual realities. In D H Jonassen (ed.) A Handbook of Research for Educational Communication and Technology, pp. 457-487 (New York: Macmillan Library Directory)

[7] Parallel Graphics Cortona VRML Client. 2014 Retrieved from: http://www.parallelgraphics.com/products/cortona/

[8] Solar System, Solar System Information, Facts, News, Photos. National Geographic 2014 Retrieved from: http://science.nationalgeographic.com/science/space/solar-system

[9] Winn W 1993 Conceptual Framework for Educational Virtual Reality Applications, Technical Report TR-93-9 (Seattle, Washington: Human Interface Technology Laboratory), Washington State University. Retrieved from http://www.hitl.washington.edu/publications/r-93-9

[10] Biryukova E A 2004 Philosophical polyionics of moral virtualizations of spiritual healing Man and the Universe 7 p. 15.

[11] Ivanov D V 2000 Virtualization of society (St Petersburg: Petersburg Oriental Studies)

[12] Kravets A S, Sayapin V S 2008 The problem of conceptualization of virtual reality Vestnik VSU. Series Humanities 1 p. 112.

[13] Roussos M, Johnson A, Moher T, Lee J, Vasilakis S, Barnes S 1999 Learning and building together in an immersive virtual world. In TV operators and virtual environments pp. 247-263.

[14] Selivanov V V, Selivanova L N 2014 VR as a method and means of teaching Mezhdunar. electronic journal "Educational Technology & Society" 17 (3) pp. 378-379

[15] Sorochinsky P V 2014 Changes in the characteristics of thinking and mental state of a person under the influence of virtual reality Bulletin of the Cherepovets State University 7 pp. 154-157

[16] Ferrey B, Kerwin L, Turbil J, Cambourne B, Hedberg J, Jonassen D, Puglisi S 2004 Developing an online classroom simulation to improve decision-making skills of novice teachers. Retrieved from: http://www.aare.edu.au/04pap/fcr04656.pdf

[17] Chi Y 2001 Virtual reality in education: rooting learning in experience. In Proceedings of the International Symposium on Virtual Education Busan, South Korea (pp. 43-54)

[18] Agarkov A P, Golov R S, Golikov A M 2015 Theory of organization. Organization of production: a tutorial

[19] Ershov V I et al 2015 Aircraft assembly technology: a textbook for aviation specialties of universities

[20] Revenko N F et al 2010 Organization of production and management in mechanical engineering

[21] Pekarsh A I, Tarasov Yu M, Krivov G A 2006 Modern technologies of aggregate-assembly production of aircraft (Moscow: Agraf-press).

[22] Abibov A L, Biryukov N M, Boytsov V V 1982 Technology of aircraft construction (Moscow: Mechanical Engineering).

[23] Shmakov A K, Yushin V A, Cheslavskaya A A, Pashkov V P 2008 Design of technological processes for assembling aircraft units (Irkutsk: ITNITU).
[24] Carey R, Bell G 1997 *The annotated VRML 2.0 Reference Manual* (Addison-Wesley)