Application of Virtual Reality in Designing and Programming of Robotic Stations

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Abstract. The article presents the subject of the practical application of virtual reality in the design and programming of robotic stations. Robotic stations designed with the use of virtual reality were created in a collaborative network study consisting of a university, enterprise and government organization - National Centre for Research and Development. An example of a project implemented within the framework described in the collaboration article is the robotisation of the manufacturing processes of aircraft engine components.

Keywords: Virtual reality · Robots · Robotic stations ·
Collaborative network · Design of robotic stations

1 Introduction

The article presents an example of the use of virtual reality in the design of robotic stations. The project was carried out as part of a collaborative network consisting of a university, a company and a government organization – the National Centre for Research and Development (Fig. 1).

The network of cooperating units in question consists of independent institutions that differ in their goals, environment, organization and culture [1, 2]. The company that is included in this network has clearly defined goals. The modern theory of the company is based on the contention that the most important goal in the company is to maximize its market value. Besides this general goal, there are also marketing goals, i.e. a level increase in sales, innovative goals - product innovation, and financial goals - profitability. The aim of the University is to educate students, conduct scientific research and create favourable conditions for innovation. The National Centre for Research and Development (NCRD) established in Poland has the following objectives:

- management and implementation of strategic research and development programs that directly translate into the development of innovation;
- supporting commercialization and other forms of transfer of research results to the economy, management of applied research programs and implementation of projects in the field of defence and state security;

- ensuring good conditions for the development of academic staff, implementing, inter alia, international mobility programs for researchers.
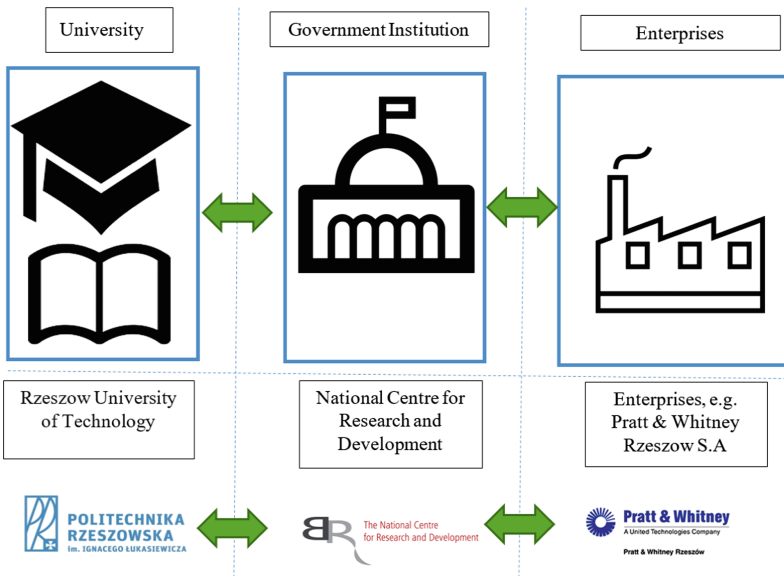

Fig. 1. Diagram of the functioning of the discussed collaborative network

In pursuing these goals, the NCRD ensures that public money spent on research and development work brings the greatest benefits to the Polish economy. Through several dozen programs, the Centre can provide financial support for a project at all levels of technological readiness – from initial industrial research to the development of an innovative product, service or technology. This offer is complemented by programs supporting the financing of international protection of industrial property and foreign expansion of young innovative companies.

The Rzeszow University of Technology, together with industrial partners, has implemented and continues to implement several dozen projects that are co-financed and implemented in cooperation with the NCRD. The team involved in the presented in this work project focuses on the design of advanced robotic stations and robotization of various types of processes in the aviation industry. An example of projects implemented within this collaborative network is the robotic quality control of jet engine components presented in the works [3–5]. Jointly implemented projects also included autodiagnostics of robotic stations and robotic machining processes in the aviation industry which are the subject of publications [6–14].

Functionally, the collaborative network based on NCRD allows companies to implement innovative solutions related to robots, for example, and researchers can conduct advanced research using the latest technologies. Projects implemented thanks

to financial and substantive support of the NCRD allow the creation of cooperation networks and the development of the units involved. Patents, scientific articles or PhD theses are often the result of cooperation. Companies thanks to the collaborative network have access to laboratories, substantive support and can acquire students as future employees. The implementation of joint projects is very important for didactics. Students may be familiarized with the work being carried out, and they may also take part in the tasks performed. An example of a project implemented within the discussed collaborative network is the robotization of the manufacturing processes of aircraft engine components. During the design and programming of the station for the machining of aircraft engine components, virtual reality techniques were used.

2   Virtual Reality

Virtual reality (VR) is an artificial image of reality created using information technology. It involves the multimedia creation of a computer visualisation of objects, space and events. It can represent both elements of the real world and completely fictional ones. In virtual reality it is possible to simulate the presence and operation of the user and feedback information is sent to one or more senses in such a way that the user has a sense of immersion in the simulation.

The virtual reality system exposes objects to the user with the help of image, sound and sensory stimuli, and allows interaction, giving the impression of being in a simulation. Sensory feedback provides users with direct sensory information depending on their physical location in a virtual environment. Sensory information is transmitted through synthetic stimuli, that is computer-generated visual, audio or tactile information. Most of the feedback is implemented via visual information, although some environments only use tactile information. In addition to simulation, the virtual reality system requires an interface that allows users to "enter" virtual reality. One of the first such devices was an invention by Morton Heilig, named the Sensorama Simulator from 1962, which was the first video game allowing immersion in virtual reality [15]. The device displayed a colourful, three-dimensional graphic on a stereoscopic display, it was equipped with a stereo sound system, an odour generator, fans that simulated breeze and a movable seat. The game consisted of riding a motorcycle on the streets of New York. The players felt the unevenness of the road, the smells of food from restaurants and the air movement resulting from the movement of the motorcycle. However, it was not possible to interact with the virtual environment objects. Heilig also started work on virtual reality glasses mounted on the head equipped with headphones. He did not complete his invention, but the potential of his solutions was noticed. The development of technology allowed for the construction and improvement of virtual reality interfaces. Nowadays VR devices are widely available and systematically increasing the number of their applications, both commercial and specialist.

One of the most frequently used examples of the practical application of virtual reality are flight simulators [16]. Pilots can practice flying in different conditions, simulate failures and ways of responding to them. Simulators of surgical operations are another important example [17]. An operation is a dangerous situation for the patient, because a single error can lead to his or her death. Following the example of flight simulators, surgical simulators provide a virtual environment in which the surgeon can use realistic touch interfaces (which look like real surgical tools) to perform surgical procedures on various patients. Virtual patients do not necessarily have to be imaginary objects. Modern imaging methods, such as computed tomography, can be used to create a three-dimensional image of the human body. Before a real operation, surgeons can practice on a virtual patient with very similar characteristics to the real patient being prepared for surgery. Surgical simulators have become particularly widespread thanks to the creation of surgical robots that allow the whole operation to be performed using a touch interface and a screen.

In [18] the authors proposed the use of virtual reality to train employees in positions where they cooperate with robots. The reason for this approach was to improve safety. Thanks to VR, an inexperienced employee is able to learn the principles of safe cooperation with machines. The work [19] presents a VR application for training in the field of management of industrial processes, with particular emphasis on pneumatic systems. The virtual application consists of a virtual laboratory and a virtual industrial plant.

3   Design and Software of a Robotic Station Created with the Help of Virtual Reality

For designing and programming a robotic station, it was decided to use currently available tools for designing and programming robots off-line. Off-line programming is recommended for use in the construction and modification of complex robotic systems. The direct benefits of using off-line programming are:

- shortening break times in production;
- automatic generation of NC code;
- numerical (CAD) representation of elements of the position – easier and faster integration of the robotic station;
- use of graphic editor in testing (verification) and optimization of the work program;
- facilitated interchangeability of programs between robots;
- the ability to create complex work programs, complex position logics, and advanced, large sensory systems.

Using modern computer programs for programming industrial robots, fast and accurate generation of control programs can be obtained. It is possible to test various organizational variants of the position and work scenarios while maintaining both easy and quick corrections and the safety of testing (e.g. collision detection) of the program, thanks to simulation in a virtual environment. The design method of advanced robotic stations is shown in Fig. 2.
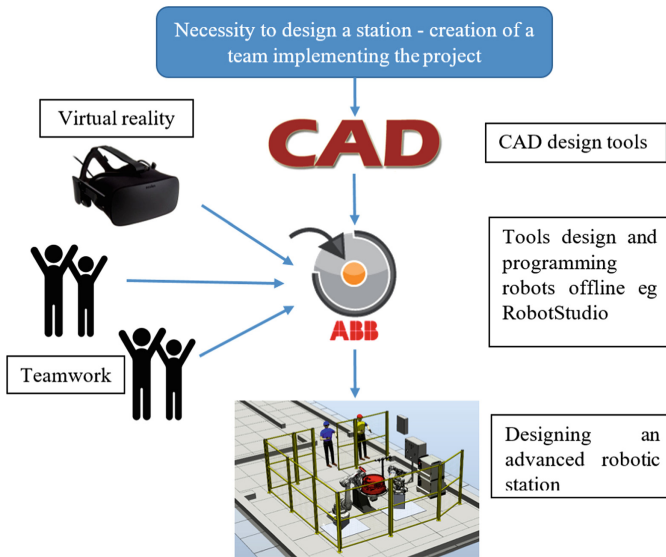
Fig. 2. The design method of robotic stations

After a review of the available solutions for designing and programming a robotic station, the ABB tool, RobotStudio, was chosen (Fig. 3). Earlier, the use of other available off-line programming tools was considered. The possibilities of using virtual reality of RoboGuide software by Fanuc, Kuka Sim Pro by Kuka and K-Roset by Kawasaki were analyzed. Unfortunately, none of these tools has such options.
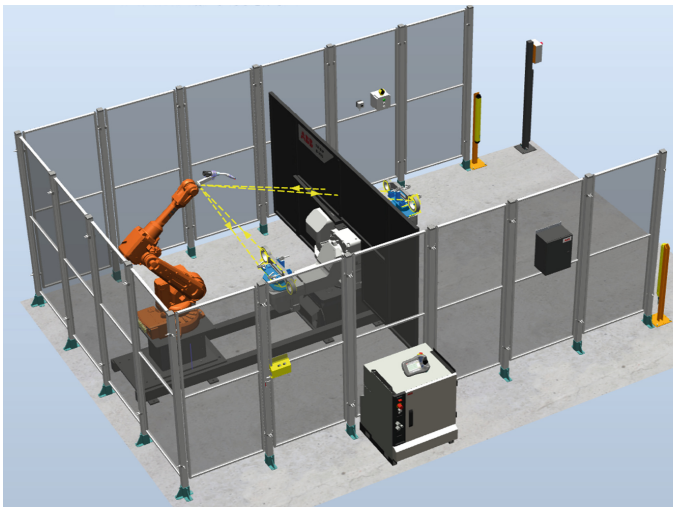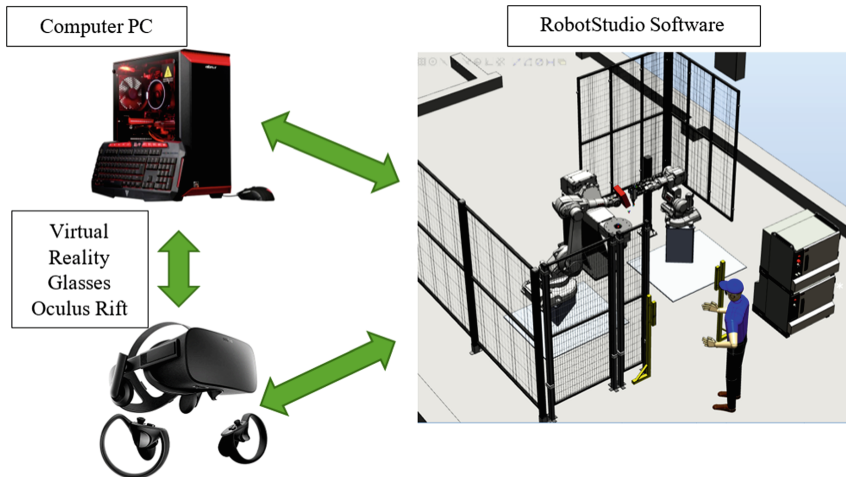

Fig. 3. View of the station designed in the RobotStudio software

RobotStudio versions available since 2017 work with VR glasses, allow the user to design and program robots in the virtual world and interact with its components (Fig. 4).


Fig. 4. The concept of cooperation of RobotStudio software with VR tools

A PC with RobotStudio software and VR Oculus Rift glasses were used to design and program the robotic station. After the glasses are put on, they display the image of the computer-generated world in front of the user's eyes. The user can look around in a natural way, moving their head or body. The Oculus Rift model used has a screen displaying to each eye an independent image with a resolution of 1080×1200 pixels. Connectivity to a computer can be implemented by cable using HDMI and USB interfaces or wirelessly. The movements of the user's head are tracked by two sets of sensors that are responsible for tracking the rotation and position of the head in space.

The Virtual Reality Meeting turned out to be a very useful option used during the design of the station. This solution, which is a function of the RobotStudio software, allows a virtual meeting of several people in one robotic station. People can be in different locations, and distance is not important. Thanks to the Virtual Reality Meeting, users can see their avatars in the form of coloured glasses, talk, draw and annotate in a virtual model of a robotic station (Fig. 5).

The RobotStudio application with the Virtual Reality Meeting option allows users to run "live simulations" where robots perform paths, objects move, and the virtual reality provides accurate perception of dimensions. Checking of ergonomics and accessibility for cleaning and servicing equipment are available. The meeting function helps in design analysis and error correction at an early stage. This results in a much shorter installation and start-up phase.
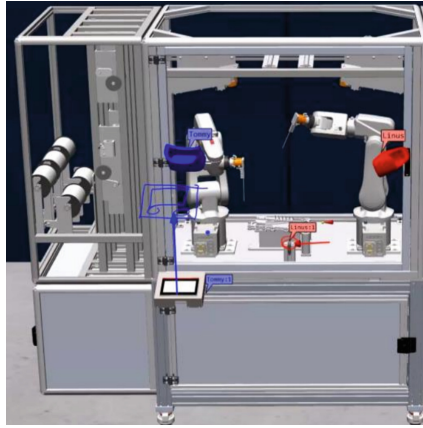
Fig. 5. View of the station designed using Virtual Reality Meeting

An example of a project implemented with the use of the off-line design, virtual reality and Virtual Reality Meeting tools, discussed above, can be seen in a robotic station for machining aircraft engine components. Pratt & Whitney Rzeszow S.A., which is part of UTC, in its operations performs technological operations involving the machining of V2500 engine diffuser castings. One of many technological operations is edge deburring. In the process of making a diffuser, there are a number of edges that require deburring, which is an operation that is carried out manually. As part of a joint venture, coordinated and co-financed by the NCRD, a robotic station for carrying out this process was designed and constructed (Fig. 6).
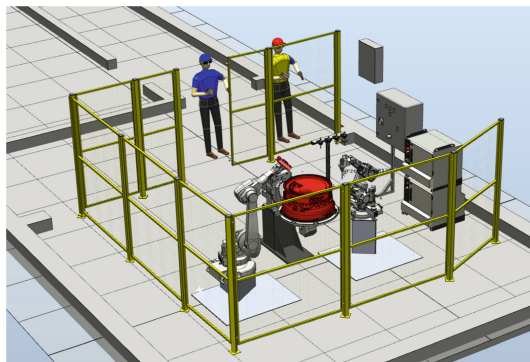
Fig. 6. View of a station designed for machining aircraft engine components

The operation of the station is divided into three stages: removal of oversizes (flash), chamfering and grinding of the machined surfaces. The whole process is performed by the ABB IRB140 robot, and the implementation of subsequent processing stages is possible thanks to the exchange of tools located in a four-position changer.

As part of the work, a precise model of the station was prepared using VR, the location of the station elements and the method of loading the workpieces were discussed with the industrial partner, and scenarios of failures, repairs and service inspections were analysed. Due to the need for meetings with engineers from the USA and Canada, the Virtual Reality Meeting function proved useful.

4   Conclusions

The article presents the available possibilities and an example of the use of virtual reality in the design of robotic stations. This innovative project was created as part of a collaborative network consisting of the Rzeszow University of Technology, the company Pratt & Whitney Rzeszow S.A. and the National Centre for Research and Development. The concept and way of functioning of this network are discussed in the article. The approach based on the cooperation of a technical university and a company, supported by the assistance of a government institution, results in interesting and advanced projects. Thanks to the cooperation of scientists with specialist knowledge and appropriate tools with a company dealing with high technologies, the benefits are shared by both sides and the level of innovation in the state is raised. The method of designing robotic stations shown in the article can be applied in the design of various robotic stations and automated systems. The use of off-line design and programming tools, virtual reality and Virtual Reality Meeting capabilities allows designing and planning in a way that was previously unachievable. The station and similar discussed in the article, developed in cooperation with the industry, are used in the education process. In the case of the station described in the article, students took part in the design of the station elements' layout and prepared some CAD models. In addition, students can see how the design and implementation of the advanced robotic station looked like. Thanks to the use of virtual reality, you can show the way the station is operated and the operation of security systems.

As part of subsequent works, techniques for designing and programming robotic stations using virtual reality will be developed. Improvement of the possibilities of joint and remote work on a given project is intended to be prepared. Advanced avatars of team members implementing the project will be added. The students will be more involved in the project. A base of virtual-interactive objects will be built, from which it will be possible to build more robotic stations as if from blocks.

References

1. Shuman, J., Twombly, J.: Collaborative networks are the organization: an innovation in organization design and management. Vikalpa **35**(1), 1–14 (2010)
2. David, T., Robert, S.: Collaborate and innovate: a new world of sourcing (2007)
3. Burghardt, A., Kurc, K., Szybicki, D., Muszyńska, M., Nawrocki, J.: Robot-operated quality control station based on the UTT method. Open Eng. **7**(1), 37–42 (2017)

4. Burghardt, A., Kurc, K., Szybicki, D., Muszyńska, M., Nawrocki, J.: Software for the robot-operated inspection station for engine guide vanes taking into consideration the geometric variability of parts. Tehnički vjesnik **24**(Suppl. 2), 349–353 (2017)

5. Burghardt, A., Kurc, K., Szybicki, D., Muszyńska, M., Szczęch, T.: Robot-operated inspection of aircraft engine turbine rotor guide vane segment geometry. Tehnički vjesnik **24** (Suppl. 2), 345–348 (2017)

6. Burghardt, A., Kurc, K., Szybicki, D., Muszyńska, M., Szczęch, T.: Monitoring the parameters of the robot-operated quality control process. Adv. Sci. Technol.-Res. J. **11**(1), 232–236 (2017)

7. Teti, R., Jemielniak, K., O'Donnell, G., Dornfeld, D.: Advanced monitoring of machining operations. CIRP Ann. **59**(2), 717–739 (2010)

8. Gierlak, P.: Hybrid position/force control in robotised machining. In: Solid State Phenomena, vol. 210, pp. 192–199. Trans Tech Publications, Switzerland (2014)

9. Barnfather, J.D., Goodfellow, M.J., Abram, T.: A performance evaluation methodology for robotic machine tools used in large volume manufacturing. Robot. CIM-Int. Manuf. **37**, 49–56 (2016)

10. Burghardt, A., Szybicki, D., Kurc, K., Muszyńska, M., Mucha, J.: Experimental study of Inconel 718 surface treatment by edge robotic deburring with force control. Strength Mater. **49**(4), 594–604 (2017)

11. Kurc, K., Burghardt, A., Gierlak, P., Szybicki, D.: Non-contact robotic measurement of jet engine components with 3D optical scanner and UTT method. In: Hanus, R., Kreischer, C., Mazur, D. (eds.) MSM 2018. LNEE, vol. 548, pp. 151–164. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-11187-8_12

12. Szybicki, D., Burghardt, A., Kurc, K., Pietruś, P.: Calibration and verification of an original module measuring turbojet engine blades geometric parameters. Arch. Mech. Eng. **66**, 97–109 (2019)

13. Hui-Ping, L., Dai-Min, C., Miao, Y.: Communication of multi-robot system on the TCP/IP In: International Conference on Mechatronic Science, Electric Engineering and Computer (MEC), pp. 1432–1435. IEEE (2011)

14. Zhsao, P., Shi, Y.: Composite adaptive control of belt polishing force for aero-engine blade. Chin. J. Mech. Eng. **26**(5), 988–996 (2013)

15. Burdea, G.C., Coiffet, P.: Virtual Reality Technology. Wiley, Hoboken (2003)

16. Mihelj, M., Novak, D., Beguš, S.: Virtual Reality Technology and Applications. Springer, Dordrecht (2014). https://doi.org/10.1007/978-94-007-6910-6

17. Gallagher, A.G., et al.: Virtual reality simulation for the operating room proficiency-based training as a paradigm shift in surgical skills training. Ann. Surg. **241**(2), 364–372 (2005)

18. Koźlak, M., Kurzeja, A., Nawrat, A.: Virtual reality technology for military and industry training programs. In: Nawrat, A., Kuś, Z. (eds.) Vision Based Systems for UAV Applications. Studies in Computational Intelligence, vol. 481, pp. 327–334. Springer, Heidelberg (2013). https://doi.org/10.1007/978-3-319-00369-6_21

19. Ortiz, J.S., et al.: Virtual training for industrial automation processes through pneumatic controls. In: De Paolis, L.T., Bourdot, P. (eds.) AVR 2018. LNCS, vol. 10851, pp. 516–532. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-95282-6_37