Novel trend in case study of industrial robot programming and production system design using the virtual reality

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Abstract. The current trend of the production systems designing using by industrial robotics aims to reduce deployment time and minimize the value of financial investments. A large number of CAD software of various standards with little shared associativity are currently used for the design of production systems. Pre-production phases are the most demanding time and cost item for designing and programming industrial robots in terms of currently used methods (online and offline programming) at the design stage of new production devices and systems. Especially the new possibilities of using virtual reality in designing manufacturing systems, and the use of non-standard methods for programming of industrial robots in immersive virtual reality environments helps to shorten the pre-production phase of design, time-consuming programming trajectories of industrial robots, as well as tune of collision situations, debugging of robot trajectories and programs, testing and simulation of future production system.

1. Introduction

Virtual reality as one of the Industry 4.0 technologies with others is a tool of the 21st century, which uses hardware and software resources in cooperation with computer support. In the last period, in addition to the term virtual reality (VR), other areas began to appear and add, which are called Augmented Reality (AR), Augmented Virtuality (AV), as well as the term Mixed Reality (MR). These mentioned terms on the figure. 1 were defined in this issue as early as 1994 in one important and cited publication [1].

![Simplified representation of a RV Continuum](image)

**Figure 1.** Simplified representation of a RV Continuum [1].

Based on figure 1, the authors wanted to bring closer and clarify in their publication the concepts that have been created over time and with advances in technological, hardware, software and computer...
innovations improved to currently used support elements such as various "headset" glasses for VR display with inseparable hardware - software, computer support, smartphones and tablets supporting various applications for augmented reality AR, as well as mixed reality MR of the two described areas [2, 3]. Based on this, but also other publications in this field of research, the original figure 1 was modified to the following form figure 2.

Figure 2. Virtuality continuum referred to as mixed reality MR [2].

Due to the constant shortening of time from the initial assignment of the research task to the final deployment of various production and robotic systems in real production, many companies are moving in addition to standard procedures for creating desktop simulations using CAD data and pre-production verification of comparison designs in a Virtual Commissioning (VC) and VR environment [4, 5]. At present, most companies are deploying and implementing the pre-production phase of designing future robotic systems with various innovative tools such as verification or creation of proposals for future production in an immersive VR environment and virtual commissioning. Just the area of virtual prototyping of the future production and new possibilities of designing and programming of industrial robots that are one of the important areas of strategies Industry 4.0 [6].

The creation, testing and verification of future production systems design using various VR headsets is subject to an iterative and concurrent design process based on the use of 3D CAD models databases and displayed VR studies in a suitable simulation environment, figure 3 [7].

Figure 3. Subsequence process design with connect specified modules displayed in VR environment [7].
The finally immersive VR simulation models provide structured and easy-to-understand design information for the design teams. This is done in such a way that would not be possible using a traditional design approach based on 2D and 3D CAD drawings. The stakeholders can analyse the design from both a general and a more detailed perspective through the possibility of navigation in the models. VR models representation allows simpler to outline and discuss about the various design solutions instead of displaying through 2D drawings. This is a new perspective from the point of view of model design and we can talk about a new approach. This new approach makes it possible to detect possible errors and correct them even at the design stage [7].

2. Objectives
The basic goals of deploying modern tools in the form of the use of immersive imaging in a virtual reality environment are defined as the follows:

- Display of new simulation designs and "factory of the future" concepts;
- Virtual prototyping of future production;
- Shortening the deployment time of future production;
- Design of new automated and robotic systems;
- Verification of designs for future robotic production (verification of a suitably selected type of Robot reachability, verification of CAD data for the design of functional units, etc.);
- Testing of designs in the form of verification of simulations (elimination of collision states, Verification of utilization of individual machines and devices);
- Debugging of industrial robot trajectories;
- Safety simulation;
- Validation of logistic layouts;
- Analysis of ergonomics of workers.

Our assumption is that it is possible to use VR tools in creating a new robotic workplace and find out to what extent it is possible to use the scheme. The aim of this research article is to present the usability rate of using modern technologies VR for displaying or creating a new design for the future robotic workplace. ABB RobotStudio software will be used to validate the robotic workplace design method via a VR headset.

3. Methodology of research
The research consists in the possibility of creating a new robotic workplace in a new way by use of VR in order to simplify and speed up the design process compared to the standard methods. The standard method which is used is the Offline method of industrial robots programming [8]. This method is most commonly used through the software developed by the individual producers of the industrial robotics or universal robotics software. The method represents the current standards in the design and creation of simulations of various robotic systems. Our method consists in a new approach and expand these possibilities and methods from the classic creation of OLP simulation to the creation of robotic simulation in the environment of virtual reality. For these purposes, we chose software that allows offline programming of industrial robots and has the ability to connect, respectively. integration of robotic simulation imaging in VR. We have experience with the use of ABB RobotStudio software, which enables these functionalities. The simulation software RobotStudio and VR headset glasses from HTC Vive were used for the research figure 4 [9].

3.1. Design of layout solution in VR
Standardly used methods of designing production as well as robotic systems are dispositional layout in appropriately selected CAD software or simulation software [10]. This method of design is currently used in the pre-production phases. The use of virtual reality as an auxiliary tool in the pre-production design phase appears to be a very effective method, as it allows not only the most realistic display of
layout designs but also fast changes in layout design with immediate interaction of coordinate system change in OLP simulation study implemented in RobotStudio software between OLP and VR module [11].

![Figure 4](image1.png)

**Figure 4.** Virtual reality simulation environment in RobotStudio software displayed by HTC Vive VR headset.

![Figure 5](image2.png)

**Figure 5.** Design and layout of a future robotic system in VR environment.

In this case, VR imaging can be characterized as a standard online design method robot programming but fully implemented in a digital environment (creation of a digital twin of a future robotic system). It is therefore a matter of connecting online and offline methods using VR environment, figure 5.

3.2. Verification of robot reachability in the case study VR

Another necessary step in verifying the correct layout design in a future robotic case study is to verify the reachability of a selected industrial robot with a technological or manipulation tool. Using by the VR haptic controllers, the end effector together with the industrial robot is guided to the required targets.
and the reachability of the robot in each desired target is verified, figure 6. In our case study, it is a robotic application of spraying a selected 3D CAD model of chassis using the industrial painting robot IRB 5400, paint tool Robobel926, positioner IRB L-ABB and CAD model of the selected part. If the layout of the robot and positioner together with the sprayed part does not suit, it is possible to change and modify this layout very easily using the haptic controllers with use the Grab and Local functions.

Figure 6. Testing of robot reachability in the VR case study.

3.3. Creation of robotic targets and paths in the case study VR
The programming of the targets and the subsequently created Path is created using haptic controllers by selecting the “Teach” function and guiding the tool together with the robot to the desired targets in the RobotStudio VR environment. Using the "Play" function, the future path of the spray robot together with the tool can be verified very fast.

Figure 7. The case study displayed in VR robot programming environment and classical OLP environment and Rapid programming language.
On the figure 7 shows the possible interaction of the created targets and the path in VR conditions and in the standard OLP mode in RobotStudio software and Rapid programming language. The targets and path created in the VR environment can be used and modified as a standard PC simulation using the classic OLP method of programming industrial robots or Rapid programming language [12].

3.4. Modification and debugging of robotic targets and paths in the case study VR
The advantages of creating a robotic simulation in the VR environment, in addition to shortening time of the creation of future robotic simulation, lies in the ability to quickly verify created targets and paths, but also in the ability to modify targets, zone adjust, speed adjust and quick tune by the translation and reorientation of created targets in a coordinate system at VR environment. Such a modification represents the user's interaction in the virtual reality environment, as the modifications executed in this way guide the user through the displayed cube with commands on the haptic controller. This method of using the Zone, Speed, Tune targets modification seems to be intuitive and should be mastered by a less skilled user as in classical OLP simulation the implementation of these modifications is more complicated and more experience and expertise of the OLP method user is expected.

Figure 8. The adjust of Zone, Speed and Fine Tune targets in the VR environment by the displayed cube with commands on the haptic controller.

4. Conclusion
The expected scientific contribution of this research is to point out and verify in the form of the resulting simulation the possibilities of designing and programming industrial robots by a different method than are the standard online and OLP methods for programming industrial robots. VR programming appears to be the future between the connection between Online and OLP programming of industrial robots, as the VR environment allows to simulate, test, eliminate collision state and create an interactive environment similar to the real one, but with immediate interaction with the OLP environment. The simulations created in this way help to shorten the deployment time of future robotic systems with using of various production, assembly and technological operations. The authors of the scientific article verified the possibilities of using virtual reality in the field of dispositional design, planning and prototyping of future production, as well as creating a simulation of a robotic workplace designed to perform a selected technological operation with a spray tool in the VR environment. Figure 9 shows a QR code which, when read via a smartphone or other suitable device recognizing QR codes, displays
the resulting simulation created in the environment of the simulation software VR - RobotStudio from ABB.

![Figure 9. The case study of the novel trend of the industrial robot programming and production system design using the virtual reality.](image)

The authors of the scientific article see the future research in addition to developing their skills and possibilities in creating various DT-VR simulations (digital twin - virtual reality simulations) through the VR, but also through the interaction of several participants in one creating case study [13]. The advantage is to connect several participants to a study using a suitably selected VR device using the Create or Join meet support implemented in the RobotStudio VR environment and to participate interactively from anywhere in the world in creating a joint shared study either in the preproduction phase or creating innovations of existing production systems and robotic workplaces.

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**References**

[1] Milgram P, Takemura H, Utsumi A and Kishino F 1995 *Augmented Reality: A Class of Displays on the Reality-Virtuality Continuum - Telemanipulator and Telepresence Technologies* vol 2351 (SPIE) pp 282–92

[2] Anon Looking to the future of mixed reality - Part I - Unity Technologies Blog

[3] Manou E, Vosniakos G C and Matsas E 2019 Understanding industrial robot programming by aid of a virtual reality environment *Int. J. Mech. Eng. Educ.* 47 135–55

[4] Kizil M S, Joy J, Manou E, Vosniakos G C, Matsas E, Çakıroğlu Ü and Gökoğlu S 2019 A design model for using virtual reality in behavioral skills training *J. Educ. Comput. Res.* 57 1723–44

[5] Choi S, Jung K and Noh S Do 2015 Virtual reality applications in manufacturing industries: Past research, present findings, and future directions *Concurr. Eng. Res. Appl.* 23 40–63

[6] Damiani L, Demartini M, Guizzi G, Revetria R and Tonelli F 2018 Augmented and virtual reality applications in industrial systems: A qualitative review towards the industry 4.0 era *IFAC-PapersOnLine* 51 624–30

[7] Rovaglio M *The Role of Virtual Reality in the Process Industry*

[8] Semjon J, Janos R, Sukop M, Tuleja P, Hajduk M, Juras O, Marcinko P, Virgala I and Vagas M 2020 Verification of the UR5 robot’s properties after a crash caused by a fall of a transferred load from a crane *Int. J. Adv. Robot. Syst.* 17 172988142090420

[9] Ružarovský R, Holubek R, Sobrino D R D and Velišek K 2019 A case study of robotic simulations using virtual commissioning supported by the use of virtual reality *MATEC Web Conf.* 299 02006

[10] Almusawi A J R, Dulger L C and Kapucu S 2019 Simulation in virtual reality: Robotic training and surgical applications *Sci. Iran.* 26 3369–74
[11] Sága M, Bulej V, Čuboňova N, Kuric I, Virgala I and Eberth M 2020 Case study: Performance analysis and development of robotized screwing application with integrated vision sensing system for automotive industry Int. J. Adv. Robot. Syst. 17 172988142092399

[12] Crespo R, García R and Quiroz S 2015 Virtual Reality Application for Simulation and Off-line Programming of the Mitsubishi Movemaster RV-M1 Robot Integrated with the Oculus Rift to Improve Students Training Procedia Computer Science vol 75 (Elsevier) pp 107–12

[13] Dahl M, Albo A, Eriksson J, Pettersson J and Falkman P 2017 Virtual reality commissioning in production systems preparation IEEE Int. Conf. on Emerging Technologies and Factory Automation, ETFA (Institute of Electrical and Electronics Engineers Inc.) pp 1–7