PERSPECTIVES OF VIRTUAL COMMISSIONING USING ABB ROBOTSTUDIO AND SIMATIC ROBOT INTEGRATOR ENVIRONMENTS: A REVIEW

Alexandru ANDREI[1],[*], Adrian Florin NICOLESCU[2], Cristina PUPĂZĂ[2]

[1] Ph.D. Student, Robots and Manufacturing Systems Department, University "Politehnica" of Bucharest, Romania
[2] Prof., Ph.D., Robots and Manufacturing Systems Department, University "Politehnica" of Bucharest, Romania

Abstract: Due to the high demand for fast equipment development which is one of the main criteria of the ongoing industrial revolution, the evolution of virtual commissioning focused on the testing area of the new equipment and machine without damaging them. In the integration of the robot automation process, 40% of the average cost of implementation is addressed to software and programming development. Due to the many types of programming languages and different robot interfaces, one of the most challenging part of virtual commissioning is to decrease the complexity of implementation due to robot manufacturer variance through unifying these two main criteria. The article reviews and compares virtual commissioning methods in terms of hardware and software components used in the control of the master type elements as PLC and the control of the slave type elements as industrial robots. In the first part, the article reviews the main features of the latest version of ABB Robotstudio, which contains technologies such as virtual meetings, virtual reality, augmented reality, and an express virtual commissioning module. Secondly, the article reviews a new software from Siemens company which is dedicated to virtual commissioning applications, where is necessary to use programable logic controllers from Siemens and industrial robots from different manufacturers such as: Staubli, Denso, Yaskawa, and Kuka.

Key words: Virtual Commissioning, ABB Robotstudio, Offline Simulation, Simatic Robot Integrator, Augmented Reality.

1. INTRODUCTION

At present, the degree of complexity of smart factories is constantly evolving and the start-up and commissioning time of automatic equipment and, of course, robotic cells must be shortened. One of the ways in which this goal can be achieved is to use a virtual start-up.

This involves developing tools that should be part of the virtual stage of the implementation, sharing, as a virtual model, many of the basic features of the final accomplishment over the lifetime of the automated equipment such as offline simulation, implementation, execution, and commissioning. This approach requires a wide-ranging digital twinning CAD implementation that can be used from the earliest stages of project development to commissioning [1]. Finding these development tools to meet these requirements can be a real challenge. For this purpose, the present paper will review the new features available in ABB RobotStudio newest release and SIEMENS Simatic Robot Integrator software. Thus, a synthetic review of these software's new features will be highlighted to help engineers in applying virtual methodologies able to support the full lifecycle of a robotic manufacturing system, from the first phases of the design and simulation of the project up to their commissioning and monitoring stages that make

them suitable for the implementation in smart factories 4.0 [2]. Because classical programming requires specialized knowledge, which makes companies react difficultly, the market has come with a wide variety of intuitive and flexible programming approaches for the industrial robotics industry. Companies need to react quickly to the very fast market changes. For this reason, now various methods are available now that can replace conventional programming so that the code of the industrial robot program can be generated very easily [3].

These main methods have been specially developed in the field of robot-human collaboration. Different from the conventional approach in robot-human collaboration, the number of people working in the immediate vicinity of the IR workspace is growing. For this reason, one of the methods for increasing the safety of the human operator has been developed by virtual reality programming and kinesthetic teaching using industrial robots' new "manual guidance" concepts [4].

2. ABB ROBOTSTUDIO REVISION 2021.4

The main way to maximize the profitability of robotic systems and solutions is the offline program. Robotstudio, the software provided by ABB for offline simulation of robotic cells, allows robot programming to be performed in an office, using a computer, without stopping the operation of robotic cells and also able to perform training, optimization, and programming without disrupting production. Revision 2021.4 brings features and options that optimize offline simulation, reduce risks

---

[*] Corresponding author: Bucharest, Splaiul Independentei 313, sector 6, Romania, Romania
Tel.: +40735157978
E-mail addresses: *aandrei2405@stud.fiir.upb.ro* (A. Andrei)

for human operators, thus increasing productivity. The main new included features of RobotStudio Revision 2021.4 are: extension of digital twin (DT) capabilities, virtual reality (VR) / augmented reality (AR) and Virtual Meeting (VM) technologies and collaboration features, Stop Position Simulation (SPS) solutions, and Virtual Commissioning (VC) capabilities.

2.1. Virtual Reality and Augmented Reality in RobotStudio

By using augmented reality technology, it is allowed to view both the robot and the peripheral robotic systems and accessories, overlapping the virtual environment over the real production environment as a hologram [5]. Augmented reality can be summed up as the transfer of virtual aspects to the real world using the computer. There is already growing competition from VR glasses manufacturers [6].

The main feature of an AR system (Fig. 1) is the combination of the virtual world and reality, as a three-dimensional real-time interaction [3]. Considering the above features, an AR system usually consists of a camera system for tracking the environment, a visual device for viewing the virtual content, and communication functionalities between interferes.

In general, a distinction can be made between HDM (head-mounted displays), projection systems, and portable devices, which often have intuitive control interfaces, such as voice control and gesture control, and software that is more powerful. AR systems are mostly used for games and research applications.

a

b

Fig. 1. Augmented Reality concepts in ABB RobotStudio:
a – interactivity using a tablet [9]; *b* – RobotStudio® AR Viewer [10].
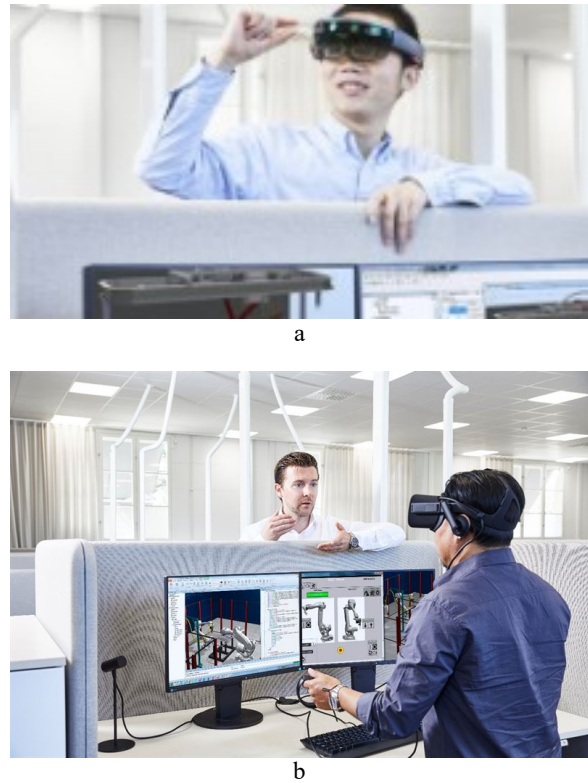

a

b

Fig. 2. Virtual Reality concept in ABB RobotStudio:
a – Google Gass interface [7]; *b* – HMD interface [8].

Main industrial applications comprise installation and maintenance tasks [11, 12].

For example, Boeing has successfully used the Google Glass (Fig 2.). industry to visualize assembly instructions that help its employees with day-to-day tasks such as assembling and commissioning through instructions and virtual information that they view using a projector. A benefit, the operator's actions are detected by the cameras.

In [15] similar methods systems for providing selection and assembly instructions are also based on a projector. The robot represents a second system [15], through which the assembly stages can be easily visualized and through which the information about the succession of events is displayed. The user can view it. An AR bottle is used to display the entire virtual content. Also, the system and its accessibility can be done with the help of a smartwatch.

Thus, the information about the performed assembly is received by the operator in coordination with the robot or by the assembly stages of the operator himself. The operator can view the entire contents of the AR with the help of a display, and the detection of the elements is done by means of a marker tracking sequence. In addition, there are systems on the market that, in addition to displaying instructions and information, can help the user when programming robots. In this case, AR focuses on the use of the route and the simulation of the robot program designed to avoid and detect possible collisions.

Knowing this it is possible to calculate a way to simulate a virtual robot model and transfer it to a real robot. The virtual content is displayed on a laptop or

computer. It is a similar system, in which the visualization of the final effector is performed next to the saved intermediate points of the IR. Content and virtual information are displayed on a normal computer monitor [16] using gestures that Microsoft Kinect detects. Once the system is in place, the virtual objects can overlap with the real objects. In addition to simulations and normal route planning, the usual tasks such as selection and placement can also be programmed using virtual parts manipulation and transposing this action into an industrial robot program. The AR content is adjusted and a tablet is used for control. The most suitable action for programming the trajectories in the field of welding and laser cutting is the use of the pen. A proven time-saving approach is the normal teaching method. If the usual methods of programming industrial robots are considered, one can see that they are often characterized by a complicated structure that often consists of an AR display system and a vision camera.

In addition, laptops, personal computers are most often used for AR display, but these devices are not practical in applications because they do not allow hands-free operations. Instead, Microsoft HoloLens makes the connection between the AR and a camera inside an HDM, which makes the system very easy to set up. Holograms can be visualized in 3D and a permanent process of scanning the environment causes the user to place holograms in the environment and in addition voice and gesture control makes the control functionality very intuitive [18].

2.2 Virtual Meetings in RobotStudio

A VM (Fig. 3) is an option that facilitates the sharing of robotic solutions in web meetings based on DT and VR / AR technologies and collaboration features.
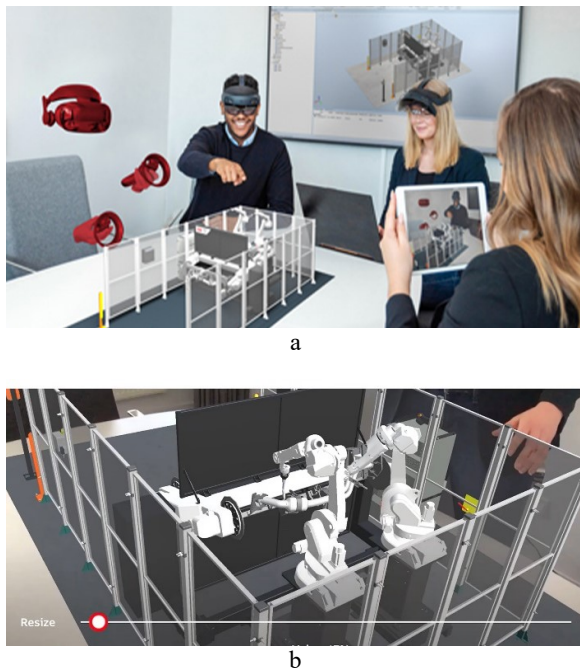

a

b

Fig. 3. Augmented Reality and Virtual Meeting concepts in ABB RobotStudio [17]: *a* – specific interfaces used in VR-VM; *b* – interactive view on a tablet using RobotStudio® AR Viewer.

This option helps a detailed analysis of the presented solutions and a detailed view of the particularities of robotic solutions and an understanding of the technical solution adopted without having to travel. The DT is a way to monitor and optimize an automation solution without disrupting factory production. It makes real-time synchronization during production feasible and at the same time makes it possible for the operator to make changes in the virtual world without altering the production process. SPS is an option that allows the ideal IR braking distance to be explicitly viewed. It allows the simulation of the robot's optimal stopping position with millisecond accuracy in order to easily use the SafeMove option for human operator's effective protection and, at the same time, it reduces the footprint of robotic cells for efficient designing the industrial systems layouts [5, 6].

2.3. Virtual Commissioning in RobotStudio

Both process optimization and virtual commissioning can be considered great responsibilities in a company. (Fig 4). Many companies with specific integration of robots are exposed to situations that little information is received for the realization of the virtual commissioning and a solution to the problem must still be found [21]. Virtual solutions can be used as tools for the design of industrial processes. At the same time, they can be used successfully in research and training in the robotic environment, especially when access to real industrial equipment and robots is limited [22, 23]. For the realization of a VC system (Fig 5.), a very important prerequisite is the design of mechanical components. Consequently, the structure of the automation system and equipment specifications must be carefully analyzed [24]. For the creation of the virtual model, the definition of the mechanical components is indispensable.
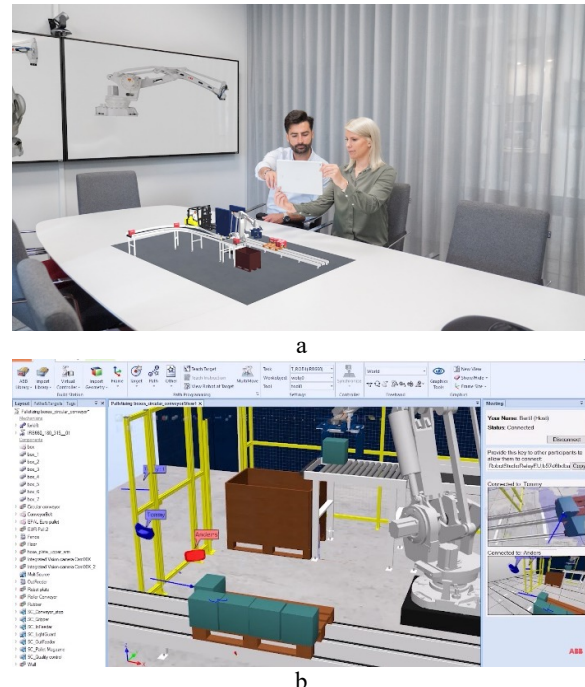

a

b

Fig. 4 Augmented Reality and Virtual Meeting concepts in ABB RobotStudio: *a* – VM using interactive AR and a tablet [19]; *b* – immersive-cooperative activities in VM using AR [20].

a

b

Fig. 5. Virtual commissioning work environment:
a –Simulation interface [25]; *b* – Virtual commissioning comparison between ABB Robotstudio interface and reality [26].

VC can also investigate whether there is sufficient clearance around obstacles. For a better evaluation and understanding of the behavior of a certain system, through an analysis of the results of the simulations in different conditions until the last stage in which the implementation takes place, the simulation can be used as a virtual experiment. For the realization of a virtual commissioning scenario, one of the most important things is this simulation component. [28]. Virtual commissioning is often considered a Hardware-in-the-Loop configuration. This component is most often used until the actual commissioning of equipment or installations in the industry, for verification purposes. In addition to this, there are other related concepts such as hybrid commissioning, where the real control is connected at the same time to the real industrial installation and to the digital simulation twin. The main advantage of a virtual implementation function is the shortening of the time for the actual commissioning. In

addition, a model is created as close as possible (Digital twin), which will be used on all uses of the system in reality [29]. Especially in Industry 4.0, for which the cost of introducing new products and reducing the implementation time is very important, more and more companies in this market segment have shown a special interest in this technology. One of the many challenges posed by this technology is the software integration of the digital twin simulation models into a simulation that contains the entire PLM system. Functional Mockup Interface [30] is a technology that makes this integration possible by creating a standard for exchanging models for functional simulation. This is introduced as a functional (FMU) model unit. These FMUs represent a uniform interface through which model integration and pure co-simulation with a common reservoir of equations is allowed. Once an event detection function is implemented, variable value jumps can also be detected. In order to increase the accuracy for simulation, these areas can be simulated with a higher temporal resolution. This standard can accept behavioral models for both-time control, closed and open loop, for example, Stateflow and Simulink can be integrated, as well as simulation models containing multiple bodies. In conclusion, it can be used for the integration of digital twins [30]. In order to guarantee the protection of the contained intellectual property, the encapsulation of the simulation models in UMF is used. However, if enough effort is made, the protection in question can be avoided. If digital twins are used that are based on sensitive algorithms, their protection must be guaranteed. In conclusion, these protection algorithms are not transmitted as part of a DT, but during the execution, it is necessary to integrate the simulation models, and the algorithms are then run on servers [30]. After the technical integration of the DT. For these models at the time of integration of DT, it is necessary to match the changed data. The IMF can often fail in practice when performing the necessary data exchange between models, even if the IMF can perform independently of tools, among other things, a simulation of the installation. Therefore, DTs need to ensure that the provision of relevant data is understood by other DTs in the same way. In this way, the meaning that a data value will take will be clearly different. This requires a semantic understanding of the meaning of the data [30].

In Fig 6, the software Virtual Universe Pro presented is the simulation software for automation items. It is used to simulate, view, and interact with another system. From an object library customizable by the user or importing a full model from the main CAD software (Solid Edge, Catia, SolidWorks, Inventor) or also based on the main 3D files formats – 3D, 3DXML, OBJ, etc. – a simulation can be created.

The entire simulation is capable to run in real-time, controlled by a PLC by a built-in virtual controller, connected to the PC or software that uses an IP connection [33].

TwinCAT 3 CAD Simulation Interface is a computer software user-friendly tool that can use a link between a 3D CAD system and TwinCAT (Fig.7). The result of this connection is a SiL (software-in-the-loop) simulation from the desired sequence on a system or machine to help get it up and running.
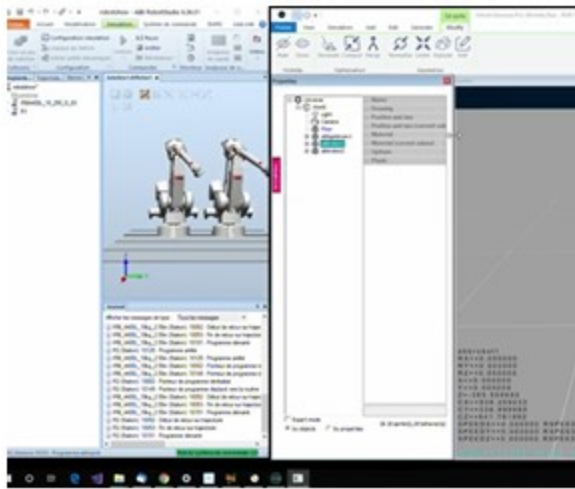
Fig. 6. Virtual commissioning using gateway between ABB RobotStudio and Virtual Universe Pro 4 [31].
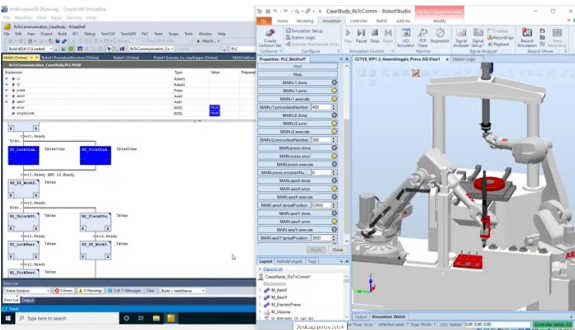

Fig. 7. Virtual commissioning of a robotic cell via software integration between TwinCAT 3 CAD Simulation Interface and ABB RobotStudio [32].

A key element in the implementation of virtual commissioning is the simulation of the 3D components of the machine and the system. Therefore, the software uses the data of the CAD tool and makes a connection with the necessary automation data. Extensive parameterization is required to achieve complex relationships, as is the case. Therefore, in the case of system expansion, in-loop software simulation is possible, which can be easily performed [34].

3. SIMATIC ROBOT INTEGRATOR

Due to the wide variety of robots (Fig. 8) and implicitly the different methods of programming and use of the interface, virtual commissioning requires a high level of complexity for implementation. Siemens has presented a software solution that makes it possible to operate several robots from the point of view of programming and the interface. The main features and characteristics brought to the fore by this software are the creation of trajectories and their validation, teach in

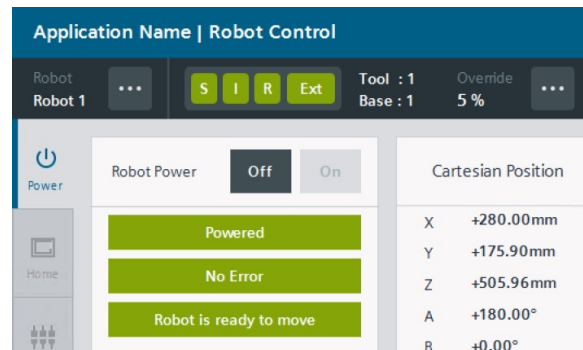**Fig. 8.** Simatic Robot Integrator - one application for robots from different manufacturers [35].

Fig. 9. Graphic interface of Simatic Robot Integrator [35].

points, the jogging mode of industrial robots more accessible.

In order to exclude the various programming languages and the different modes of data management and control, the software brings these above main issues into a single interface through which the user can select different libraries of industrial robots for which the programming is performed. KUKA, Motoman, Staubli, Comau, and Denso libraries can be used in the software interface. The main options and menus of the graphical interface are Move, Position List, Power, Move path, Teach Path, Robot messages (mainly alarms and warnings), configuration. Universal communication between the industrial robot and the PLC is allowed by unifying the interface (Fig.9). between the Simatic S7-1500 and the robot controller.

In order to move any robot using the jog mode, first, the user has to have to go to the interface and select the Jog Screen, then select which axes would be moved and after that, it is easy to move using the "+" and "−" keys. After the robot reaches the desired position it is necessary to press the "teach position" key.

For setting the global home position there, the user can move the robot any time using the control panel (Fig. 10). First, it is necessary to move the robot to a position in jog mode and make that the home position. After that, for setting the globally valid home position it is necessary to select the screen named "Home position" from the panel. From here, the user can see the robot current position and ride alongside the position currently found as the home position. By clicking on "save" it will be overwritten the existing home position with this
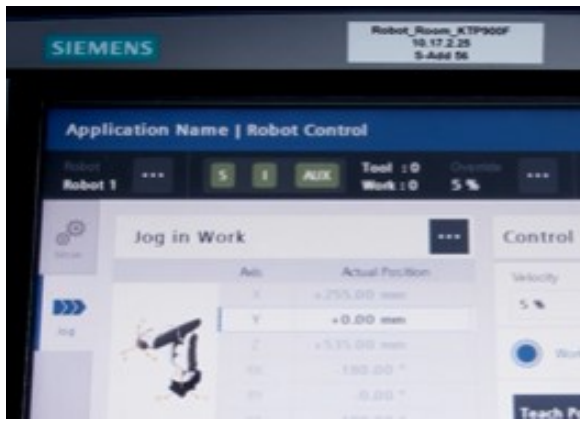
Fig. 10. Real interface of Simatic Robot Integrator Panel [36].

current position. The current position is set now as the "home position" and now is possible to go there any time.

For creating a hole path using existing target positions. For the begging the user can select the "teach path" function from the panel, now the user can see an empty path that has to assign a name. After the user creates all the points needed, it is necessary to add a motion type to each point. After repeating the process for all the points the user can select the "Move path" function, select the newly created path, and press "play".

In order to control the several robots from different manufacturers simultaneously, first select for example the Kuka robot from the interface, then select the "move path" function, and finally, you can press "play". After that, the user can repeat the process for Denso, Yaskawa, etc., and press "play" again for each of them. For stopping all the robots at the same time, the user has to press the "Emergency Button".

4. CONCLUSIONS

Benefit from a single engineering environment, such as Simatic Robot Integrator, critically reduce the time and money spent on engineering, especially by increasing task efficiency, thanks to a uniform operating concept for PLCs and robots, multi-vendor robot programming and uniform HMI front plates for robots from different manufacturers. Reducing programming errors becomes simpler by operating with this software thanks to manufacturer-independent robot programming. The software also allows using of all the TIA diagnostic options for all robots from different manufacturers and includes them in plant condition monitoring. Thus it is possible to operate the robot functions when is needed, without external assistance, and to simplify the implementation of standardization, servicing, and maintenance strategies as well as benefit from TIA diagnostic capabilities for the robotic manufacturing cells.

REFERENCES

[1] A. Martins, H. Costelha, C. Neves, *Supporting the Design Commissioning and Supervision of Smart Factory Components through their Digital Twin*, 2020 IEEE International Conference on Autonomous Robot Systems

and Competitions (ICARSC), pp. 114-119, IEEE, April 15–16, Ponta Delgada, Portugal, 2020.

[2] S. Konstantinov, M. Ahmad, K. Ananthanarayan, and R. Harrison, *The Cyber-physical E-machine Manufacturing System: Virtual Engineering for Complete Lifecycle Support*, Procedia CIRP, vol. 63, 2017, pp. 119-124.

[3] S. Blankemeyer, R. Wiemann, L. Posniak, C. Pregizer, A. Raatz, *Intuitive Robot Programming Using Augmented Reality*, 7th CIRP Conference on Assembly Technologies ans Systems, Procedia CIRP, Vol. 76, 2018, pp. 155-160.

[4] *Univeral robots, collaborative robots benefits*, 2017, available at: `https://www.universal-robots.com/products/ur-robot-benefits/`, accessed: 2022-03-02.

[5] *The world's most used offline programming tool for robotics* available at: `https://new.abb.com/products/robotics/robotstudio`. accessed: 2022-03-02.

[6] F. Zhang, C.Y. Lai, M, Simic, and S. Ding, *Augmented reality in robot programming*, Procedia Computer Science, Vol. 176, 2020, pp.1221-1230.

[7] *An introduction to RobotStudio features – Digital Twin*, available at: `https://new.abb.com/products/robotics/robotstudio?fbclid=IwAR1jPgJjQ57OZyL18M3UCDKGHDb_rOcWrVKegKBBlqgj__ciaM_P3hg74sg`, accessed: 2022-02-03.

[8] *An introduction to Robotstudio Features – Virtual commissioning*, available at: `https://news.cision.com/abb/i/abb-robotstudio-s-new-virtual-meeting-capabilities-allow-collaboration-around-the-world,c2437160`, accessed: 2022-01-30.

[9] *RobotStudio AR Viewer smartphone app designed to simplify ABB robot installation*, available at: `https://www.therobotreport.com/robotstudio-ar-viewer-app-designed-simplify-abb-robot-installation/`, accessed: 2022-03-16.

[10] *RobotStudio® AR Viewer*, available at: `https://play.google.com/store/apps/details?id=com.abb.hayes&hl=it&gl=US`, accessed:2022-01-24.

[11] Fraunhofer-Anwendungszentrum Industrial Automation, .smartfactorydesignspace.2017.available at: `http://www.smartfactory-owl.de/designspace/designspace.html`, accessed: 2022-03-14.

[12] V. Elia, M.G.Gnoni, A. Lanzilotto, *Evaluating the application of augmented reality devices in manufacturing from a process point of view: An AHP based model*, Expert Systems with Applications, Vol. 63, 2016, pp. 187-197.

[13] A. Sacco, A. Google glass takes flight at Boeing, available at:`http://www.cio.com/article/3095132/wearable-technology/ google-glass-takes-flight-at-boeing.htm`, accessed: 2022-03-05.

[14] M. Funk, *Augmented Reality at the workplace*: *A context-aware assistive system using in-situ projection*, Dissertation, 2016.

[15] S. Makris, P. Karagiannis, S. Koukas, A.S. Matthaiakis, *Augmented reality system for operator support in human-robot collaborative assembly,* CIRP Annals – Manufacturing Technology, Vol. 65, No. 1, 2016, pp. 61–64.

[16] O. Danielsson, A. Syberfeldt, R. Brewster, L. Wang, *Assessing Instructions in Augmented Reality for Human-robot Collaborative Assembly by Using Demonstrators*, Procedia CIRP, Vol 63, 2017, pp: 89-94.

[17] *An introduction to Robotstudio Features – Virtual meetings* available at : `https://new.abb.com/products/robotics/cs/robotstudio`, accessed:2022-02-21.

[18] J. Lambrecht, L. Kastner, J, Guhl, J. Kruger, *Towards commissioning, resilience and added value of Augmented Reality in robotics: Overcoming technical obstacles to industrial applicability*, Robotic and Computer-Integrated Manufacturing, Vol. 71, 2021, 102178.

[19] *ABB offers Augmented Reality on a smartphone to simplify robot installations*, available at:
`https://new.abb.com/news/detail/66541/ar`
`-smartphone-robot-installations`, accessed: 2022-01-05.

[20] *ABB RobotStudio® Virtual Meetings*, available at:
`https://www.youtube.com/embed/yNpcRSxUsqI?ht`
`ml5=1&rel=0&wmode=transparent&autoplay=1`,
accessed: 2022-02-25.

[21] R. *Virtual Commissioning of Wheel Robot Processing*, International Symposium on Advanced Topics in Electrical Engineering (ATEE), pp. 1–4, IEEE, March 25–27, 2021.

[22] B. Jakubiec, *Virtual environment as a tool for analysing the operation of an industrial robot*, Przegląd Elektrotechniczny, Vol. 1, No. 2, 2020, pp. 100–103.

[23] R. Holubek, R. Ružarovský, and D.R. Delgado Sobrino, *Using Virtual Reality as a Support Tool for the Offline Robot Programming*, Research Papers Faculty of Materials Science and Technology Slovak University of Technology, vol. 26, no. 42, 2018, pp. 85–91.

[24] P. Rueckert, S. Muenkewarf, K. Tracht, *Human-in-the-loop simulation for virtual commissioning of human-robot-collaboration*, Procedia CIRP, Vol. 88, 2020, pp. 229–233.

[25] *Configure, design & commission* available at:
`https://twitter.com/ABBRobotics/status/14896`
`07143959396362`, accessed: 2022-02-28.

[26] *ABB RobotStudio® Virtual Commissioning available* at:
`https://www.youtube.com/embed/9MFZCAFerzc?ht`
`ml5=1&rel=0&wmode=transparent&autoplay=1`
accessed: 2022-01-16.

[27] J.O. Oyekan, W. Hutabarat A. Tiwari, R. Grech, M.H. Aung, M.P. Mariani, L. López-Dávalos, T. Ricaud, S. Singh, C. Dupuis, *The effectiveness of virtual environments in developing collaborative strategies between industrial robots and human*, Robotics and Computer-Integrated Manufacturing, Vol. 55, 2019, pp. 41–54.

[28] F. Tao, Q. Qi, L. Wang, A.Y. Nee, *Digital Twins and Cyber–Physical Systems toward Smart Manufacturing and Industry 4.0: Correlation and Comparison*, Engineering, Vol. 5, No. 4, 2019, pp. 653–661.

[29] A. Khan, M. Dahl, P. Falkman, and M. Fabian, *"Digital Twin for Legacy Systems: Simulation Model Testing and Validation,"* in IEEE International Conference on Automation Science and Engineering, vol. 2018- August, pp. 421–426, IEEE Computer Society, 12 2018.

[30] M. Grethler, J. Ovtcharova, M.B. Marinov, *Proc Service Prototyping Based on Digital Twins for Virtual Commissioning Scenarios*, 2020 XI National Conference with International Participation (Electronica 2020), pp: 1-4, IEEE, July 23–24, 2020.

[31] *Virtual commissioning: Abb RobotStudio: Virtual Universe Pro 4: Using the gateway available* at:
`https://www.youtube.com/watch?v=s8Ju4ivZKio`,
accessed: 2022-01-25.

[32] *Virtual commissioning of a robotic cell via software integration between TwinCAT and ABB RobotStudio available* at:
`https://www.youtube.com/watch?v=QG22pVg31XI`,
accessed: 2022-01-25.

[33] *VIRTUAL UNIVERSE PRO simulation software available* at:
`https://www.saelig.com/miva/merchant.mvc?Scr`
`een=PROD&Product_code=M00046001`, accessed: 2022-02-19.

[34] *TE1130 | TwinCAT 3 CAD Simulation Interface* available at: `https://www.beckhoff.com/en-`
`en/products/automation/twincat/te1xxx-`
`twincat-3-engineering/te1130.html`, accessed: 2022-01-29.

[35] *Industry Information Live Webinar* available at:
`https://assets.new.siemens.com/siemens/asset`
`s/api/uuid:67b251fc-6654-4cc7-ba06-`
`edc7c2777211/version:1588145588/simatic-`
`robot-integrator-presentation.pdf`, accessed: 2022-03-14.

[36] *Tips and Tricks with SIMATIC Robot Integrator - Part 1 - Move in jog mode and teach position – YouTube*,
`https://www.youtube.com/watch?v=Zrg-s0xnaBo`,
accessed: 2022-03-05.