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Virtual commissioning and digital twin of yaskawa motoman robotic cells based on the industry 4.0 context

Abstract

The objective of this research is to develop a methodology that makes use of the Digital Twin calibration and virtual commissioning to digitally validate robotic mechatronic cells, and minimize the time of installation and implementation of the project on the "factory floor" in the context of I4.0. Currently a major problem related to Virtual Commissioning activities is the lack of precision between the virtual model and the physical model, due to the difficulties related to the construction on the factory floor of the previously generated 3D model. The proposed methodology of calibration, calibration and validation of the digital twin can be applied to different production segments, and this is a competitive differential in relation to automation solutions strictly developed for the automotive industry, also allowing professional qualification at a distance with virtual reality that the project will make it possible as an unfolding.

Keywords: digital twin, process simulate, robotics calibration, industry 4.0, roboticist, virtual commissioning

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Introduction

There is a growing increase in global demand for high quality products and short life cycles, so companies try to adapt to this new reality. This demand puts pressure on the world and industries to undergo a new technological revolution. Industry 4.0 (I4.0), which has been known as the "Fourth Industrial Revolution" Lasi H et al.,[1] is also emerging in order to meet this new global demand. One of the concepts that will be widely used in I4.0 is that of Digital Twin, which, from a production perspective, incorporates the virtual context into the real context of a productive system. Digital Gemini are very realistic virtual models of the current state of the process and their own behavior in interaction with the environment in the real world Rosen R et al.,[2] including equipment, and all the steps to carry out a certain production process. Second Sub S et al.,[3] the increasing use of Virtual Commissioning during the development process of automated factories, paired with the growing demand for better quality control leads to the need for improved virtual plants that systematize the necessary configuration procedures for the realization of their processes. Common plant simulation techniques based on the concept of virtual commissioning of robotic cells go beyond the need to validate control algorithms, that is, new approaches need to be developed to meet the demand for reconfiguring your operational resources in a systematic way, compatible with the flexibility that these autonomous resources currently have.

The need for new solutions in Robotic Engineering for the design of complex projects involving physical systems and the virtual part associated with them, has never been more present. Virtual commissioning technology can be considered as one of the established trends in automotive assembly Makris S et al.,[4]; Eros E et al.[5] Among other benefits, it promotes a more efficient treatment of the complexity associated with assembly systems, capable of causing a reduction in the acceleration time of the system itself and a reduction in the development time of the product capable of meeting the market's competitiveness.

Virtual commissioning tests that are capable of evaluating the safety of a robotic cell involving a layout change, possibility of robot collision, validation of the programmable controllers' programming, in addition to peripherals that simulate trajectories of industrial and collaborative robotic manipulators, are fundamental to decrease costs and maintaining the competitiveness of most companies. As we are in a transition of industrial revolution, that is, between the third and going to the fourth industrial revolution, most companies and professionals working in the area of Robotics still do not know how to proceed in an I4.0 context. In this way, the development of methodologies that follow the concepts of I4.0 becomes relevant. The objective of this research is to develop a methodology that makes use of the Digital Twin calibration and virtual commissioning to digitally validate robotic mechatronic cells in the context of I4.0. Industrial robotics and the complexities of 4.0 processes are rapidly reshaping the manufacturing industry. Succeeding in this new scenario means adopting this complexity and using it as a market advantage over competitors who implement legacy and less sophisticated processes. The factories of tomorrow will be more integrated, robotized and will allow greater flexibility in products and services Goeriche D et al.[6]

Second Colombo AW et al.,[7] the production systems of the future must be significantly flexible and respond dynamically to continuous changes in orders, ensuring high productivity. This adaptation process must be fully automated to maintain considerable levels of efficiency. Therefore, it is necessary to include not only the specifications of each order, but the status of all production components and even external information, such as transportation systems, in the decision-making process. These resources can be achieved with the integration of advanced information and communication technologies in the production process. This integration of technologies in physical processes is leading to cyber-physical systems (CPS). By providing updates and services to CPS, customer loyalty can be increased. The machine manufacturer can decide whether to provide these services himself or whether to publish the relevant specifications to allow independent developers to offer services. The quantity and quality of these services can have a major impact on customers' purchasing decisions. Another important factor in the customer's decision process for the acquisition of robotic cells is the demonstration of the viability of the solution through simulation. In this context, the digital twin (digital twin) standardized and well elaborated, favors the results of the simulation because it reproduces in a more reliable way all the real characteristics of the predicted applications of the mechatronic cell.

Second Bedenbender H et al.,[8] reports that the Companies aim to implement sustainable manufacturing of robotic cells, in order to improve profitability, reducing resource consumption, global expenses, as well as satisfying the regulatory input of ecological impacts. In addition, the widespread adoption of industrial robots, necessary to satisfy the ever-increasing requirements in terms of manufacturing quality, customization and flexibility, further increased the need to improve the energy efficiency of robotic cells.

Analysis of experimented data

We intend to research, investigate and integrate a solution with *Siemens Digital Industries Software* commercial called "*Tecnomatix Process Simulate version 15.1.2*" so that it is possible to test: the quality of the researched solutions and algorithms; computational complexity and adequate dimensioning of the necessary automation resources. We also aim to create a test of concept containing all parts of the simulation system. This initial stage will allow us to estimate precisely the needs for robotics, automation, IT resources, and the quality of the algorithms and the general viability of the proposal. The objectives of this project in terms of scientific and technical challenges to be overcome will be to propose a methodology, study and procedure to which it is feasible to find the "absolute zero" to carry out and validate the calibration of the virtual commissioning with a 95% accuracy margin and 100% depending on the complexities of the applications. It will also demonstrate that the calibration of the Digital Twin and the virtual commissioning of industrial robots are reliable, viable and useful for the main applications of the advanced industry. The value proposition is to show that the investment by companies in projects that make use of the methodology to be developed from the initial design phase, can significantly reduce their costs with tryout time, start-ups, engineering, prototypes, implementation on the shop floor and costs with third parties for programming rework.

This methodology should be able to demonstrate that Digital Twin calibration and commissioning are feasible for industrial robots regardless of their application in the industry. The necessary procedures for network protocols, customization and development of standards will be important steps for companies to reach maturity for the digital transformation towards industry 4.0.

The proposed research project will have as one of the main scientific and industrial contributions, the creation of a method for calibrating the digital twin (Digital Twin) of the study. It is a current topic of knowledge frontier, where the industry lacks this solution Figure 1.

Robot manufacturer's use enabled software that performs simulation, generation of trajectories in a graphical environment, determination of cycle time and offline programs. All of them have two aggravating factors, the first is that they do not perform virtual commissioning (logic blocks, control interface integrated with PLC, emulation of communication networks, customization of standards, calibration of robots, security systems, cyber-physical systems, reality virtual, interlocks, collision studies and others) in a satisfactory degree of detail for validation of the digital twin. The second aggravating factor is that their library of robot models is "closed", that is, they can only simulate their own robotic manipulators. The software from the main manufacturers are: *KUKA-KukaSim and OfficeLite; YASKAWA MOTOMAN-MotoSim; ABB-RobotStudio and FANUC-RoboGuide*.

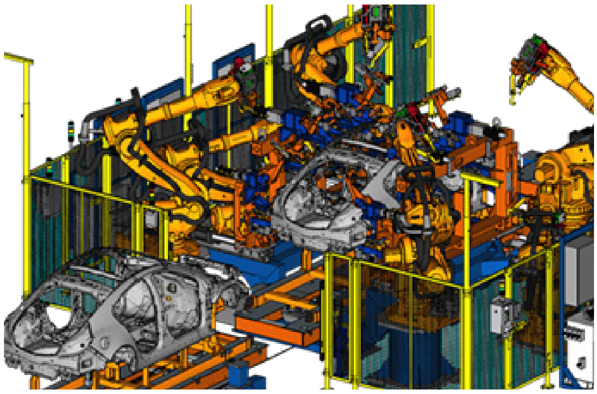

Figure 1 Virtual commissioning and digital twin methodology.

For the manipulation applications present at the *Advanced Robotics Institute* – IAR, in Brazil (São Paulo), both industrial robots that will be employed in the research have their respective initial positions (*HOME POSITION*) changed in relation to the original factory values where all joints have values equal to zero. In addition to the confined and narrow environment for handling the robots, the fixing and screwing of the base of both are not perpendicular and are also not parallel to the XY plane of the work table, which increases the programming difficulty by 30%. Other differentials of this research besides the "Absolute Zero" technique are that all the analyzes of potential elastic energy for the study of 24v cables from the sensors and pneumatic hoses leaving the central handle of the manipulator until the midpoints of the claws will be studied in depth. Such analysis is important because on the shop floor it is relevant to predict trajectories that interpolate excessively and points with singularities that cause the rupture of the connection cables.

The fact that the proposed methodology enables the delivery of robotization projects using virtual commissioning with an assertiveness of approximately 95%, demonstrates that it is feasible. However, we would have a very high technological risk if we went for a direct implementation without first minimizing the scientific risks Figure 2.

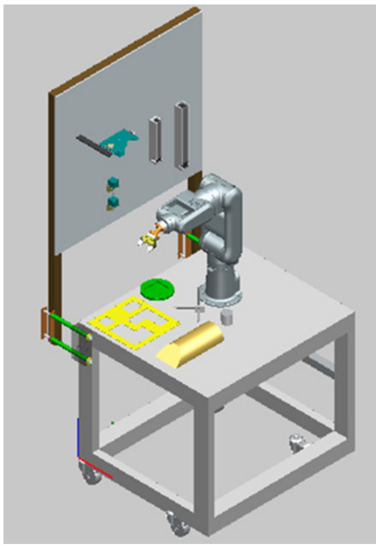

Figure 2 Example of a digital twin robotic cell developed at the advanced robotics institute–IAR.

In the methodology, different procedures will be developed, according to the complexity of applications and processes, for example: welding, painting, glue, palletizing and handling. The study techniques and methods to be used in the research will have as main objective to focus on the calibration of the Digital Twin, virtual commissioning, systems integration and implementation on the factory floor. This project uses a methodology and describes an application of virtual commissioning technology applied to robotic cells.

It is a mistake to imagine that this proposed project does not involve technological research and that it is only obtaining processes using existing *software*, and that the use, mastery and handling of the *software* tools called *Process Simulate by Siemens Digital Industrie Software* takes us clear and intuitive to an understanding of the digital twin calibration. The development of a virtual robot calibration and commissioning methodology using "absolute zero", so that it can be applied directly to real robots on the shop floor and can also be used by different types of industries is quite complex. To confirm this complexity, the IAR team carried out several projects in the Brazilian industry in recent years under the responsibility of the responsible researcher together with the team of specialists from *Siemens Digital Industrie Software*, integrators, systemists, robotic engineering offices, realizing this way, the complexity of the topic and the opportunity for contribution reported by the *software* manufacturers themselves in the calibration of all phases of the study. In Brazil there is still no consulting company that researches and uses absolute zero in its real implementations with robots in the Industry.

One of the main motivations of Industry 4.0 for our project was the creation of automated manufacturing systems, which can produce products tailored to the customer with high levels of efficiency. All stages of the process have been continuously adapted to obtain optimized results with the aid of Process Simulate resources. Another advantage of this concept is that the production system is highly flexible, so adaptations to new technologies and products can be made with little effort. This can be a great competitive advantage, considering the constant decrease in the product's life cycle and time to market for new products Figure 3.

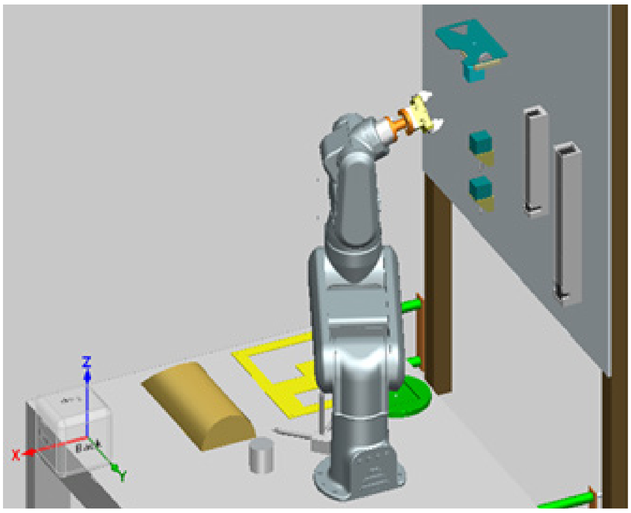

Figure 3 Final example of task simulation with the yaskawa MHJ robot in a robotic cell.

The robot's accessibility is the validation that the manipulator can reach a destination location. That is, the digital twin helped to foresee the problems of singularities in the positions with high indexes of bumps that cause excessive mechanical wear in the robot, reducing the useful life of the equipment. Since the characteristics of an asset (robot) can be described at any layer level, the simulation task can be started as soon as a minimum amount of information is available. Thereafter, the modeling can be extended to include parts of the asset, or the assets can be aggregated. This allows you to design a highly flexible system Tantik E et al.[9]

The digital twin of a robotic cell allows paralleling the mechanical, electrical and automation design as well as systems engineering tryouts. Waiting times for phases of information exchange between equipment can be avoided in this way. Through the simulation of industrial robots, extensive tests allow the detection and correction of errors in the design and functions, making real commissioning very fast. According to the Six Sigmas management system, error costs increase by a factor of ten with each stage of development. With simulation, perceptions of virtual tests can improve engineering quality at an early stage. Testing the PLC code during virtual commissioning increases confidence that the interaction of the electrical, mechanical and the robot controller is working as intended by the analyst and robotist. This helps to avoid high costs and minimizes errors. Problems during actual commissioning take time and increase labor and material costs, especially with international projects. To overcome these difficulties, everything can be tested safely virtually without the need for the operator of the robotic cell. Industrial robots are designed to work constantly, with no downtime. Adolphs P et al.[10]

Conclusion

The standardized acquisition and integration of the digital twin with the simulation of a robotic cell was the challenge of this work. The current approach met the proposed goal for a robot manufacturer. In many cases, robotic cell simulations are more complex and require more analysis time. This result can be extended to different robot manufacturers, automation suppliers and robotized processes, as it requires a comprehensive solution based on a more sophisticated digital twin. It is also possible to use different manufacturers of simulation software where the focus is on process simulation, combined with factory simulation to achieve flexible production for increasingly personalized products. The benefits of the robotic cell simulation brought technical gains for the robotists and financiers for the companies that reduced tryouts and the number of engineers and technicians during the running of the real robotic cell.

The positive impacts of the results will allow the company to provide consultancy and training services in Automation Engineering, with a focus on robotics, and accelerate the migration of companies from various segments to the Industry 4.0 scenario. In turn, the advantages of using new virtual commissioning approaches for the production and maintenance of automated systems involving robotic cells are: much more stable startups, time savings in the offline programming of robots and programmable controllers, risk handling involving security of the cells in relation to the possibility of collision between robots, creation of a consistent communication platform for cooperation between systems design teams of this nature and, finally, obtaining a higher level of maturity for projects involving industrial robots. Different professionals such as systems engineer, electrical and pneumatic system designers, robotic automation engineer and automation analysts will be able to interact in a uniform, continuous and integrated manner with the mechatronic system.

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Conflicts of interest

The author declares that there was no conflict of interest.

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