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Research Article

DIGITAL TWIN AND VIRTUAL COMMISSIONING OF ROBOTIC CELLS BASED ON THE INDUSTRY 4.0 CONTEXT

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Abstract

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. 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.

Keywords: Digital twin, Process simulate, Robotics calibration, Industry 4.0, Roboticist, Virtual commissioning.

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 *et al.*, 2014), 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 *et al.*, 2015), including equipment, and all the steps to carry out a certain production process. Second (Sub *et al.*, 2016) 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 *et al.*, 2012; Eros *et al*., 2019). 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.

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Digital twin and 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.

MATERIALS AND METHODS

We intend to research, investigate and integrate a solution with Siemens Digital Industries commercial software, Software 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, 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).

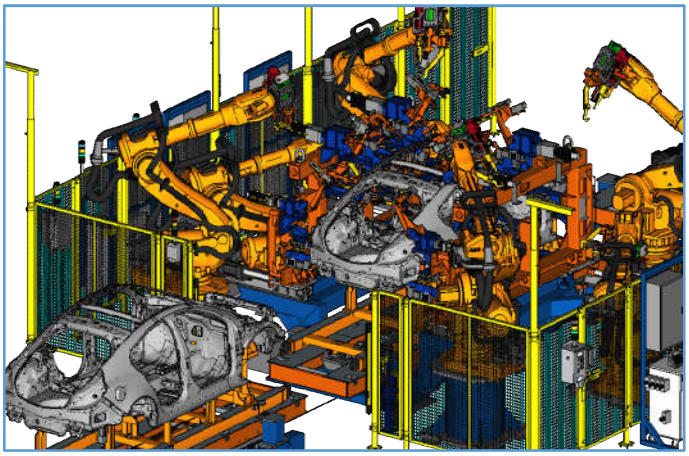

Fig. 1. Virtual Commissioning and Digital Twin Methodology

Robot manufacturers 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.

RESULTS AND DISCUSSION

For the manipulation applications present at the Advanced Robotics Institute - IAR, 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 themanipulator 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.

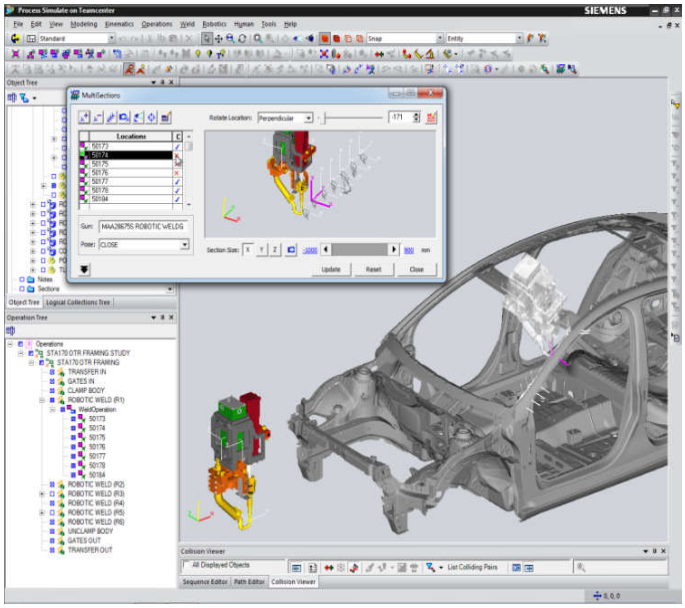

Fig. 2. Calibration of Virtual Commissioning and Advanced Kinematics

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.

CONCLUSION

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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