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Review Article

Proposed Virtual Commissioning of Robotic Cells based on the context of Industry 4.0

Corresponding author: Rogerio Adas Pereira Vitalli *

** Robotics Advanced Institute, I.A.R., Department of Special Projects, São Paulo, Brazil*
** vitalli@iar.eng.br*

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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 Industry 4.0. The project is based on a proposed approach to combine 3D depth data - measured by means of accurate CAD models and by CAE - so that it is possible to calibrate the data obtained from the Digital Twin through virtual commissioning before being transferred of virtual to the system real physical. The methodology will be based on innovative procedures for: (i) calibration of the Digital Twin; (ii) optimization of the factory layout; (iii) elimination of the possibility of collision between robots, grippers and devices, (iv) specification of the necessary interlocks involving the exchange of signals, operation logic and generation of all the specific offline programming of each industrial robot, considering the safety of the equipment of the robotic cell, during the processes. We intend to research, investigate and integrate a solution (figure 1) with commercial software from Siemens Digital Industries Software (formerly SIEMENS PLM) called "Tecnomatix Process Simulate" so that it is possible to test: the quality of the solutions and algorithms surveyed; computational complexity and adequate dimensioning of the necessary automation resources.

Keywords: *Digital Twin, Virtual Commissioning, Tecnomatix Process Simulate, Factory Floor, Robotic Engineering.*

1. 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), called the "Fourth Industrial Revolution" [5], 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 Twin genuine 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 [11], including equipment, and all the steps to carry out a certain production process. According to [13] the increasing use of Virtual Commissioning (VC) 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 Ciber Physical Systems (CPS) and the virtual part associated with them, has never been more present. The virtual commissioning technology can be considered as one of the established trends in automotive assembly [12] and [3]. 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

***Corresponding author**:

Rogerio Adas Pereira Vitalli, Robotics Advanced Institute, I.A.R., Department of Special Projects, São Paulo, Brazil
Email: vitalli@iar.eng.br
DOI:

layout change, possibility of the robot collision, validation of the programming of the PLC (programming logic controller), as well as peripherals that simulate trajectories of industrial and collaborative robotics manipulators, are fundamental to decrease costs and maintaining the competitiveness of most companies. As we are in a transition from an 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 digital twin calibration and virtual commissioning to digitally validate robotics cells in the context of I4.0. The positive impacts of the results will allow the company to provide consultancy and training services in Robotic 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 the safety of cells with respect to the possibility of collision between robots, creating 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 robotic system.

2. STAT OF ART

This is a research of an applied nature, in which the theories addressed in the bibliographic references will be used in order to contribute to the improvement of works and research such as that of [9] that presents a concept for "virtual robot" and program development (VIPD) for assembly processes with industrial robots. The concept aims at the possibility of creating and completely validating robot programs for assembling processes with the help of a simulation environment. VIPD provides a consistent communication platform for the cooperative work of different design teams during the engineering workflow system. Recently, relevant issues regarding energy consumption assessed at the commissioning stage are shown by [10] and [4]. Second [7] the current methodology applies Virtual Commissioning (VC) as the last step in the automation engineering phase, to reduce the commissioning time of the control system. However, VC can provide value throughout the automation of the engineering process, in which a structure called Integrated Virtual Preparation is introduced in Commissioning (IVPC). A formal model of the control logic, combined with the same virtual code of mathematical models of the production system shared between the preparation, implementation of the control system and VC phases allows for early validation of the project. There are not yet enough methods and procedures that follow an appropriate methodology to guarantee adequate results of Digital Twin calibration and virtual commissioning of robotic cells. These problems cause rework in the programming of the robots, often reaching 30% of the total cost of the project. Other problems of order are collisions between tools, mechanical devices, machines and other peripheral automation equipment. For practical reasons and high costs, no modifications and corrections are made to devices after their manufacture. It is also known that there is a tolerance between what is designed and what is manufactured; therefore, the importance of the commissioning calibration will be to adjust all "zeros" of robots, devices, tools, peripherals and others to a "absolute zero" validated with the objective of avoiding variation when the entire offline program of the virtual study is transferred to the real environment. Here are some articles dealing with the themes. [1], proposes a virtual commissioning methodology that requires the integration of different technologies, such as PLC (programmable logic controller), device communication via OPC (OLP for process control), offline robot programming, HIL (hardware-in -the-loop), as well as the design of devices and tools using computer aided design (CAD) applications.

3. PROJECT METHODOLOGY

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 techniques and study 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 shop floor. This project uses a methodology and describes an application of virtual commissioning technology applied to robotic cells. The investigation mechanisms used in scientific technological research will be based on a wide consultation in the literature followed by the researcher's experience. The information will be searched and collected in books, scientific articles, on websites of the German Government and others. The main databases used were Scopus and DSpace @ MIT (database of the theses of the Massachusetts Institute of Technology) (DSPACE @ MIT), Ethos (thesis database of British Universities), Unicamp Digital Library and CAPES Portal. [2], [6], [14], [15], [16] and [17]. This is a research of a practical and applied nature, in which the theories addressed in the bibliographic references will be used in order to contribute to the resolution of the problems of calibration and digital commissioning already mentioned above. This proposal adopts the project methodology presented in [1] which involves three different aspects: theoretical aspects, tools and applications. These aspects are addressed in a cyclical and repetitive manner. To solve the problems detected in the applications, the related theoretical aspects are studied, proposing a review of the approaches, modifications, and improvements. Through the development of new tools, the changes made in the theoretical aspects are applied to the application problems. It is an "Engineering" approach that, in this work, considers the formal aspects associated with the definition of models, the methods of analysis applicable via existing computational tools and the applications in industrial processes as an engine of development and conception of new paradigms. The three aspects identified in [1] are: simultaneously, conditioning each other. Developments in the three identified areas benefit from the synergies resulting from activities in each of the other two areas

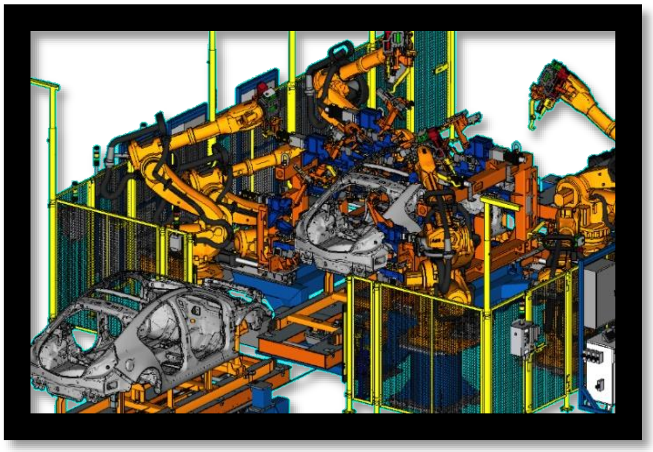

Fig. 1: Digital Twin of the application.

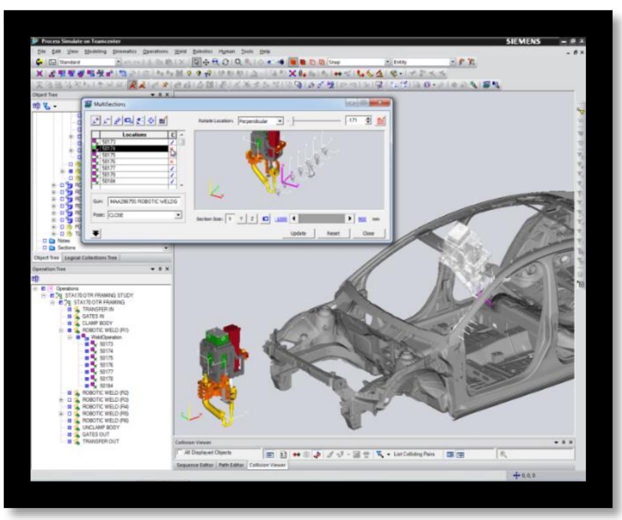

Fig. 2: example of the development of the Kinematics of Robotic Subassemblies

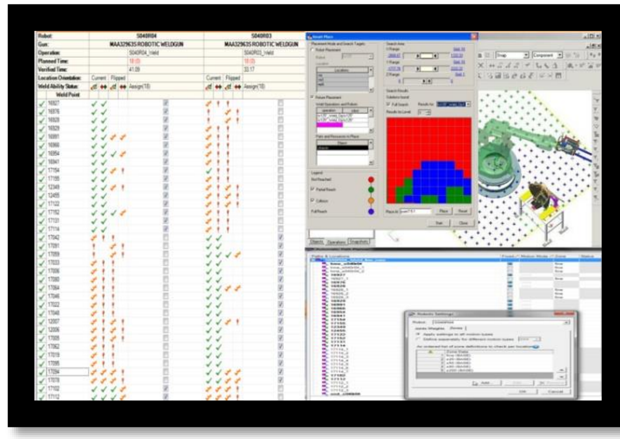

Fig. 3: Collision Analysis and Robot Cell Optimization

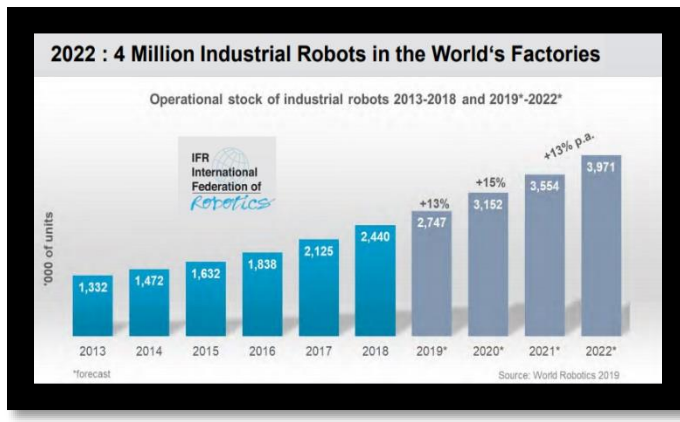

Fig. 4: Operational Stock of Industrial Robots in the World´s Factories

3.1. Step 1

It consists of a bibliographic survey and the collection of information on the various topics related to the work. Topics directly related to work are:

a. Industry 4.0;
b. Training in SIEMENS Process Simulate software;
c. Digital Twin;
d. Calibration and absolute zero;
e. Virtual commissioning;
f. Validation of Virtual Study with Industrial Robots;
g. Customization and Communication Standards;
h. Offline programming.

This list is not static, that is, other themes can be introduced during the project.

3.2. Step 2

It consists of the technical development of the work in divided subgroups: analysis of robots, mechanical devices, analysis of robot claws and PLC. Topics directly related to work are:

a. Application analysis, Technical specification of Robots and Cell Layout (Analysis made from the modeled 3D project file sent by the client);
b. Robots and Mechanical Devices Tools Project (taken from the modeled 3D project);
c. Development of the Kinematics of Robotic Subassemblies (Robot and peripherals, performed in Siemens software);
d. Development of operations and preparation of their sequences (Siemens -Process Simulate software (Tecnomatix) - Operations tab);
e. Layout Interference Tests, Range Tests, Crash Tests and Layout Optimization Suggestion (Siemens Software - API Work Place);
f. Preparation and Definition of the Standard Commissioning tests;
g. Signal mapping between sensors, actuators and PLC;
h. Development of Robot Control Logic (Logical instructions);
i. Development of Interlocks for Robots.

3.3. Step 3

It consists of the development of signal security protocols between robots and PLC; in the elaboration of offline programming, customization patterns according to the client's needs, among others. Topics directly related to work are:

a. Programming Interpolated Trajectories and Robot Movements;
b. Definition of the Sequences of Operations of the Robotic Cell;
c. Commissioning of Security and Operations of the Robotic Cell;
d. Development of Templates for Downloading and Uploading Programs;
e. Development of Customization of the Whole Cell;
f. Generate the Digital Twin of the Study and Objects for Calibration (API - Calibration).

3.4. Step 4

It consists of the definition of "absolute zero" for calibrating the digital twin and virtual commissioning, tests of the virtual study with the real environment and development of validation tests for offline programming. Topics directly related to work are:

a. Definition of regions and positions for Digital Twin Calibration and Virtual Commissioning; Here is the biggest contribution of the project, there is still no methodology that defines the best regions and positions for calibration);
b. Tests with the Virtual "Absolute Zero" of Commissioning with the Cell's Real;
c. Real Tests with Robots;
d. Validation of Results with the Robotized Cell.

4. CONCLUSION

The projected increase in the use of robots reinforces the commercial potential of this project and will enhance the provision of consultancy services in virtual commissioning, which will allow integrating companies and end customers to become more competitive and productive, enabling fairer competition in the global market. The unfolding of the project, results in good practices in the process of validating the commissioning and all its complexity of calibrating the study and simulating the "virtual to the real" and implementation on the factory floor. To be successful in this result, a lot of practical experience in the area and research applied to problems that have not yet been solved and that companies need solutions are needed. Virtual Twin has gained significant momentum as a technological development breakthrough with the potential to transform the reality of companies. Digital twin, acting as a mirror of the real world, provides a means of simulating, predicting and optimizing physical manufacturing systems and processes. Using Digital Twin, together with intelligent algorithms, organizations can achieve data-driven operation monitoring and optimization, develop innovative products and services, and diversify value creation and business models.

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