FACTORIES OF THE FUTURE: BEYOND THE LIMITS OF INDUSTRIAL ROBOTICS

The use of robots to realize high-precision machining opens new scenarios in the field of advanced automation

The European scientific and technical community knows that the economical and industrial growth of the old continent requires the development of manufacturing solutions capable of ensuring consistent product quality and ability to quickly adapt to frequent and sudden changes in the market, through the use of advanced technologies.

The industrial robotics is the ideal technology platform to build the foundations for a significant innovation in production systems. In fact, industrial robots combine high flexibility and adaptability, effective (re)configurability at batch change, easiness and speed of programming, operation robustness and complete integration with advanced technology in the field of mechanics, information technology and mechatronics. Furthermore the costs of development, design, installation and maintenance allow the implementation of innovative solutions with very interesting investment return indices also for small and medium-sized enterprises.

For these reasons, robotic systems are already widely used in many fields, from aerospace to automotive industry, from metallurgical to plastics and composite materials industry, from pharmaceutical to food industry, from ceramic industry to industrial logistics.

Every day thousands of the latest generation robots perform operations with high repeatability and consolidated reliability, such as handling, machine tool tending, palletizing and logistics, and carry out processes of painting and glazing, cutting and welding, deburring and finishing procedures or complex assembly (Figure 1).

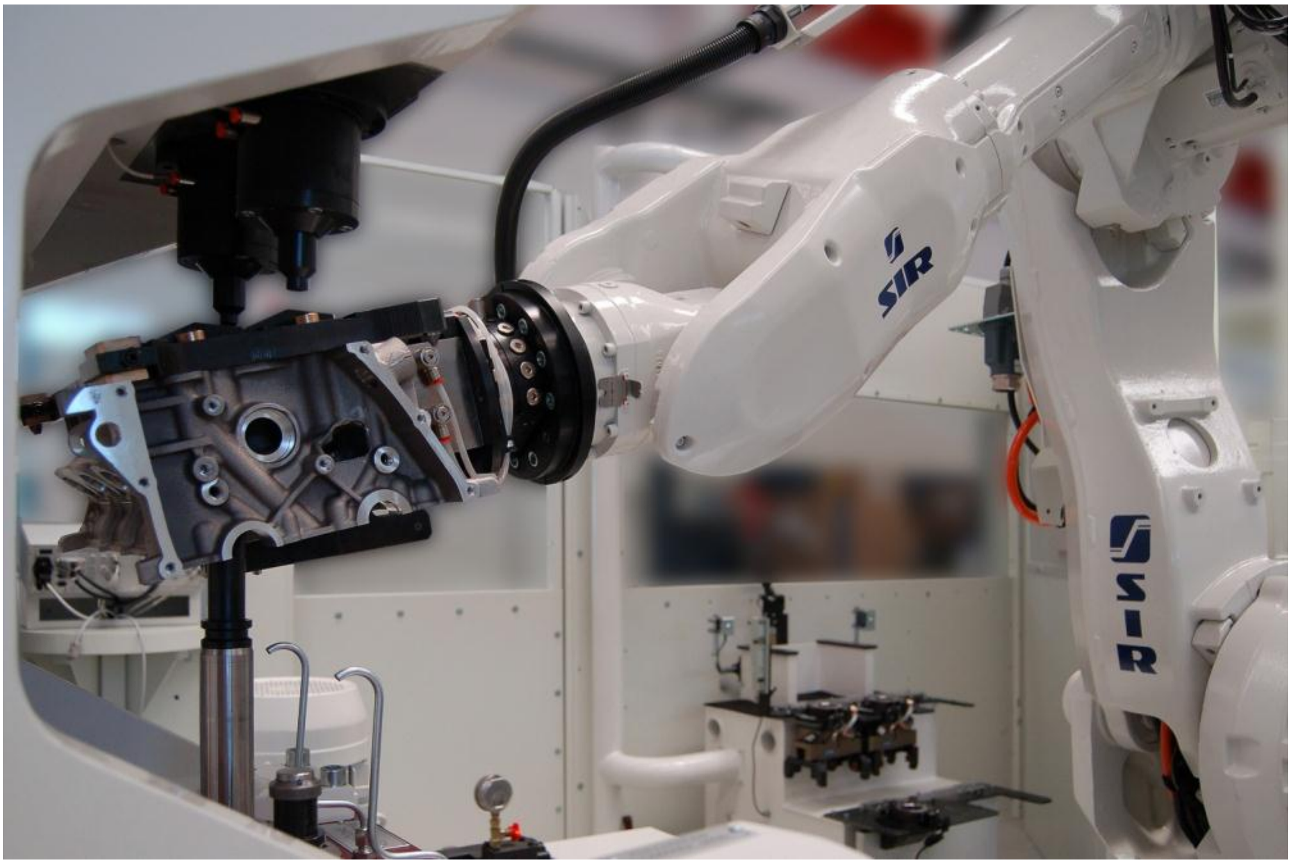

Figure 1 - Detail of the automated assembly process of valve seats and guides for high performance engines (Courtesy: SIR Spa – MO, Italy).

However, robotic systems still lack the accuracy required to significantly extend their scope to perform high-precision machining. In fact, the intrinsic structural characteristics of robots are not yet capable to guarantee the absolute accuracy of joints positioning and the performance of control systems don't offer autonomy and capacity for real-time response to changes in the process forces or, in general, in the environmental conditions.

As a result, only few large companies with highly specialized design experience can really bring to the limit, at an acceptable cost, the potential of existing robots to perform complex machining processes. These excellent results are the fruit of the important investments in advanced technological resources and depend on the application of creative engineering insights and accurate tuning of the development methods.

Advanced simulation environments are used to study in detail and optimize the robotic processes, to validate the solutions in terms of configurations reachability, of operations safety, of process efficiency and to minimize the machine downtime related to the generation of the robot code (Figure 2).

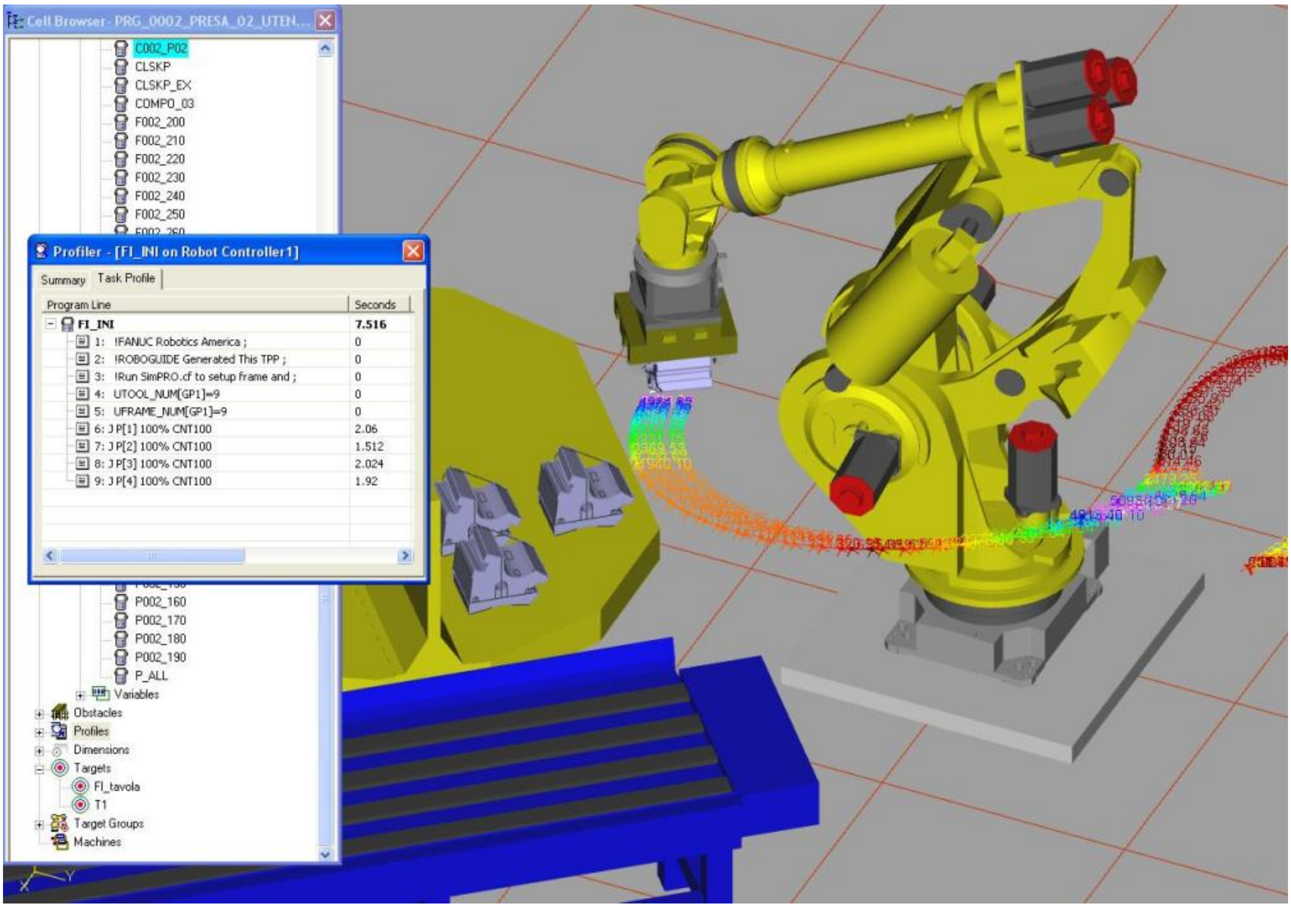

Figure 2 - Simulation of the machining process of austenitic manganese steel castings (Hadfield) and generation of the robot code by FANUC ROBOGUIDE software (Courtesy: SIR Spa – MO, Italy).

Active and passive compliant strategies are used to design devices that can ensure consistent quality of machining through the compensation of errors due to the dimensional and geometric variability of raw parts or to the natural instability of the boundary conditions (Figure 3).

Figure 3 - Radial compliant spindle for the finishing operation of a motorcycle shaft (Courtesy: SIR Spa – MO, Italy).

Finally, sophisticated machine vision systems are implemented to guide robots in the interaction with their surroundings and proceed, for example, the recognition of the position and the automatic pick up of mechanical parts placed in unstructured environments such as industrial bins (Figures 4, 5, 6). Industries can reach such results only through a radical predilection for industrial research and relevant technical challenges, aiming to the integration of complementary technologies, such as monoscopic vision, stereoscopic vision and active triangulation.

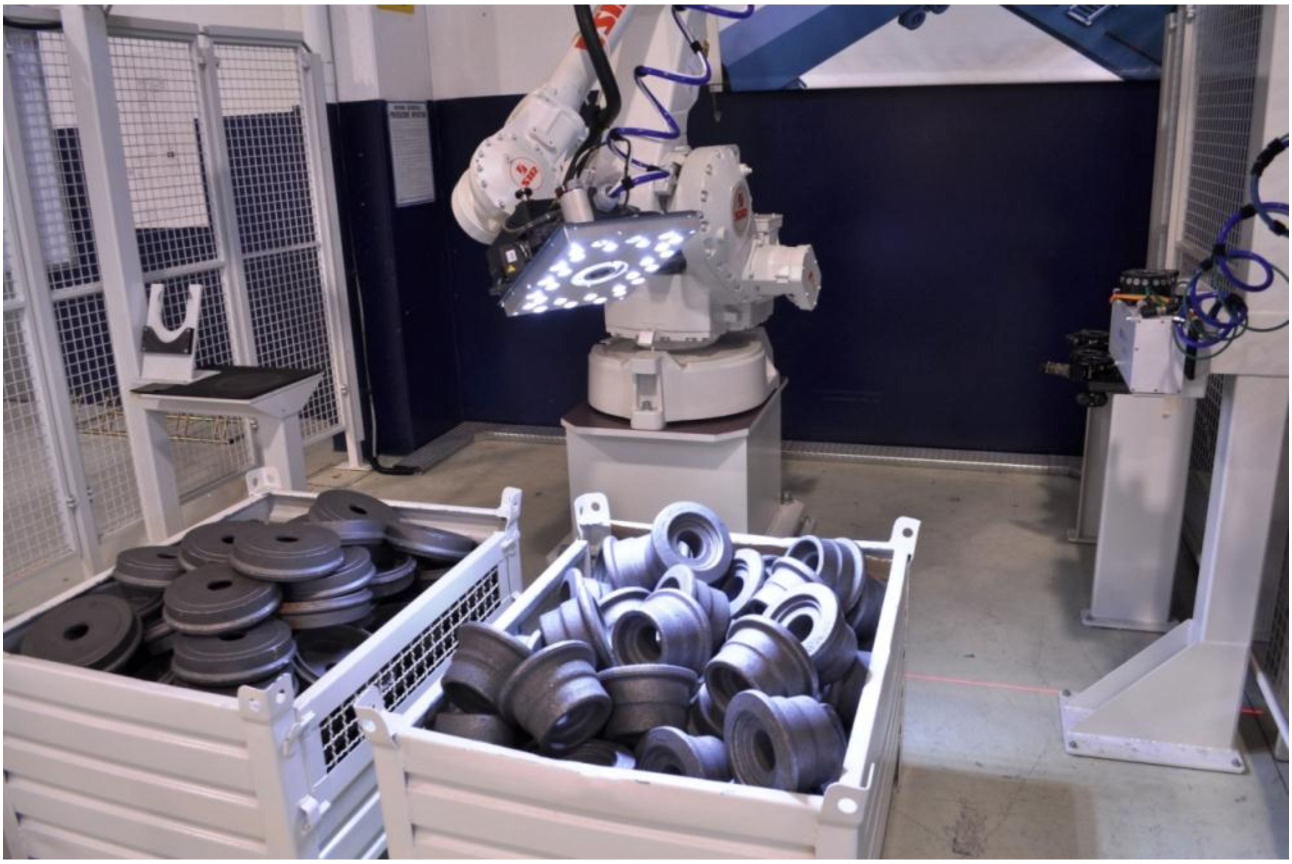

Figure 4 - Robotic system arranged with a stereoscopic vision system (3D) (courtesy: SIR Spa – MO, Italy).

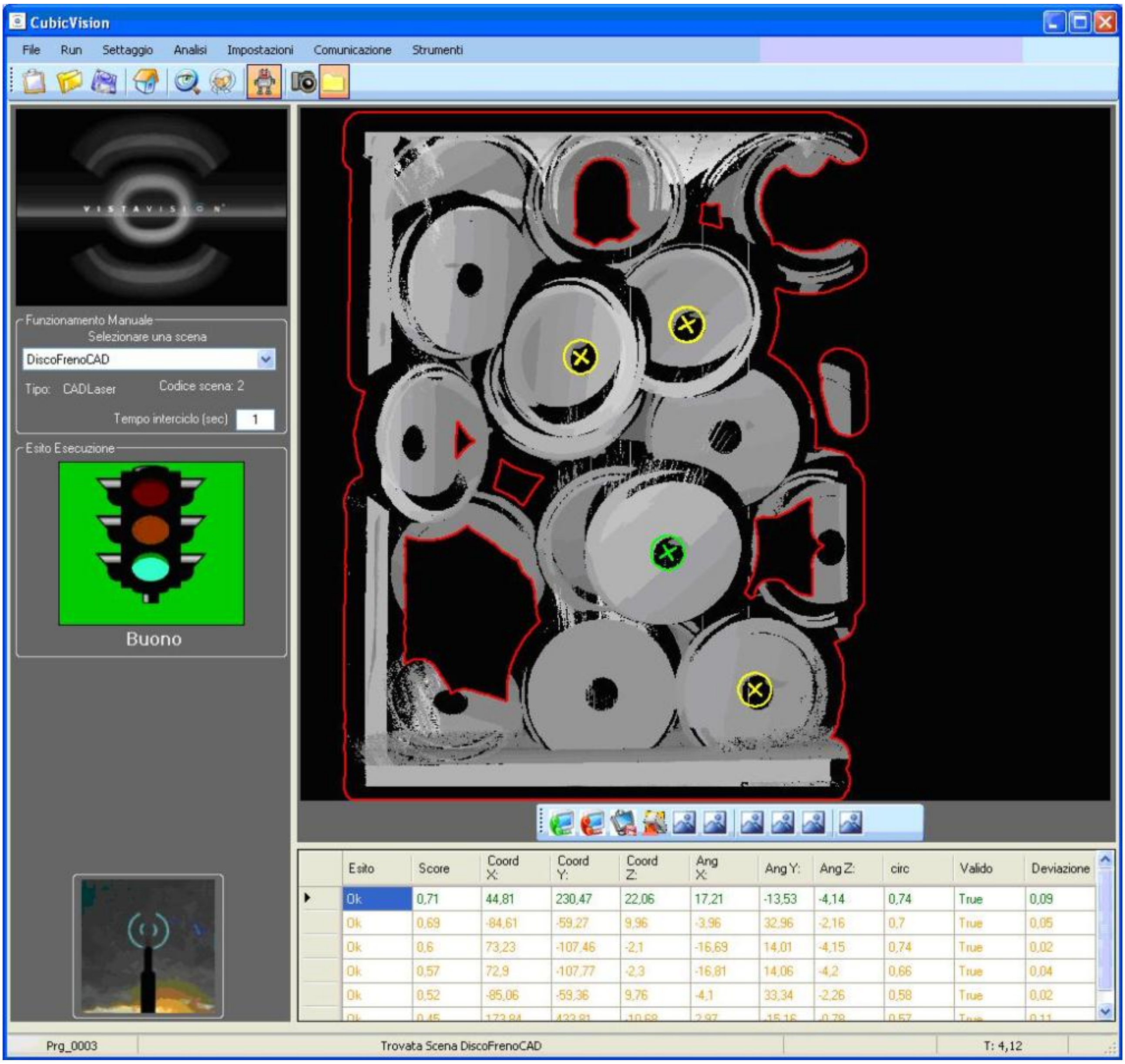

Figure 5 - Image processing interface for 3D robot guide (courtesy: SIR Spa – MO, Italy).

Figure 6 - Vision system based bin picking (courtesy: SIR Spa – MO, Italy).

The European Community decided to invest on the development and production of architecture for robotic systems capable of performing mechanical finishing with an accuracy comparable to that achievable with modern CNC machining centers and CAD/CAM systems, funding the project "COMET - Plug-and-produces COmponents and METhods for adaptive control of industrial robots, enabling cost-effective, high precision manufacturing in the factories of the future". The ambitious goal is to create, within 30 months of work and with a budget of around 8 million euros, a robotic system that is easily integrable into production processes (plug-and-produces) and capable of achieve precision machining up to 50 microns.

The consortium involved in the project, as shown in Table 1, consists of 14 partners recruited from universities, research centers and companies throughout Europe. Among those, is noteworthy the presence of SIR Spa in Modena, Italian leading enterprise in the development of robotic solutions for industry. SIR Spa has been also invested with the honor and the burden of the scientific coordination of research activities: this centrality role is derived from the international recognition of expertise, proven in more than twenty years of activity at the highest level in the difficult field of Industrial Robotics, and from the scientific support provided by the strong relationship the company has built in years with the Department of Mechanical and Civil Engineering (DIMeC), University of Modena and Reggio Emilia. The relationship between SIR Spa and DIMeC led them to found an integrated research laboratory, where young and motivated researchers and expert engineers can share equipments, resources, knowledge and experiences.

Table 1: European project COMET - Plug-and-produce COmponents and METhods for adaptive control of industrial robots enabling cost effective, high precision manufacturing in factories of the future.

Project name	Plug-and-produce **CO**mponents and **MET**hods for adaptive control of industrial robots enabling cost effective, high precision manufacturing in factories of the future
Coordinator	Jan Willem Gunnink (DELCAM PLC)
Scientific Coordinator	Marcello Pellicciari (UNIVERSITY OF MODENA AND REGGIO EMILIA - SIR SPA)
Partners	DELCAM PLC (United Kingdom), NIKON METROLOGY NV (Belgium), BRANDENBURGISCHE TECHNISCHE UNIVERSITAT COTTBUS (Germany), FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V IPA (Germany), AMRC MANUFACTURING LIMITED AMRC (United Kingdom), TEKS SARL (France), SIR SPA (Italy),

	DEMOCENTER-SIPE CENTRO SERVIZI PER L'INNOVAZIONE E IL TRASFERIMENTO TECNOLOGICO SCRL (Italy), UNIVERSITY OF PATRAS (Greece), STAMATIS GIZELIS AE (Greece), N.BAZIGOS ABEE (Greece), LUNDS UNIVERSITET (Sweden), NISAFORM SRO (Czech Republic), ARTIS GESELLSCHAFT FUER ANGEWANDTE MESSTECHNIK MBH (Germany)
Start and end date	September 1st, 2010 - March 31th, 2013
Budget	8,0 M€
European funding	5,3 M€
Project references	VII Framework Programme - European Economic Recovery Plan (EERP) Factories of the Future Public-Private Partnerships (PPP) - FoF.NMP.2010-1, Plug-and-Produce components for adaptive control.
Website	http://www.cometproject.eu

From the technical point of view, the COMET project aims to achieve these results through the integration of four complementary enabling technologies, implemented in a modular architecture to be achievable with standard industrial robots, produced by major manufacturers, expecting to save at least 30% compared to the use of traditional centers.

The project, as shown in Figure 7, involves the design and prototyping of a series of robotic manufacturing cells, built on the basis of four converging technologies. The first of these concerns the definition of a series of mathematical models, developed under the guidance of the Brandenburg University of Technology (BTU) of Cottbus (Germany), related to the univocal description of the kinematics and dynamics of modern industrial robots, in order to develop in practice, an open and neutral library, independent of the individual producer of robots, providing a "signature" that can identify and characterize the performance of each single robot.

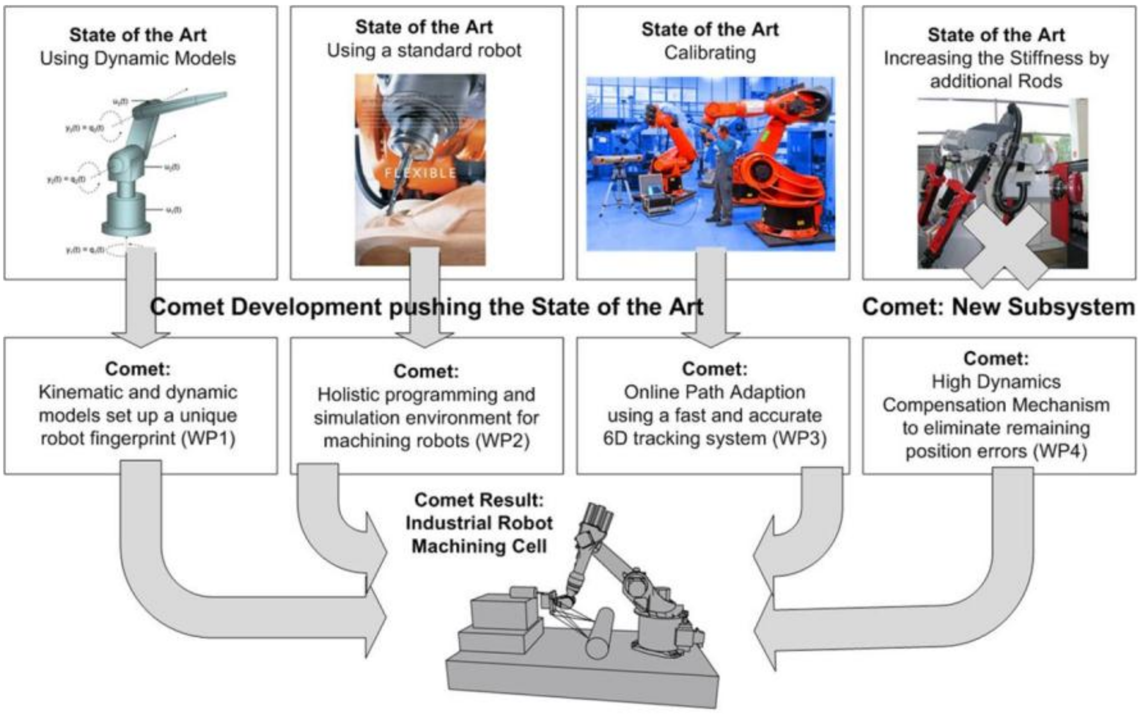

Figure 7 - Integration of the four innovative technologies provided by the COMET project.

The second technology proposes the implementation of an innovative 3D programming and simulation environment that was built on the basis of trading platform DELCAM PowerMILL, that allows to develop machining robot paths starting from the specific dynamic characteristics identified by the robot signature. To ensure the industrial applicability, this modulus shall contain specific functions for the prediction of the singularities of axes and collisions, for the management strategies of machining and process parameters, and for the generation of thousands of robot target points.

The third technology is related to the prototyping of an optical tracking system of last generation, obtained by the development of existing measurement systems NIKON METROLOGY NV, which is able to assess the deviations of the robot axes from the programmed positions, to calculate the necessary corrections for minimizing the positioning errors, and to communicate results to the robot controller in real-time.

The latest technological effort concerns the engineering and the development of a high dynamic compensation system developed by the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) in Stuttgart (Germany). This device consists of a piezoelectric actuator with a flexible coupling, and it will be able to compensate low-amplitude errors within a wide bandwidth, in order to bring the machining precision to values exceeding the mechanical limits of the robots themselves.

Thanks to a concrete approach, researchers and SIR Spa engineers designed an experimental work cell with a modular structure, that is able to gradually accommodate the various technologies developed within the project, allowing to verify their industrial effectiveness. The satisfaction of the constraints due to the stringent technical specifications related to equipment installation and the indeterminacy of many parameters related to the developing devices have required a major design effort, dealt with the aid of virtual prototyping techniques and to the use of the simulation tools and behavioral offline programming system (Figures 8, 9, 10, 11).

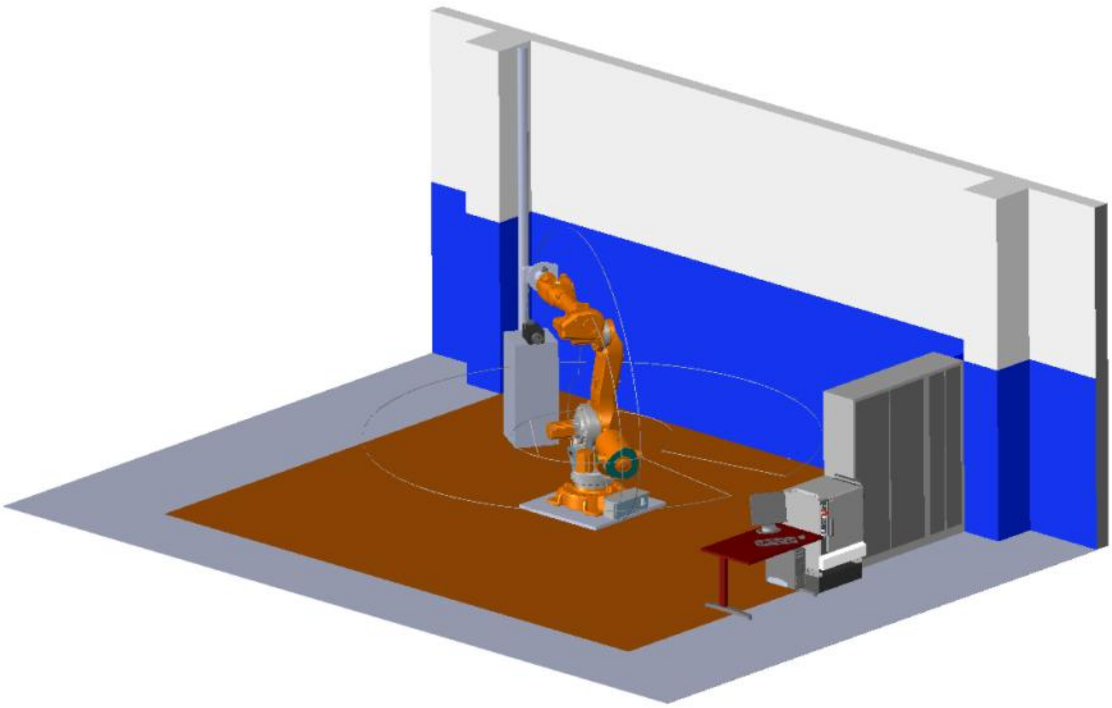

Figure 8 - Layout of the COMET experimental cell for testing the BTU-DELCAM system.

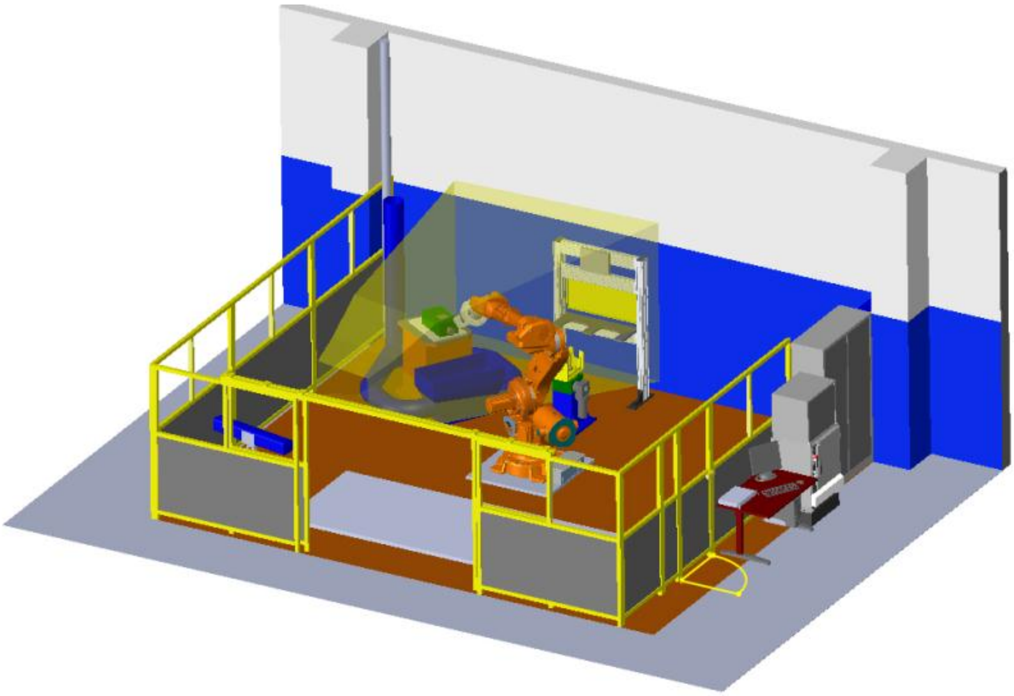

Figure 9 - Evolution of the COMET experimental cell for testing the Nikon system (Courtesy: SIR Spa – MO, Italy).

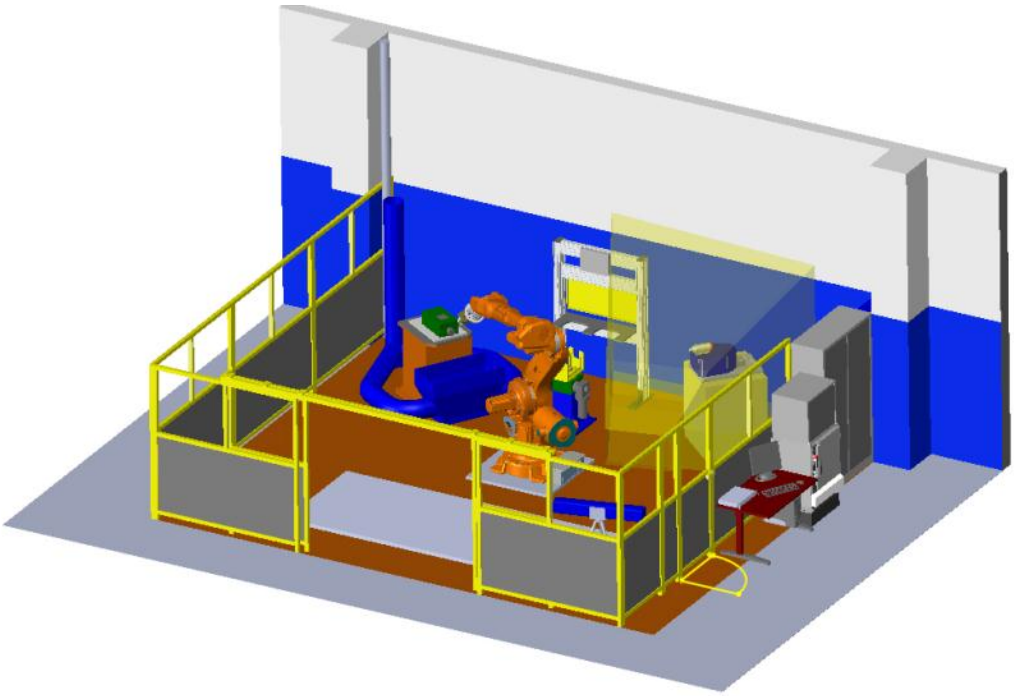

Figure 10 - Final configuration of the COMET experimental cell implemented with BTU-DELCAM, NIKON and IPA systems (Courtesy: SIR Spa – MO, Italy).

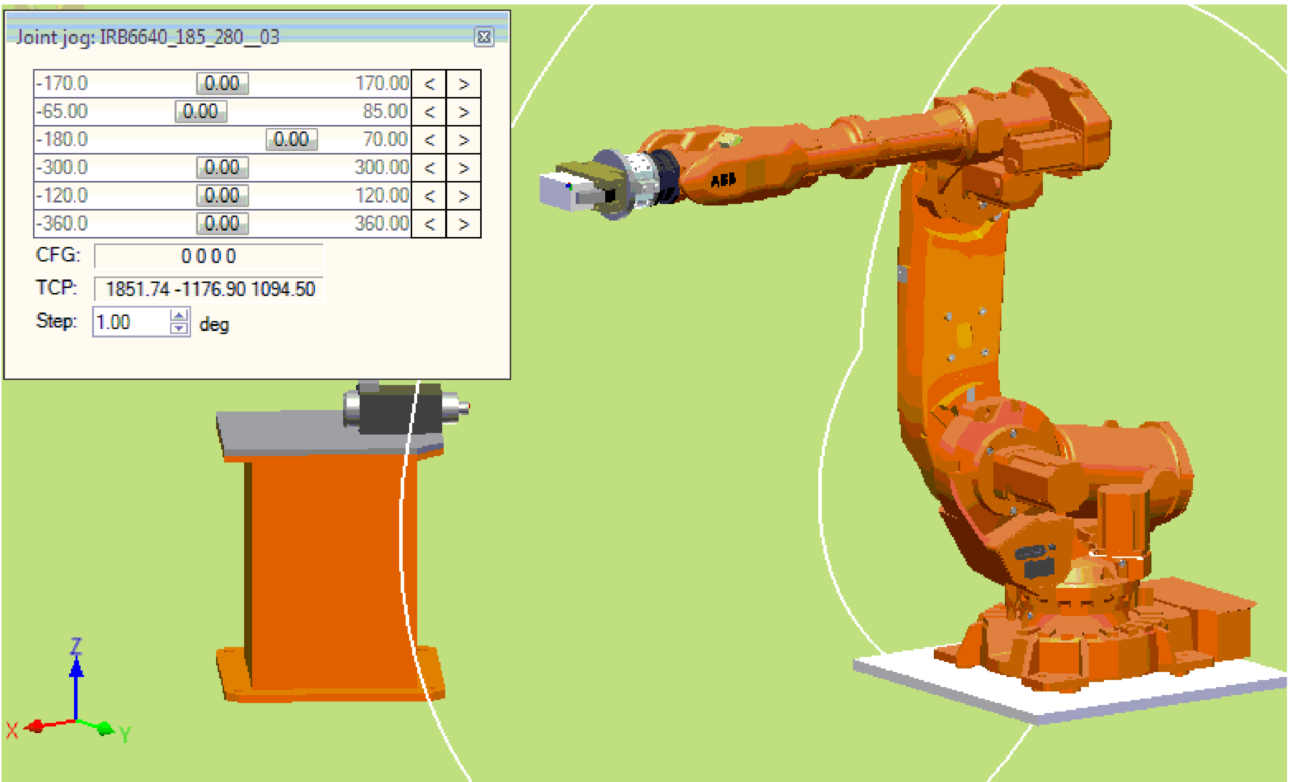

Figure 11 - Simulation and robot code generation by ABB RobotStudio software (Courtesy: SIR Spa – MO, Italy).

The experimental cell, still under construction, was at first equipped with a robot ABB IRB 6640-185 with controller IRC 5, to enable the researchers involved to study and experimentally investigate the basic mechanisms underlying the robotic machining process, so as to systematically identify the main issues related to meet performance requirements in terms of accuracy (Figure 12). Using Design of Experiments techniques, therefore, the effects related to the variability of dexterity and stiffness of the robot within its work volume are being analyzed and the process parameters are identified, aiming to achieve the correct modeling of contact forces for predicting the system behavior. Once tested the real robot performance, the applicability of the developed technologies and the factual impact of the system will be evaluated with respect to the industrial robotics market.

Figure 12 - The COMET cell robot during the first experimental tests (courtesy: SIR Spa - MO).

Although the first results obtained in the many activities already performed are very encouraging, the road ahead is still long before achieving the ambitious goals proposed, and there is much work to be done for the team of researchers involved in the project. The partners from across Europe will meet in Modena in mid-September to discuss the research lines needed to transform the COMET research project in the near future of industrial robotics.