Towards Intelligent Industrial Automation

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Leonardo is actively involved in the development of solutions based on technologies for Industry 4.0 to provide its customers with innovative industrial automation solutions and at the same time improve the efficiency of production, operation, maintenance, logistics processes as well as the quality and competitiveness of products in Aerospace and Defence. The "Secure Connected Factory" platform represents Leonardo's solution that is conceived to support the digital transformation in the industrial sector for operation and maintenance, through a model that integrates advanced applications, technologies such as Internet of Things (IoT), big data, blockchain, augmented and virtual reality, hyperconnectivity and digital security. Artificial Intelligence (AI) is likely to play an increasingly decisive role in the collaborative integration of machines, human beings and resources and automation. This paper aims at highlighting some relevant aspects of Leonardo's adoption of AI techniques for Intelligent Industrial Automation in already developed and cross divisional underway project initiatives. involving Electronics, Helicopters, Aerostructures and Cyber Security Divisions with a common and shared approach.

Digital transformation is at the heart of every industry's strategy, influencing business models, competitiveness, sustainability, production, maintenance, logistics and operations. Data, information and Cyber Physical Systems (CPS) are at the core of the emerging paradigm for Industry 4.0 which integrates computational, communication and control capabilities with Artificial Intelligence (AI) in its various forms [1]-[5].

In such emerging scenario, machines, humans and resources will be able to communicate and work collaboratively, creating a complex system capable of automating processes, making decisions, adapting to new situations, detecting anomalies or new requirements and acting accordingly. In the process of digitizing the factory, Leonardo is engaged with the dual role of system integrator and manufacturing company, starting from the design to the secure and traceable control of the supply chain, predictive maintenance, logistics, simulation and training.

In the industrial automation sector, and more specifically in the manufacturing plant, AI driven automation is likely to provide new solutions toward the achievement of the zero defect, zero failures, zero accidents and zero inventories goals, according to World Class Manufacturing (WCM) program adopted in Leonardo.

Moreover, the adoption of Virtual Reality (VR) and Augmented Reality (AR) technologies, supported by AI algorithms, can dramatically enhance the capabilities to execute training sessions (reducing the need of real equipment often not available) and to support maintenance operations providing (hands free) technical information on the fly and remote assistance. However, in order to achieve the true potential of industrial AI, some challenges should be overcome. Despite data availability is incredibly increasing in the industrial sector, labelled datasets with minimum bias relevant for AI applications are still scarce. By learning from inaccurate datasets outcome results can be flawed. Moreover, an Artificial Intelligence System is often perceived as a black box, with a lack of a compelling evidence of the reasoning inside the deep layers of a neural network in AI decision making system. From these considerations originate the recent relevance of Explainable AI (XAI), an emerging field in machine learning that aims to address how black box decisions of AI systems are made, [6]. Hence, there is an emergent need for a systematic design and implementation of AI based solutions defining methodologies, tools and framework for consistent industrial applications, leveraging research outcomes.

To achieve these goals, Leonardo is investing in Industry 4.0 technologies, also collaborating with Universities, Centres of Excellence, SMEs and Startups, according to an open innovation model and participating to relevant national and European projects, such as:

- "Leonardo 4.0", a MIUR funded project, encompassing a strong cooperation among Leonardo Divisions (Cyber Security, Electronics, Aerostructures and Helicopters), University Institutions and Italian SMEs;
- "CPS4EU", a project funded by EC and MISE, involving three Leonardo Divisions (Cyber Security, Aerostructures and Aircraft), Academic Institutions and other European partners [7].

SECURE CONNECTED FACTORY PLATFORM

The “Secure Connected Factory” (SCF) platform represents Leonardo’s proposal for digital transformation in the industrial sector.
It integrates advanced technological components (Figure 1) such as Internet of Things (IoT), Big Data Management, AI algorithms, Mixed Reality (MR), hyperconnectivity and digital security with development and data science methodologies.
It enables the development of innovative data-centric applications such as predictive analysis, predictive maintenance, quality control, machine efficiency analysis (OEE, Overall Equipment Effectiveness), energy consumption monitoring, support to operators (access to telemetry data, holograms, virtual assistant/chatbot), responsive and self adapting solutions (Cyber Physical Systems).

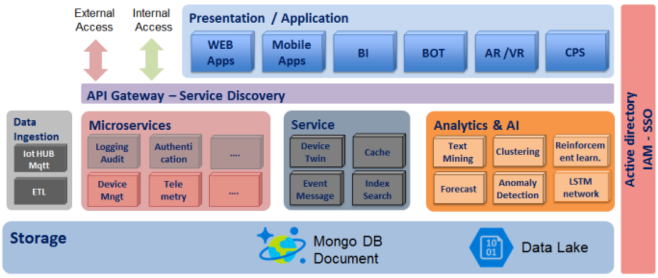

Figure 1 – SCF Architecture

The platform is conceived with a *Secure by Design* approach, starting from the design and development phase of the software to the use of secure gateways. It also offers the possibility of integrating a module for the identification of cyber-attacks and their impact on resources and production processes through the use of automatic learning on data coming from sensors and from a SIEM (Security Information and Event Management). The Secure Connected Factory is a significant first step towards data-driven intelligence-based automation (Figure 2) with high degree of connection among different systems, paving the way for deeper and broader integration coming in the next steps.

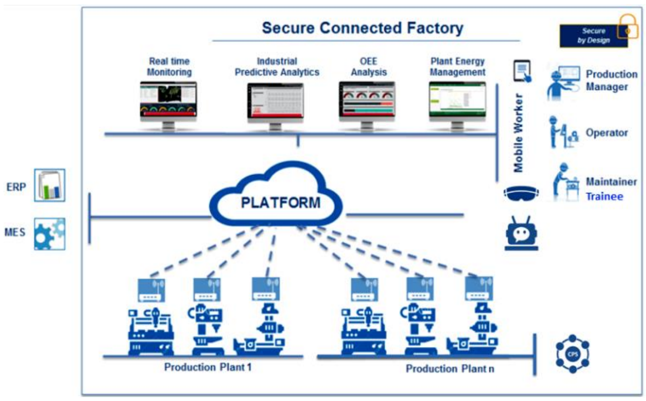

Figure 2 – SCF Business Scenario

In fact, a higher level of awareness is still required for redesigning the processes around the new paradigms, managing transparency levels among the different segments of the process chain belonging to different structures, and accurately assessing costs and benefits specific to each target objective. In order to face the complexity of the new paradigm of industrial automation, it is essential that the industry operates better and better according to an ecosystem logic.

LEONARDO 4.0 PROJECT

A concrete application in Leonardo of the innovative aspects of "AI for Industrial Automation" is represented by the MIUR project "Leonardo 4.0" aimed at applying the Industry 4.0 paradigm at Leonardo production sites, with the collaboration of the University of Salerno and selected SMEs. The project is a cross-divisional initiative involving Electronics, Helicopters, Aerostructures and Cyber Security Divisions with a common and shared approach.

Cyber Security Division

In some production sites Leonardo is expected to develop specific data driven solutions exploiting Artificial Intelligence and mixed reality through the SCF platform. Data driven modelling may uncover hidden patterns, unknown correlations and other useful information for asset health prediction- This would generate, for example a remaining useful life value, which can be used for prognostics and integrated with other technologies for improved productivity and innovation.
The complexity of using Artificial Intelligence in industrial automation requires a strong collaboration among AI specialists and domain experts for enabling more comprehensive, robust and accurate understanding.
The Cyber Security Division leads the coordination of the project and addresses the realization of the use cases through the configuration of the platform and the development of ad hoc software programs, leveraging a strong collaboration among data, analytics, platform and operation and domain specifics experts.

Electronics Division

Leonardo’s Foundry in Rome, Tiburtina site, is a technological production line for both Monolithic Microwave Integrated Circuits (MMICs) and R&D prototypes in GaAs (Gallium Arsenide) and GaN (Gallium Nitride) (Figure 3).

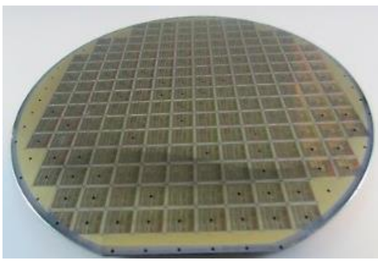

Figure 3 – Example of GaAs wafer produced at the Foundry

In order to make it more competitive in terms of cost and volume capability, it is necessary to introduce industrial production best practices, changing the way the production has been approached until now.
Artificial Intelligence is the way to carry out such a change through machine learning solutions. Furthermore, good

ergonomics, in terms of interfaces design will also increase employee's efficiency and effectiveness.
IoT solution through connected manufacturing equipment, cyber-physical systems and big data-based analytics of production processes are keys to improve the overall system performance.Among the various objectives of the site, particular attention should be paid to the optimization of human-machine interfaces and the quality control of processes through Machine Learning techniques.

Figure 4 – L band 3D Radar

At the Fusaro and Giugliano plants, where the various subsystems of radar are produced and their integrated logistical support is managed, Leonardo 4.0 is intended to design and implement an integrated solution for the optimisation of production processes currently in use. The realisation of systems through the processes of digitalization and automation in assembly and testing areas, also based on AR and VR technologies, will guarantee an increased production rate, better product quality, and a consequent cost reduction (Figure 4 and Figure 5)

Figure 5 – The Four-channels Software Defined Radio

The Carsoli site deals with the design, development and realization of optical Coatings (surface coatings, Figure 6) that are applied to the surfaces of optical components of precision in order to improve or alter the optimistic and/or mechanical characteristics of those surfaces. In this case, objective of the Leonardo 4.0 Project is the creation of an automatic system for the acquisition and processing of signals from production and testing machines, to respond promptly when any deviations would appear, before they turn into irreversible problems.

Figure 6 – Example of lens coating made in Carsoli

Helicopters Division

Within the Helicopters Division, the departments of Customer Support and Engineering participate in the project with the aim of building and making operative an environment that will enhance the rotorcraft in service capabilities, improving the analysis of in-service occurrences (malfunctions, failures, lack of performances, design or manufacturing deficiencies, etc.) to enable subsequent actions for recovery and improvement.
Currently, within Engineering and Customer Support the data coming from the in service fleets are different in nature, non-homogeneous and are managed via various and fragmented data bases, structured and unstructured, distributed across the departments and across people. The development and deployment of a harmonised, unique, effective and efficient environment for processing such data in view of diagnostics and prognostics of the events occurring in service across the fleets, represent a huge potential both for customers support and for product improvement and recovery. Moreover, accuracy of the analysis can be boosted by extending the base of information thanks to additional data, which include further relevant details coming from the customers. This is the case of data coming from off the shelf Maintenance Management tools used by several customers' Maintenance Organizations and data from smart tagging applied on major components, so granting completeness of dataset and enhancement of analysis.
The achievement of such capabilities would lead totangible impact on customer satisfaction, reduction of the Aircraft-On-Ground time and, potentially, decrease of the maintenance burden and costs.
Thanks to the timely and deep analyses supported by the Data Analytics approach, positive impacts both on Design and Production are also expected. In fact, the ability to perform root causes identification of malfunctioning and lacks of performance can lead to detect both project weaknesses and manufacturing issues.
The management of in-service occurrences data is currently based upon individual customised tools that are spread across the Company departments, are not interfacing among each other and are mostly based on human brain analysis. The significant amount of data makes it quite unlikely to obtain in this way an efficient and effective analysis for each platform and above all across the platforms showing common troubles.
The use of AI techniques within a comprehensive Data Analytics environment will enable:

- to make comprehensive statistics and trend analyses on the whole set of data, isolating the events with higher costs and key performance indexes for the Company;
- to identify recurrent patterns and unexpected cross correlations among the events, exploiting the fact that some design solutions are common or similar;
- to monitor the effectiveness of the corrective actions undertaken, also comparing the expected results with those actually obtained;
- to manage data coming from different platforms.

The environment will be fully modular and able to scale to accept further data types and dimensions.
The available information constitutes a "data lake", which also in the structured data bases is affected by "dirtiness" that has to be filtered off. This cleaning is expected as one of the functional output of the AI techniques application.

Moreover, a lot of information, belonging to the past and coming from the components repair and overhaul, is captured in documents in scanned pdf format and either written in printed characters also affected by ‘noise, e.g. presence of hand written letter in the text, or, the oldest, written by hand. The capability of extracting relevant cleaned information from such mines is the object of a parallel advanced application of the AI algorithms. Considering the long lifecycle of a helicopter these data represent a precious source of information for aircraft which are still in service.

Aerostructures Division

At the Grottaglie plant of the Aerostructures Division (Figure 7), where composite fuselage sections are produced for the Boeing 787 Dreamliner, a system is to be developed for the automatic analysis of the treatment cycles of the autoclave polymerization process, for the control and certification of product quality standards. With the real-time acquisition of process data and the generation of ML models (clustering, classification, regression) it will be possible to correct any emerging drifts in real time.
Another aspect to be constantly monitored deals with the quality of holes in the drilling process of the composite fuselage section. Image recognition of drill bit cutting edges, enabled by AI algorithms, will be used to predict the remaining useful life of the drill bit, thus avoiding the generation of hole defects (ovalization, surface damage).

Figure 7 – Grottaglie Plant: Boeing 787 assembly area

CPS4EU PROJECT

The introduction of responsive and self-adaptive solutions exploiting Cyber Physical Systems (CPS) is investigated in the framework of the European CPS4EU project aimed at strengthening European and national industrial competitiveness. A CPS is the link between the physical and digital worlds and is becoming increasingly important in digitisation processes characterised by real-time interaction between components of complex systems, as well as by interactions with operators (human-in-the-loop). In this context, automatic learning techniques (ML, DL, AI) are often confined to the cloud. However, distributed applications need to respond quickly to changing boundary conditions. The CPS4EU addresses this need by creating CPS that are able to make decisions independently and quickly, and to customize their function as the environment changes as well as to cooperate, learn and modify their actions on the basis of data collected in real-time. The CPS4EU is a joint initiative with a predominant presence of France, Germany and Italy for innovation in Industry 4.0 and provides for numerous use cases in the Energy, Industry Automation and Automotive domains.
A set of diversified use cases will be developed through strong collaboration among Cyber Security, Aerostructures and Aircraft divisions of Leonardo, which is a key for the profitable usage of Industry 4.0 technologies.

Automatic Vacuum System

The use case will deal with a specific assembly process on large composite structures and aims to automate drilling activities on such structures that are currently human driven.
Two people are needed to carry out drilling activities: one person drills while the other one is positioned on the opposite side of the large structure and has to vacuum the carbonfiber dust that is produced. The use case will automate the movements of the vacuum system to enable it to go “following” the drill position (Figure 8).

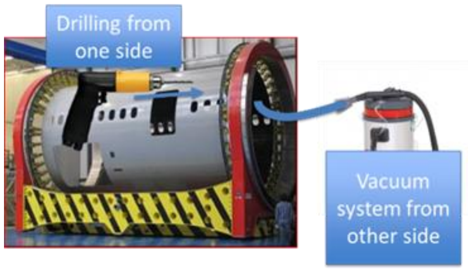

Figure 8 – Automatic Vacuum System

Trimming quality improvement

The improvement deals with the process of trimming composite and metal structures, during which the delamination – a failure in which the layers of the material separate from each other – is often experimented. This is due to different phaenomena that are difficult to manage because of the high complexity and high numbers of variables involved (vibration, detachment from tool, tool wear, speed, humidity, temperature, air pressure, etc.).The objective of this use case is to create CPSs for the collection of data coming from sensors and numerical control machines and for their analysis through advanced algorithms, in order to understand the main root causes of defects. To complete the cycle (Figure 9), the CPSs, reacting to different conditions, will be able to modify in real time the machine parameters so to avoid the damages or defects.

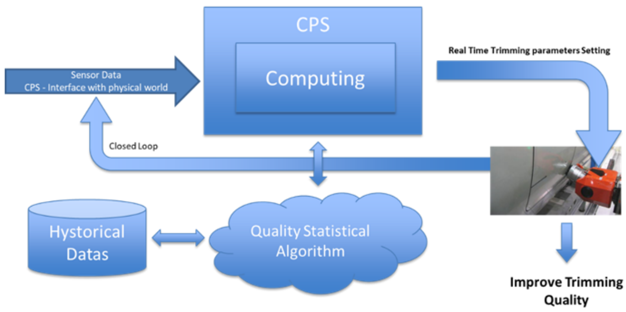

Figure 9 – Trimming quality improvement

Thermoplastic Production Line Monitoring

A new Thermoplastic Production Line is going to be

installed in Leonardo's Grottaglie plant to manufacture thermoplastic matrix composites parts. The fusion consolidating process is performed by a variety of machines, as it involves applying both heat and pressure at the interface between composite materials. The objective of this use case is to create a CPS system able to support the entire production scheduling, monitor and control process parameters and orchestrate production flows.
The environment is made up of several "working stations" (Figure 10), each of them being dedicated to one specific task, among which:

- grasping station, which grasps and holds the composite part so that it can be moved from one station to the next by a robot arm;
- heating stations, where the part is heated in an infrared oven;
- casting stations, where the part is moulded by "casting under pressure";
- edge-trimming station, where the part is trimmed;
- unlock station, which releases the part once the process is completed.

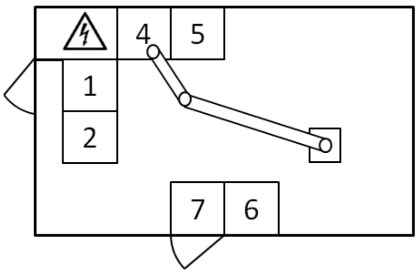

Figure 10 – Thermoplastic Production Line Monitoring

Health Management System for Aircraft

The Health Management System is devoted to gathering, collecting and analysing data concerning aircraft fleet maintenance. This use case includes the study and design of a solution able to collect and manage the large amounts of data generated by monitoring the operating status of a system and of its main components during the use in service, in order to optimize the management of the individual system and / or its components.
The overall system (Figure 11) consists of different components, located both on-board and on-ground, providing data and HW / SW framework, whose objective is to collect and correlate all data in order to support the following users:

- Maintenance Operator, who performs the maintenance tasks according to the planning;
- Engineers, who analyses data and schedules the maintenance tasks, if needed;
- Logistic Operator, who manages parts transportation and optimizes spares according to the needs.

Data coming from aircraft are essentially *Failures related* (i.e. events featuring possible impacts on aircraft availability) and *Performances related* (used to monitor the health status of aircraft systems). The first ones have to be fixed as soon as possible, while the second ones are used to anticipate future possible failures, whenever possible.
Warehouse data are related to equipment/components removed from aircraft to be repaired (at Customer or Supplier premises) and equipment/components available as spare parts at the warehouse;

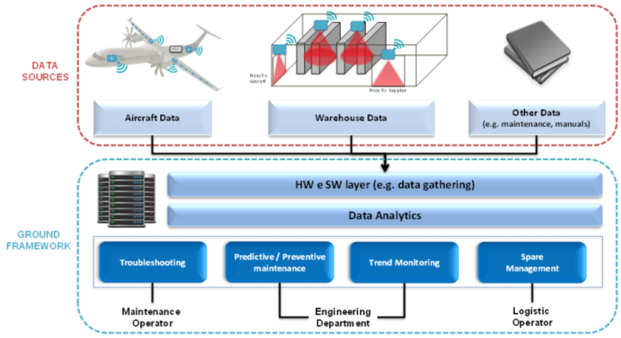

Figure 11 – Overall system description showing both the on-board and on-ground components

Other data could be constituted by *manuals* or *other documents.*
The focus should be onto the on-ground framework and in particular on the following features:

- Troubleshooting, which provides support to the Maintenance Operator in order to limit the aircraft downtime;
- Trend Monitoring, which allows the Operator to monitor the aircraft systems performances;
- Predictive / Preventive maintenance, which is intended to anticipate possible failures by analysing performance data;
- Spare Management, which aims to optimize the warehouse and supply chain management, thus reducing the risk of aircraft downtime due to missing spare parts.

All such use cases will take advantage of data driven models generated through innovative algorithms and are characterized by high performance embedded computing, connectivity with local and remote sensors and collaboration among CPSs.

CONCLUSIONS

The traditional industrial automation paradigm is in its evolutionary phase that is driven by increasingly challenging market requirements in terms of cost, quality, time-to-market, flexibility and competitiveness. AI is no longer confined to innovation laboratories, and its transformative possibility applied to the industrial sector is widely perceived positive, despite its evolutionary path is articulated and it could proceed at different speeds in different sectors. In fact, in some areas the industrial process is complex and strongly regulated. In addition, there is the need for a more adequate data governance, accurate processes of training of intelligent algorithms and systematic development of AI methodologies, tools and skills for strategizing the efforts toward the realization of Industrial Automated systems. The process of digital transformation is therefore underway, but structured systemic and synergic work will be required among all the actors involved, in order to guarantee a more secure, deeper and wider integration and to ensure "end-to-end" digital continuity extended to the entire production and logistics chain. The path towards the adoption of innovative technologies based on AI techniques in the industrial sector represents for Leonardo a long-term challenge that is just undertaken and currently focused on the evolution of the production process. Significant developments are expected from the application of these innovative technologies to Leonardo existing products, for efficient management of their life cycle and related logistical support services, towards the digital and intelligent industrial automation.

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