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DESIGN-WITH-IOT AND DESIGN-FOR-AUTOMATION: A PROPOSAL FOR PRODUCT DEVELOPMENT ORIENTED FOR EXCELLENCE

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Abstract: *This paper presents two methodologies for the design and development of new products called Design-with-IoT (DwIoT) that aims to integrate IoT technology into products, focusing on a set of guidelines for its implementation, and the concept of Design-for-Automation (DFA), important in the development of new automation-oriented products in an industry 4.0 context.*

Key Words: IoT, product development, product design, Automation

1. INTRODUCTION

With the advent of the Internet of Things (IoT) applied to the industrial environment (Industrial IoT), the product strategy is no longer focused on a line of physical products. With this trend, a large part of the production strategy rather focuses on services and end-user/consumer interaction. To cope with this transformation, companies need to change their focus from industrial design to strategic aspects, designing ecosystems instead of products. This means that companies will have to focus more on people who know the company's strategy, brand strategy, product experience and end-users experience.

No less important is the way today's connected products are designed. With IoT ecosystem's, the subject is no longer just about methodologies to produce physical objects, but also about projecting things in a virtual space.

Knowing the use of a product in real time offers great opportunities for companies that produce physical products. Thanks to the inclusion of IoT technology, companies can find out how their products are used, whether it is an industrial environment or a consumer product on a day-by-day basis and monitor the context or how often they are used. Usually, a product is sold for a specific period before being reviewed and updated. With IoT, companies can collect information from the moment the product is used. For example, and by analogy to the software development process, after the software is being released from version 1.0 to users, the company quickly proceeds with the next versions. This approach is still unusual in the world of physical products. Without IoT technology integrated into the design, version 2.0 of the product would be developed and released to the market only much later. A strategy based on Design-with-IoT helps in the design and production of the next version. This means that the company has a connection with the end users of its products. In this way, the company behind the brand will be able to create products, experiences and services that are more relevant to consumers, instead of being just a product that someone likes or dislikes.

On the other hand, the true value of a product integrated with IoT, after its initial release, is not the volume of sales it generates, but rather in the data it provides [1]. It may not be easy for a company to adopt a new strategy in which it not only launches a product, but also collects data to improve it. Large production companies already have a product development process in place. When this process ends and the product is launched, another equipment, in sales or after-sales services, assumes the continuity of the tracking process.

A product that is put for sale on the market but maintains a connection to the company has implications for the organization and its structure. Organizational change may be required to accommodate this new concept of product management. This can be a challenging step for companies, mainly financial, because it takes a considerable investment to change the process of product management [1].

In global terms, there is a recognition that, to be competitive, the production industry needs to modernize and adapt to an increasingly technological era. The concept of Industry 4.0 accelerates the definition of the standard for all industrial automation to achieve the goal of holistic and adaptive automation system architectures. For a company to become competitive and flexible is not at the expense of low-wage strategies, but rather using advanced technologies, focusing on automation to enable a successful transition.

Industry 4.0 is an interdisciplinary strategy, where the areas of knowledge in Mechanical Engineering, Electrotechnics, Electronics and Information Technologies need to work together for an automation implementation with state-of-the-Art requirements. The traditional automation pyramid takes on a new form and new information models emerge, such as the European standard RAMI 4.0 which is a three-dimensional map focused on the most

important aspects of Industry 4.0, as depicted in Figure 1.

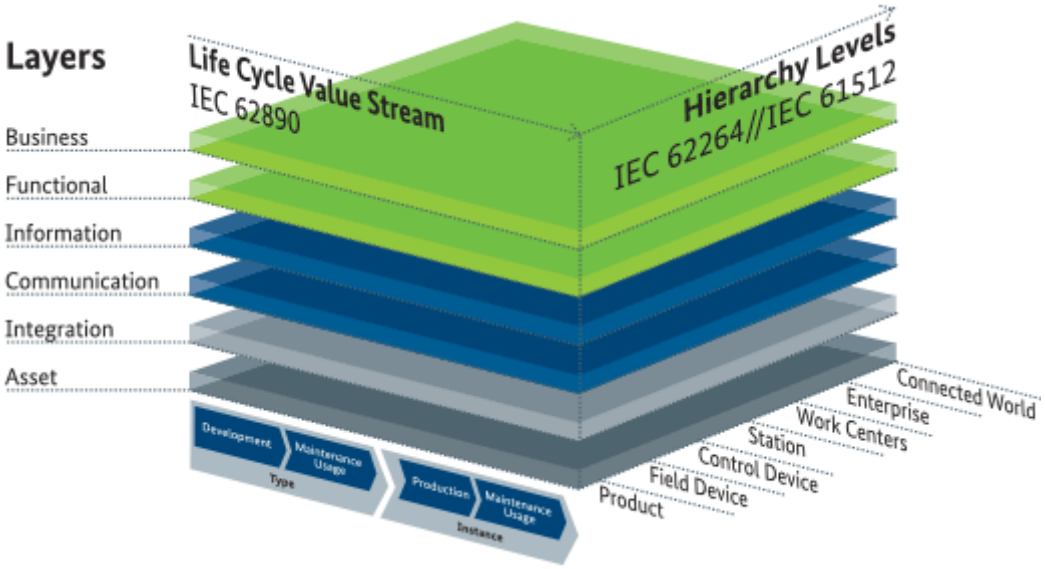

Figure 1. RAMI 4.0 reference model

This reference model guarantee that all stakeholders in a process share a common perspective and develop a common understanding throughout the life cycle of a product. RAMI 4.0 defines a service-oriented architecture (SOA), where each component of an application provides services to other components via communication protocols, in a secure manner, independent of vendors, products, and technologies.

The following sections presents two distinct but complementary approaches that should be taken into account when developing automation products aligned with the Industry 4.0 concept and Industrial IoT.

2. DESIGN-WITH-IOT

Design-with-IoT (DwIoT) is a methodology for designing and developing new products that aims to promote the integration of wireless communication technologies, Artificial Intelligence, Big Data, Machine Learning, into the manufacturing processes of the product. Consequently, the design for IoT should be flexible and adaptable to these changes. To this end, we propose to follow a series of commonly accepted guidelines [2][3][4] for its implementation, which stands out:

- Security – Data privacy and security are keys to a good design for products that integrate IoT technology. Users should feel confident in their smart devices, which are safe and cannot be hacked, so that they are not at risk of losing their privacy or suffering a data breach.
- Troubleshooting – The team responsible for the design of IoT devices and systems should carefully examine users' problems and needs to provide a better solution to their real-life problems.
- Responsible use of data - IoT systems usually generate huge amounts of data. Those responsible for product design should analyze the data that is central to its operation, which makes all IoT devices useful and functional.
- Creating an integrated product – All contact interfaces between the product and the user must be designed to guarantee the perfect functioning of the system and, therefore, an adequate user experience.
- Testing and scalability – It is recommended to align the useful lifespan of the hardware and software elements of the IoT device. When a product is being integrated into an IoT system, it can become difficult to replace it with a newer version. This may also happen with software because it can be costly or difficult to update, due to security and privacy reasons. It is therefore crucial to test the product thoroughly before its entry to the market. Prototyping and fast iterations of the hardware and complete system in the early stages of the project are essential. To avoid problems that may occur at the time of updates, it is also important to anticipate possible background technological changes, such as new communication protocols, mobile communication technologies (4G/5G), and new hardware development architectures (microprocessors and microcontrollers).
- Context – IoT systems work at the intersection of the digital and physical worlds. The actions performed by digital commands can impact the real world. Although a digital command can be reversed, it may be impossible to undo the physical action that originated from it, so it is essential to create a safe environment for users to have a sense of control.

Finally, and no less important, we face with the constant evolution of IoT technology, which the DwIoT approach must always follow. It is therefore a methodology integrated into a broader trend, the Digital Transformation [5].

3. DESIGN-FOR-AUTOMATION

A product that follows the guidelines of Design for Automation (DFA) good practices is aligned with industry 4.0 concepts, and allows manufacturing companies to reduce product costs, decrease assembly time, and increase production volume. Below are some rules that, when followed, are preparing the development of products with an eye in the future of manufacturing processes [6][7]:

- Thinking like a robot – If you think about the operation of a manipulator robot on an assembly line, its range of motion and workspace are limited. They can also be equipped with different working tools, depending on specific needs, grippers, suction cups, electromagnet, etc. The structure of the robot is also an important issue. Depending on the application, it may make sense to use an anthropomorphic robot, a SCARA robot or a parallel (Delta) robot for tasks that require high speed and decide whether it makes more sense to use a rigid or collaborative robot. Accuracy and repeatability are other factors to consider. When designing a product for automation, it is important to imagine the operation of the robot and try to replicate the operation as if we were a robot. Can e reach a desired point, with the desired orientation, the speed, precision, and flexibility required? Is the tool the most suitable for the object to handle? Issues like these need to be addressed in the development process.
- Simplify assembly – When we think of an automatic assembly process, assembly order is a key point, since a given automatic station follows a sequential flow of processes. It is important to prioritize the parts/objects to assemble to increase assembly speed and reduce tool change times whenever there are customizations or changes to the product to be produced. Obviously, there are complex processes that require automatic parallel and synchronized assembly processes, but the same concept is applied to each workstation individually, always with the aim of reducing production times and increasing the flexibility of an equipment.
- Consider ready-to-use products (off-the-shelf) – To ensure that a product is DFA-ready, it is important to analyze each part/consumable that constitutes it, to assess whether they can be automated in an assembly process. For example, "Can this component be manipulated by a robot? Or can it be easily assembled in an automatic station?", "how easily can we handle this part?", "are there other parts that perform the same function and are ergonomically more adapted to an automatic process?" Such issues should be considered in defining the constituent components of a new product to be produced.
- Prepare equipment for quality control – Market demands are increasing and demand for zero-defect production is already constant, so automation solutions are increasingly required to incorporate automatic inspection solutions such as artificial vision. Part location, component counting, defect management and barcode readings are common operations nowadays done by artificial vision systems in a quality control process. In DFA logic it is important to design the parts and equipment in a way that they support these artificial vision systems whenever justified, to increase the quality assurance of the products to be processed. It is also important to design the work areas and light scenarios so that image processing produces the expected results.
- Do not forget the packaging – The packaging also adds value to a product and should not be overlooked. The packaging design should also be DFA-oriented, allowing for quick and simple assembly, but also capable of ensuring consumers a positive experience when unpacking a product.

DFA issues should be addressed in the product development process and some issues should always be considered during the development of automatic systems [8][9]:

- Doing business planning – The development of an automation-oriented product should include not only technical requirements, but also business, marketing, and product lifecycle requirements. It makes no sense to automate a process if there is no reasoned history of the volume of the parts produced, the life cycle that can be expected for the product and the variability that may be associated with it.
- Establish KPIs and Operational Metrics – For any automatic manufacturing process, a set of performance indicators and operational metrics should be established to assess system performance. It is common to evaluate the performance of an equipment through the Overall equipment effectiveness (OEE), but it is also common to establish other performance metrics adapted to the ongoing process, e.g., cycle times, defect percentages and acceptance, etc.
- Understand the added value and cost of the product at each stage of the process – At each stage of the process it is necessary to know the value of the materials that are being consumed or added, as well as the value of the operational work that is being performed. Understanding the value of all components inside and outside the process helps in optimizing resources.
- Define and organize Dashboards, technical reports, data processing and analysis – With the generalist growth of data volume produced by sensors and actuators from an equipment, there is also a growing need to extract knowledge from these data. Preparing equipment aligned with DFA best practices is also to provide it with capabilities to implement artificial intelligence techniques to optimize processes and decision-making on the equipment itself, as well as to enable connectivity to cloud computing

platforms, as well as graphical visualization of the current state and production registry of the machine.

4. CONCLUSIONS

Automation technologies require new and increasingly complex design considerations, which the development engineer must take into consideration, in the incessant search for excellence in the design of increasingly customized and technologically evolved products.

The integration of IoT into product design, called Design-with-IoT (DwIoT), will have huge implications for the near future. Electronics that are not smart, or without connectivity, will be discarded and neglected by end buyers. Consumers will automatically assume that an "electronic" product means "intelligent and combined with integrated connectivity". If it is not connected, the product may not meet the expectations of consumers, soon will be worth much less. Thus, the distinction between industrial and consumer products will be increasingly tenuous. People expect from a product, whether for home use or in the workspace, to offer the same level of logic and intuition. As a result, areas that have generally not been affected by technological changes in the past will have to adapt.

On the other hand, traditional concepts of automation based in hardware, with hierarchical communications that originated isolated products can now evolve thank to DFA methodologies to flexible systems and machines, with distributed control that originate customized products and that are an integrated part of the production structure.

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