Product Lifecycle Management Enabled by Industry 4.0 Technology

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Abstract. The rise of a new digital industrial paradigm known as industry 4.0, powered by several enabling technologies such as flexible and collaborative robots, autonomous vehicles, internet of things, cloud and manufacturing servitization, is seen as the key enabler for the fourth industrial revolution: the digital manufacturing. However, there are still several challenges related to the effective adoption of these technologies and to enterprise level interoperability so that an entire cyber physical production system can work seamlessly. Besides the set of challenges faced by industrialists, this research work presents innovative results towards a plug and play seamlessly integration of technologies, from the shop floor to the enterprise management layers, ensuring a total integrated architecture supporting the full product lifecycle management.

Keywords. Industry 4.0, Internet of Things, Product Lifecycle Management, Cyber-Physical Systems, Intelligent Product Ecosystems.

1. Introduction

Factory, process and product lifecycle integration is a key objective pursued but not yet truly realized. Technological advances lead companies to dramatic productivity improvements. The rise of new digital industrial technology known as industry 4.0, a transformation that is powered by several foundational technological advances such as autonomous robots and vehicles, internet of things, business intelligence and cloud technologies seems to be the missing enabler towards universal data-integration networks evolving truly automated value chains [1][2].

The medium term vision stays on connected resources, products and people all along the value chain, thus forming a true cyber physical environment. These hyper-connected cyber physical systems can interact with one another using standard communication protocols. However, it is observed that currently, many organizations are far from having their systems integrated. Enterprise interoperability is vital across many organizations and industries as it enables businesses to obtain the benefits of new technology without having to discard existing IT investments [1]. Many times shop floor level technologies are integrated, but there's a big gap from field control level to the management and strategic levels. Figure 1 depicts the several resources and the Industry 4.0 integration layer that is seen as the key enabler towards connection of all the objects using Industry 4.0 standard protocols along all product lifecycle phases [3] [4]. In this paper we will specifically focus on the service and maintenance phase and its importance due to high value associated services and new business models enabled by new advancements [5][6].
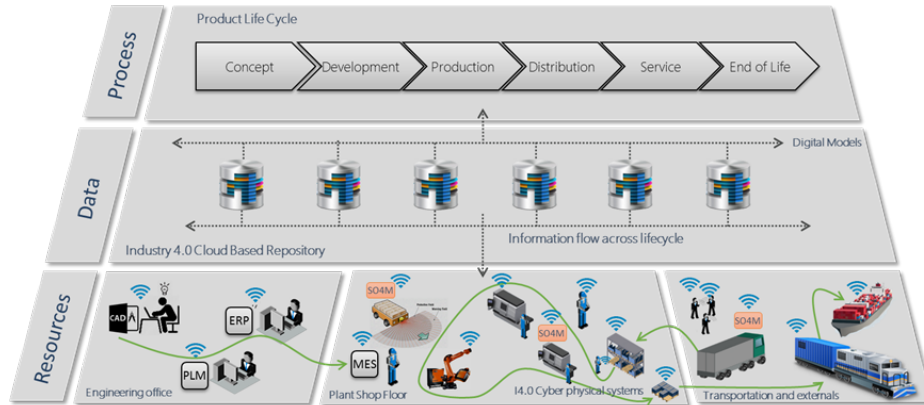
Figure 1 - Industry 4.0 as key enabler for product lifecycle management

The paper is organized in 3 main sections. Section 2 introduces existing Industry 4.0 concepts and reference models as well as enabling technologies and discusses its role in product lifecycle management. Section 3 addresses issues related to maintenance services and discusses the main benefits and opportunities that may envisioned by the usage of Industry 4.0 technologies. Section 4 presents a business case, where developed and implemented technology, including hardware and software are presented.

2. Product Lifecycle Management and Industry 4.0

In the last decades, product lifecycle systems progressed from systems dedicated technical data management to much broader concept. World class manufacturing organizations have expanded their product lifecycle management systems and their methodologies, to ensure an increase in the product life cycle coverage and traceability. Industry 4.0 paradigm forces new challenges, such as the development of intelligent products, factories and processes, and its integration through digital models. It is foreseen that future of production includes mass customization, flexible production systems, collaborative manufacturing networks and high level of servitization [3] [7] [8][3]. The creation of added value is then achieved by investing in supporting software and cloud based services, leading to smart products, capable of being customized and controlled remotely in a cyber physical environment using internet of things technologies. Today, PLM systems manage product data and control processes but the vision is to develop solutions for smart products and services, according to an integrated approach [5].

The Reference Architectural Model for Industry 4.0 (RAMI 4.0) introduces the concept of Industry 4.0 component. It is a model to describe in detail the properties of cyber-physical systems, i.e. real objects in a production environment linked to virtual objects. The real objects necessarily need to contain a set of defined properties in order to be considered compatible. One of the properties is the ability to communicate in real time and exposure of data and functions. An important prerequisite is that an Industry 4.0 component collects all the relevant data throughout its lifecycle, providing these data to the network of companies involved in the value added process. The data storage and respective communication methods are aggregated into what is called the administrative shell [1].

Consequently, Industry 4.0 advancements and methodologies offer new prospects toward the full lifecycle incorporation. Industry 4.0 establishes a change from enhancing physical advantages for streamlining how information and data are employed along the lifecycle. This computerized improvement lead to an end-to-end data stream going through the whole product lifecycle [9]. In the operation phase, new technologies can be used to add high valued services to products, such as maintenance services. The next chapter presents a typical maintenance process in mechatronics industry and a complete solution that was developed and tested in the context of a European project.

3. The Importance of Maintenance-as-a-Service

Maintenance management is now a major business concern and many organizations are not resilient enough to deal with business losses due to production delays. Breakdowns and downtime have an impact on the plant capacity, product quality, and cost of production, as well as health, safety and environment. The management of maintenance in large industrial operations is complex and has a significant impact on the profitability of the business. Maintenance of equipment is a significant part of the total operating costs in most industry sectors but its real impact is often misjudge [6]. The maintenance function is evolving from being corrective, to planned, to predictive to finally self-fixing. Industry 4.0 technologies can be used to help unlock the unused potential of consumer equipment by providing real-time data on performance levels.
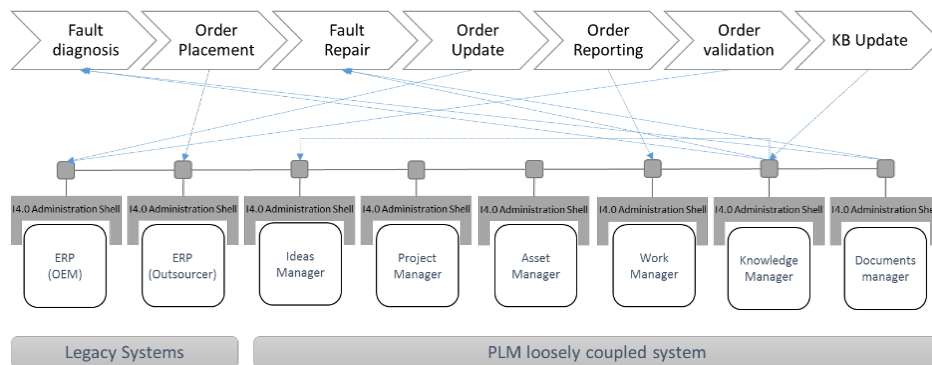

Figure 2 - System modules supporting maintenance activities

A data-based approach is taking maintenance to the next level and "Maintenance-as-a-Service" will soon become the order of the day. This approach will allow equipment to be monitored and fixed remotely. New business models will emerge where a product will be sold not at a fixed price, but rather on the basis of the throughput it can deliver in a given time [9]. The manufacturers will take responsibility for the equipment and ensure that you get the most out of it while they receive an annuity and additional business based on product and service quality. Total cost of ownership will soon take centre stage as the key measure of success [6]. Figure 2 depicts a typical maintenance process where an industry 4.0 enabled equipment send alerts to a cloud based maintenance management system. Based on the fault type, the manufacturer can remotely solve the problem or contact a partner to the job. Industry 4.0 technologies are the key enablers, integrating all the needed information (data, drawings, manuals, knowledge base, etc.).

4. Supporting System Implementation and validation

The developed application encompasses several modules such as ideas, projects, assets and tickets management as well as a knowledge base and a documents management system. All integrated using internet standard protocols. These modules support the full maintenance process. For instance, in the fault diagnosis task, the knowledge base and the documents manager are used. All the communication and integration requirements were achieved through the development of a compatible interface based upon the Industry 4.0 compliant protocols. In the case of this demonstration, the management system (Figure 3) was implemented in .net C# and uses a SQL Server Relational Database, so a specific Administration Shell for this system was implemented following the Project Reference Implementation, as RAMI 4.0 doesn't impose a specific standard so far.
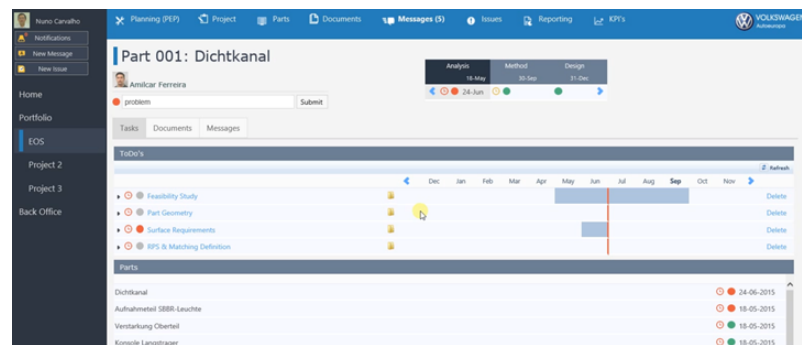

Figure 3 - Developed application

A smart object for manufacturing (Figure 4) is able to collect data from its surrounding environment and to process that data as the user intends. It is possible to identify three major components of the SO4M: Sensing, Communication, and Processing. The sensing part is responsible for collecting information from the environment, the communication used for interaction with the PLCs on the operating machines and the processing part, the "brain" in this SO4M, responsible for connecting and interpret the data. It is important to consider the requirements of the SO4M, so that, when the project is finished, it is possible to analyse which of them are complete and operational. In order to allow the SO4M to interact with the surrounding industrial environment, it was created an input/output interface (in form of a Printed Circuit Board), along with some crucial components to the proper functioning of the system. Initially there were defined the key features that this component should have in terms of digital inputs, Analogue inputs, Relay Outputs, Real-time Clock, Serial Port and a DC-DC Converter.
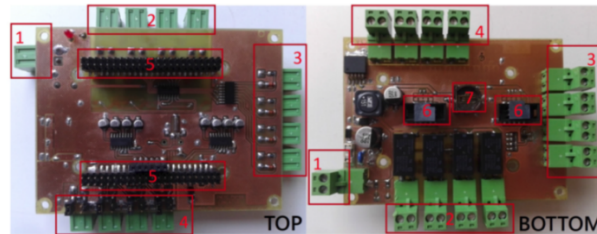
Figure 4 - Developed smart object for manufacturing

In order to test and validate the developed solution, a new machine was supplied with a smart object for manufacturing (SO4M) incorporated and installed in the costumer plant. When the machine started producing, the Smart Object for Manufacturing (SO4M) embedded in the machine sends a "new machine added" message, which triggers the creation of a new monitoring process instance for this customer. The instantiated process monitors in a continuous way the machine operation. To test the system, a fault in the laser sub system was forced and the embedded Smart Object sent an alert to the maintenance system using internet communication protocols to the manufacturer maintenance team (a screen with the technical assistance requests is in-stalled in the maintenance room). The flow of information is shown in Figure 5. Also, the standard repair process presented in section 3 is spawned.
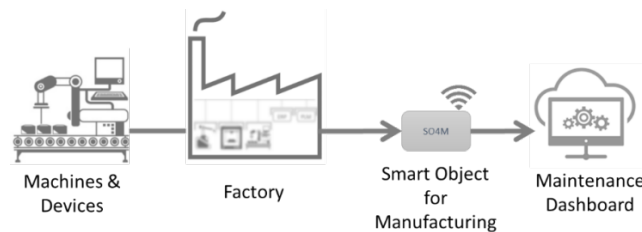

Figure 5 - Global information flow through smart objects

As the equipment was installed in Australia, the manufacturer selected a suitable partner. As the partner in Australia don't have an ERP, he reports the work done via the cloud based portal and all information needed to do the job (documents, manuals, specifications, etc.) is shared through the cloud based portal. Figure 3 shows an interface of the application. Note that for a given part or equipment, all the information, including tasks, data, documents and messaging exchange are integrated in one Maintenance Dashboard, simplifying process execution the activities and information flows.

5. Conclusions and Further Developments

Several technologies related to Industry 4.0 are being tested and introduced in industry. In this paper we presented several technologies and described the successful introduction of those technologies in mechatronics maintenance services.

Despite the success of the pilot business case implemented in the mechatronics industry, several challenges were identified related to the adoption of the technology and with the enterprise interoperability, so that the entire CPPS can work seamlessly. Most of today's IT systems are not fully integrated. Companies, suppliers, and customers are

rarely linked. Nor are departments such as engineering, production, and service. Functions from the enterprise to the shop floor level are not fully integrated. Even within engineering departments a full integration is still missing. Industry 4.0, is seen as the enabler to make companies, departments, functions, and capabilities more cohesive, as cross-company, universal data-integration networks evolve and enable truly integrated product lifecycle management.

Acknowledgements

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