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Procedia CIRP 38 (2015) 3 – 7

www.elsevier.com/locate/procedia

The Fourth International Conference on Through-life Engineering Services

Industrial big data analytics and cyber-physical systems for future maintenance & service innovation

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Abstract

With the rapid advancement of Information and Communication Technologies (ICT) and the integration of advanced analytics into manufacturing, products and services, many industries are facing new opportunities and at the same time challenges of maintaining their competency and market needs. Such integration, which is called Cyber-physical Systems (CPS), is transforming the industry into the next level. CPS facilitates the systematic transformation of massive data into information, which makes the invisible patterns of degradations and inefficiencies visible and yields to optimal decision-making. This paper focuses on existing trends in the development of industrial big data analytics and CPS. Then it briefly discusses a systematic architecture for applying CPS in manufacturing called 5C. The 5C architecture includes necessary steps to fully integrate cyber-physical systems in the manufacturing industry. Finally, a case study for designing smart machines through the 5C CPS architecture is presented.

Peer-review under responsibility of the Programme Chair of the Fourth International Conference on Through-life Engineering Services.

Keywords: Cyber-physical systems; industrial big data; predictive maintenance; intelligent maintenance systems

1. Introduction: Unmet Needs in Today's Industry

During past several decades, manufacturers and service providers have taken a significant step towards improving the quality of products and services, and optimizing their processes in order to maintain their competency and respond to market demands. Since the development of the concept of preventive maintenance and Total Productive Maintenance (TPM) in 1951 [1], maintenance practices have evolved from being organization-centric focused on quality, to customer-centric focused on value creation and smart services. This evolution has led to the development of Prognostics and Health Management (PHM). PHM solutions are capable of transforming the data into desired information and knowledge about the invisible patterns of degradation in assets, and inconsistencies and inefficiencies of the processes. These patterns are mostly invisible, until a failure occurs [2]. The discovery of such underlying patterns avoids the costly failures and unplanned downtime of machinery. Such maintenance scheme leads to greater asset sustainability and eventually near-zero breakdown. Moreover, making these invisibles visible can help adjust and tune the processes to make them more consistent and efficient.

Despite the inherent challenges of developing PHM for complex machinery and processes, this field of research has grown significantly and has facilitated the development of intelligent maintenance systems. In the past several years, the rapid advancement of Information and Communication Technologies (ICT) has facilitated the implementation of advanced sensors, data collection equipment, wireless communication devices and remote computing solutions. Such technologies, along with the advances in predictive analytics, are changing the face of the modern industry. Integrating advanced analytics with communication technologies in close conjunction with the physical machinery has been named cyber-physical systems (CPS) [3].

Since the creation of its concept, CPS has been an ever-growing terminology in today's evolving industry. It

Peer-review under responsibility of the Programme Chair of the Fourth International Conference on Through-life Engineering Services.
doi:10.1016/j.procir.2015.08.026

addresses the integration of physical systems with computational models. Such scheme has a vast area of application including process control, energy, transportation, medical devices, military, automation, smart structures etc. [2]. Currently, the CPS concept is still under development. In the area of asset management, CPS has the potential to provide self-awareness and self-maintenance capabilities. The implementation of predictive analytics as part of the CPS framework enables the assets to continuously track their own performance and health status and predict potential failures. By implementing this predictive analytics along with a decision support system, proper services could be requested and actions taken to maximize the uptime, productivity and efficiency of the industrial systems. CPS, as the central hub for data management in fleet level, plays a critical role in achieving the above-mentioned goals.

2. Internet of Things and Evolution of Industries

The Internet of Things (IoT) [4] is able to gather, sort, synchronize and organize the data from different sources within a factory or business. It provides a tether-free and connected data management platform with real-time streaming and processing capabilities. Such platform brings about the capability of implementing big data predictive analytics for transformation of data to information to knowledge to action through a CPS structure. The pipeline of data to action has the potential to create value in different sections of a business chain. For example, valuable information regarding the hidden degradation or inefficiency patterns within machines or manufacturing processes can lead to informed and effective maintenance decisions which can avoid costly failures and unplanned downtime. From business perspective, such platform can effectively be used for customer relation management, supply chain management, execution branch and enterprise resource planning. This is made possible through the collection and intelligent analysis of massive amount of data gathered from numerous sources including market trends, economical factors, current and future demands and enterprise resources. Figure 1 provides an schematic view of how big data analytics can create value within different sections of industries. In the next section, the structure of CPS along with its implementation aspects is discussed.

3. Cyber-physical Systems

The CPS structure, proposed in [5], consists of five levels namely 5C architecture. This structure provides a guideline for the development of CPS for industrial applications. This CPS structure consists of two main components: 1) the advanced connectivity that ensures real-time data streamlining from the physical space to cyber space and feedback from the cyber space; and 2) intelligent data analytics that constructs the cyber space. The proposed 5C structure provides a workflow that shows how to construct a CPS system from the data acquisition to value creation. The framework of CPS in different levels is shown in Figure 2. The 5C structure consists of Smart Connection, Data-to-info Conversion, Cyber, Cognition and Configuration levels.

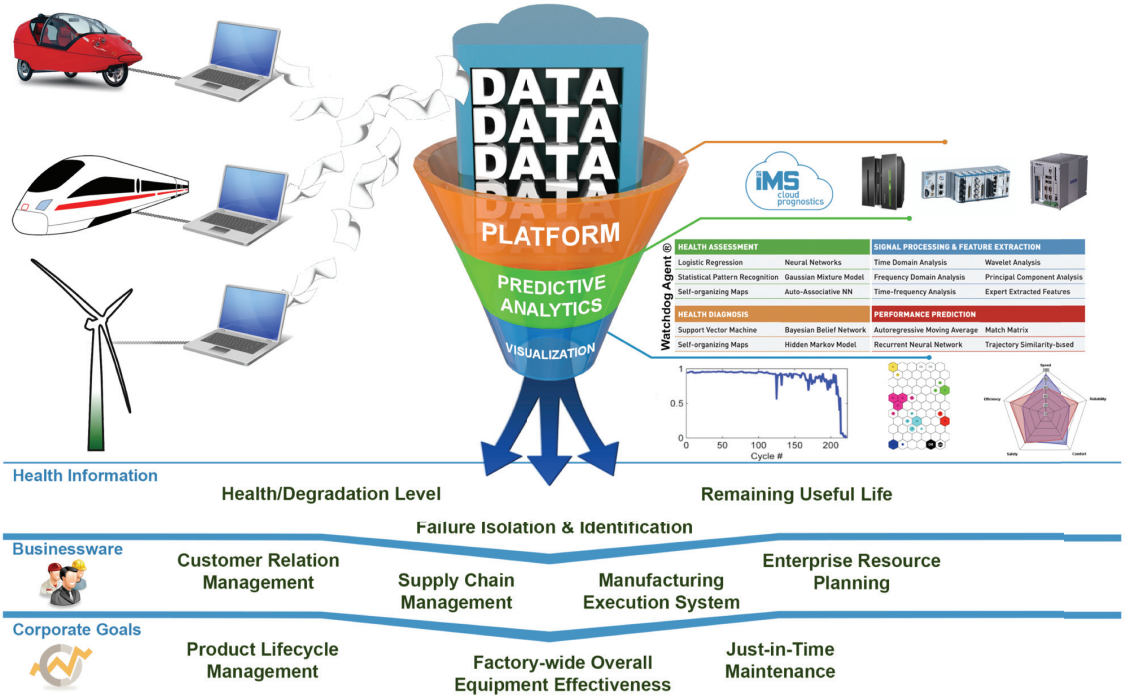

Figure 1. The framework of big data analytics platform for predictive manufacturing [2]