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Introduction to cyber manufacturing

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Abstract

Cyber manufacturing is transformative concept that involves the translation of data from interconnected systems into predictive and prescriptive operations to achieve resilient performance. It intertwines industrial big data and smart analytics to discover and comprehend invisible issues for decision making. With the advent of Internet-of-Things (IoT) and smart, predictive analytics technologies, companies have been building a networked data-rich environment, which calls for a systematic methodology to transform raw data into meaningful and actionable operations. This paper introduces a fundamental framework and architecture for cyber manufacturing systems.

Keywords: Cyber manufacturing; Cyber physical systems; Big data; Cyber security; Internet of things

1. Introduction

Today's manufacturing operations integrate resources in a more complex manner and global scale. Such levels of scale and complexity requires extensive collaboration. Through open innovation, companies can use crowdsourcing to bring in new resources to accelerate the innovation processes [1]. To achieve this, open platforms that consist of a wide spectrum of analytics tools are needed to support design, manufacturing, and services—currently, there are many on-going efforts to accomplish this. For example, GE has announced Predix™ as a cloud-based service platform to enable industrial-scale analytics for management of asset performance and optimization of operations [2]. National Instruments has introduced Big Analog Data™, which is a three-tier architecture solution [3], and has ported the Watchdog Agent™ Toolkit into its LabVIEW development environment to support the rapid creation of smart analytics solutions throughout different big data applications [4,5]. Germany is supporting Industry 4.0 as a new initiative to transform cyber-physical production systems as next-generation smart manufacturing systems [6].

The number of efforts in this area is exemplary of the need for a multi-scale platform to address the following transformations in tomorrow's manufacturing:

1.1. Transformation from machine-based to evidence-based decision making

Traditionally, manufacturing system management heavily depends on experienced personnel. As these personnel, many of which are members of the "baby boom" generation, begin to retire, a great wealth of knowledge, know-how and understanding are lost. Therefore, a smart analytical system is needed to transform experience-based know-how into evidence-based decision making for sustainable operation.

1.2. Transformation from solving visible problems to avoiding invisible issues

Manufacturing issues can generally be divided into visible and invisible categories [7]. Through smart analytics of interconnected multidimensional systems, correlations and

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causal functions can be modeled so that meaningful and actionable operations can be extracted.

1.3. Transformation from control-oriented machine learning to data-rich deep learning

Conventional artificial intelligence-based machine learning technologies have been developed primarily for smart machine control. However, in a networked, data-rich environment, data conditions are dynamically changing which necessitates greater resilience in modeling of unknown issues. And rather than control, the purpose of cyber manufacturing is to enable users to comprehend the invisible causal relationships and make optimized decisions.

2. Definition

Cyber manufacturing is a transformative system that translates data from interconnected system into predictive and prescriptive operations to achieve resilient performance (Fig. 1). It intertwines industrial big data and smart analytics to discover and comprehend invisible issues for decision making. In addition, a cyber-physical interface (CPI) plays a key role in cyber security for connected machines (see Section 3.2.1).

Cyber manufacturing evolved from e-manufacturing, which is a systematic methodology that enables manufacturing operations to successfully integrate with the functional objectives of an enterprise through the use of tether-free (i.e. Internet, wireless, web, etc.) communication and predictive technologies [8]. As indicated in Table 1, both e-manufacturing [8] and cyber manufacturing aim to reduce unexpected downtime and integrate operations with enterprise objectives. However, cyber manufacturing is targeting a system that is much more complex and data-rich, where technologies including smart analytics, distributed systems, control science, and operation management need to be integrated to construct a cyber-physical model [9]. Also, unlike problem-specific solutions in e-manufacturing, cyber manufacturing deploys digital twin technologies to support the life cycle of products. This will enable control systems to compensate or responsible personnel to intervene at the right time on the right assets. Currently, GE is developing Brilliant Manufacturing as a transformational system in the cyber manufacturing environment [10].

3. Challenges

3.1. Lack of standards for seamless connectivity

Compared to existing Internet-enabled industries, manufacturing assets are less connected, and even those assets that are tend to follow customized protocols. In spite of progresses made in CNC machines, which resulted in protocols such as MTConnect [11], the majority of the equipment use different types of sensors, hardware and software, which leads to different data formats and acquisition requirements. Such situations leave end-users faced with challenges to bring seamless connectivity into their manufacturing plants. Currently, there are several initiatives to address standardization issues and to make technologies more open-access. The Digital Manufacturing and Design Innovation Institute (DMDII) has announced an open-source project called Digital Manufacturing Commons (DMC) [12,13], that enables technology developers to access and interact with data from various vendors. The National Institute of Standards and Technology (NIST)

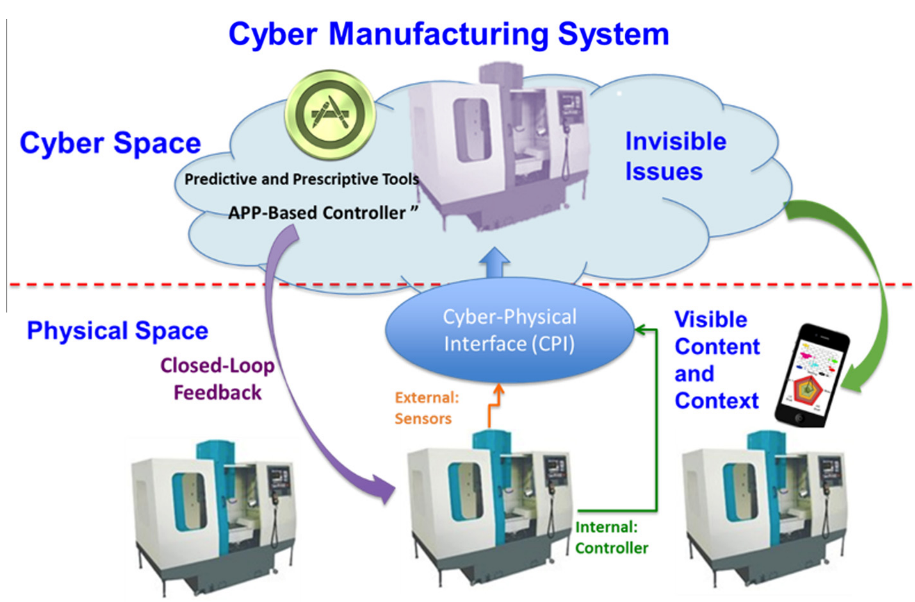

Fig. 1. Cyber manufacturing system.