Fall | 16

Emerging Technologies and Their Roles in Smart Manufacturing

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This paper explores manufacturing organizational structure and function along side emerging technologies such as smart-connected devices, cloud computing, and big-data. Additionally, this document investigates how, with the integration of breakthrough technical innovations, statistical and machine-learning methods can be implemented to generate value from the high volume of data collected from these cyber-physical systems in specific areas of manufacturing, including product design, process and planning, quality management, maintenance, scheduling, supply chain, and other various business functions.

PHYSICS 365 – Cyberscience: Computational Science and the Rise of the Fourth Paradigm

Table of Contents

Introduction

With the abundance of computational and technological advancements emerging in the 21st century, industry is on the verge of a data revolution. Smart-connected products, cloud-based computing, and data storage innovations are transforming the way companies operate in every aspect of business. Companies within various industries are looking to harness insights from advanced statistical methods and machine learning algorithms that will refine and polish their value chain. Specifically, the manufacturing industry is seizing the opportunity to enhance product design, process and planning, quality management, maintenance, scheduling, and other various aspects of the field through big data analytics.

The rise of the concepts of Smart Manufacturing (in the United States) and Industry 4.0 (in Germany) have become more popular due to recent developments in cyber-physical systems, big data, cloud computing, and industrial wireless networks [1]. Breakthrough technology in Internet of Things (IoT), Big Data, and Cloud Computing are highly regarded as the three main aspects of smart manufacturing. The integration of these technologies enables manufacturing companies to realize the full effects of intelligent manufacturing. This paper identifies technological innovations and how they will enable factories to become more intelligent and optimize a companies value chain through a highly correlated network of connected devices, deep integration of data with cloud platforms, and industrial big data analysis.

Internet of Things (IoT)

While there is no universal definition for the Internet of Things, it is generally considered to be the interconnection of devices embedded with software, sensors, and connectivity that interact with the network by exchanging data from internal and external sources to each other. A man named Kevin Ashton, cofounder of the Auto-ID Center at Massachusetts Institute of Technology (MIT) that created a standard system for radio-frequency identification (RFID) and various other sensors, coined the term. In an interview with *Smithsonian Magazine*, Ashton was asked to describe his interpretation of the "Internet of Things" and stated that in the past computers were only subject to the information that was given to them, now with the emergence of smart-sensors, computers have the ability to interpret their environment and relay information through a network [2]. Furthermore, the Internet of Things is the idea that devices are not only connected to the network, but also connected to each other. This is known as the Web of Things (WoT), various products are connected and working together cohesively to exchange information autonomously.

IoT devices establish a new way of monitoring, controlling, and optimizing processes and performance. The sensor data enables users to monitor the condition of the device and the environment, the connectivity to a network enables users to remote-access the device for control and configuration, and lastly the combination of both the monitoring and remote-access empower users to interpret data in real-time to improve utilization, uptime, and product performance [3]. The insights that these products offer have resulted in the immersion of this technology in various cases, for example industrial automation and management of manufacturing equipment and assets. In fact, manufacturing is the leading sector when it comes to research and implementation of IoT technologies, driven in part by the need for real-time information to optimize productivity [4].

Additionally, manufacturing is leading in research and implementation of IoT technologies due to various industrial processes such as Asset Management and Supervisory Control and Data Acquisition applications. Due to the real-time data exchange from IoT devices hosted on machinery on the plant floor, management systems can monitor and display the current status of assets, which allows for greater vision of plant floor operations and contributes to more effective maintenance and optimal response time. Additionally, due to the connectivity of these devices from machine to machine (M2M), machines can now communicate with each other to support internal logistics, part traceability, and to exchange part specific data such as dimensions and compensation values that are used at machining and tooling operations further down the production line.

While a system integrated with IoT devices has tremendous value, there are challenges that must be overcome to support this infrastructure. In order to ensure stability at a company-wide level, there must be solutions to account for heterogeneous devices across facilities, fusion of information from various sources, reliability in harsh industrial environments, and strong safety and security constrains.

Cloud Computing

Cloud computing is a technology model for enabling the delivery of IT resources (i.e. servers, storage, applications, etc.) on demand [5]. Cloud is implemented, generally, in one of three major formats: 1) Software as a service (SAAS), which is access to software applications over the internet rather than having it locally on a personal hard drive, 2) Platform as a service (PAAS), which allows users to rent software development or production environments to develop and deploy new applications without investing in hardware and software licenses, or 3) Infrastructure as a service (IAAS), which gives organizations access to computing infrastructure whether it be for computer processing or data-storage. Due to manufacturing's deep IT infrastructure roots, cloud-based solutions offer a strategic advantage and will impact virtually every aspect of modern manufacturing. From enterprise resource planning and financial management software, to hosting database servers that store the massive volume of data collected from the variety of plant floor operations connected to IoT devices, and analytics packages that will derive insights from this data, cloud computing will be an integral part in how these companies manage their internal operations and how they facilitate outreach to customers. One interesting example of how cloud solutions can improve customer relations and internal shipping is the support of online supply chain portals that allow customers to see and fulfill material orders. This solution indicates when a product is being prepared to ship and when it is in transit, ultimately delivering direct insights regarding the logistics of orders and streamlining communication among business partners.

One area of pain that manufacturers have to face is intelligently integrating data stream from myriad partners, platforms, and devices. This is much more difficult to do inside companies' own data centers as opposed to in well-networked data centers operating in the cloud [5]. Overall, utilizing a hub of remotely located datacenters that enable cloud-computing (host software, computer processing, and data storage) capabilities is a crucial step in modernizing manufacturing as it provides benefits such as speeding up innovation cycle times, accelerating time to market, facilitating collaboration, supporting supply chain integration, increasing operational efficiency, and reducing cost [5].

Big Data Analytics

With the IT landscape now revolving around IoT and the creation of a large amount of data hosted on a centralized server, whether it be in the cloud or a local datacenter supported by the organization, the need for artificial intelligence algorithms, programmed by statistical and machine learning methods is necessary for automated decision making after smart sensing/monitoring. The data obtained from various sensors and devices is what is referred to as "Big Data". There is a variety of data information being collected from IoT, and is diverse in nature without standardized metadata, which means that it may be structured or unstructured with diverse data models, types, formats and query languages.

With the abundance of data, there are two main methods in which this information is utilized. The first is real-time data analysis and continuous processing. An example of this would be overall equipment effectiveness (OEE), in manufacturing, which tracks cycle time of a machine tool, how many good and bad parts are processed with certain piece of equipment, if a machine is operational or not, and other additional performance characteristics. The second is deep data analysis, which takes into account real-time and historical data to predict outcomes. For example facilities will use deep data analysis to predict when a manufacturing asset may break down thus allowing maintenance to take preventative steps to ensure there is limited downtime [6]. Another interesting aspect in which Big Data will undoubtedly affect is Continuous Process Improvement (CPI). CPI is defined as an ongoing activity aimed at improving processes, products and services through sustainable changes over a period of time [7]. The traditional method of improving processes is through Lean Six Sigma or statistical analysis of process data in order to identify the critical parameters and the variables that have the most impact on the performance of a value stream and to control their variations. However, because of the significant leap in amount of data, these traditional methods require a breadth of new big data analytics tools, such as Hadoop MapReduce, which is a software framework for easily writing applications which process vast amounts of data (multi-terabyte data-sets) in-parallel on large clusters (thousands of nodes) of commodity hardware. By utilizing these large clusters, one is able to sift through massive amounts of data and carry out statistical analysis. One entry from the IEEE International Conference in 2015 about big data discusses how a team was able to use Hadoop MapReduce for big data-driven clustering, which they found was an efficient way of discovering real-time unusualities in a manufacturing process and their route-cause analysis [7]. The other aspects of manufacturing that are affecting by big data analytics include: research & development, quality management, and product development.

Conclusion

The integration of these three innovative technologies: Internet of Things, Cloud Computing, and Big Data Analytics is the heart of Smart Manufacturing and will be the catalyst for technological innovation in industrial solutions. The data collection generated through smart-connected devices on the plant floor and their connection to cloud-based storage services functions as the back-end infrastructure for big data analytics that will modernize all aspects of manufacturing.

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