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A Study of Big Data and its Applications for Manufacturing Information Systems

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Abstract : This paper is aimed at discussing the recent developments on the Internet of Things and its applications, and also the impact of recently evolved Big Data on manufacturing information systems is mainly discussed. Big Data analytics has been identified as most important technology to support data acquisition, storage, and analytics in data management systems in modern manufacturing. The main idea of the presented work is to clarify the requirements of predictive systems. Also to identify challenges in research and opportunities on Big Data Analytics to support cloud-based and other information systems.

Keywords : Big data analytics (BDA), Internet of Things (IoT), software as a service (SaaS), platform as a service (PaaS), infrastructure as a service (IaaS), predictive manufacturing, cloud manufacturing, cloud computing

1. INTRODUCTION

May it be the monitoring shop floor operations, fine-tuning supply chain operation, measuring the consumer sentiment, or any other large-scale analytic challenges, big data is has tremendous impact on the enterprise. The amount of business data that is generated is rising steadily every year and more and more types of information are being stored in digital formats. The important challenge is learning how to deal with all of these new data types and determining which information can be used to provide some potential value to your business. It is not just access to new data sources, selected transactions or events, but the patterns and the relationships among these elements that are of interest. Collecting huge volumes of diverse types of data very quickly does not create value. We need analytics to uncover insights that will help our business.

An Analytics system is defined as a system to process the data inputs into outputs such as knowledge, wisdom, and decisions in the system operation. The system complexity depends on the numbers of inputs and outputs, their correlations, as well as their dynamic characteristics with respect to time considering the domain of Manufacturing, for that matter any other domain as well, An information or decision system can be measured by its capabilities of dealing with the volume, variety, and velocity of data. And also its responsiveness in making decisions about system operations. Emerging information technology affects the development and the performance of manufacturing information systems greatly.

In our paper, we are motivated to have a thorough literature review to (*a*) study the concepts, and research trends of big data and its Analytics; (*b*) gain the valuable insights into Big Data and its influence in particular on manufacturing process; and (*c*) identify new challenges and opportunities of Big Data Analytics.

2. BIG DATA – WHAT IT IS? WHY IT IS? HOW IT IS?

Collection of Data and its analysis are key to any information system. The complexity and the capacity of an information system relates closely to the data that is available and the ways to process the data. With the rapid

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development of hardware and software, data has become ubiquitous. The latest advancements in technology, the evolution of Internet, wireless networks, and low-cost memory,etc. have contributed to the exponential growth of data.

Dealing with data has been more deeply woven into the fabric of our lives than ever before. Big Data has emerged as a new research field called data science, and Big Data Analytics comes as a promising methodology to retrieve knowledge from the so-called massive data.

In that line, One example of such organizations is the SAP , which has provided a no. of successful Big Data applications. They include over $1 million savings from fraud detection by the American Airlines annually, $100 million untaxed earnings by the State of Sao Paulo in Brazil and a 3- to 15- times increase in purchase rates from HMV in Japan. The study has shown that data-directed Big Data Analytics achieves up to a 6% productivity boost; Similarly, a study conducted by IBM indicated that the organizations that leverage big data will outperform their peers by more than 25%.

The ultimate driving force for all these is to fill any gaps of interactions among people and also change the business models of organization. The development of embedded systems, micro systems, and electronics stimulates the innovation and value adding across economies (European Commission, in it report, 2013). The recently developed Internet of Things (IoT) has attracted the interest of public and investment in many research domains all around the world. Also the cloud-based application needs support from Big Data.

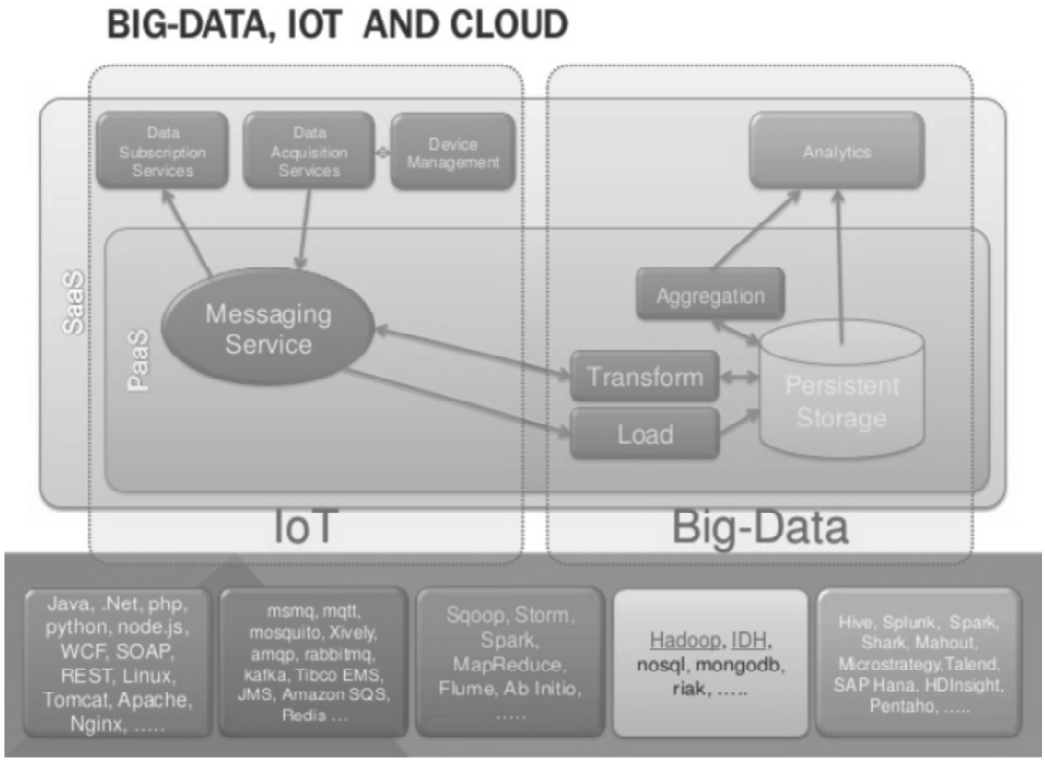

Fig. 1. Bigdata, IoT and the Cloud.

As shown in Figure 1, an Information system can be compared analogous to a manufacturing system. The acquired data can be viewed as Enterprise data materials and the products are knowledge, wisdom, or decisions. For data collection, IoT enables the cloud to gather data from various data sources including the Internet, sensors, log files, traditional Relational Database Management Systems (RDBMS), and tracking systems. The volume of data is growing consistent with Moore's law [11]. For the management of fast growing data, cloud computing offers reliable services by deploying cloud data centers. Some examples of such technologies are MapReduce and NoSQL. They are needed to deal with big data and to retrieve relevant data effectively. For utilization of data, different tools are developed to analyze the retrieved data and extract knowledge to support decision-making activities.

The present trend is the Service based economy. Organizations are getting their products (knowledge, wisdom, or decision) via services. They are able to access data and data-processing tools from a cloud anywhere and at anytime it is required. The cloud includes internet-based data access to affordable computing applications. The data that is stored in the cloud is operated in the *write once and read many* (in short - WORM) term. This is different from the traditional *write many and read many* (in short - WMRM) in storage systems. Thus, the data stored in the cloud can be accumulated rapidly as big data, particularly when there are millions of things input data into the cloud. The concept of Big Data is about the characteristics of the datasets and the methodologies for processing the data.

There are several definitions of Big Data, and most of the definitions refer to the growing technologies to capture, aggregate and process an ever-greater volume, velocity, and variety of data [7]. Big Data refers to the data whose volume, velocity, and variety is more than the capacity of an organization to process and analyze it in an orderly manner. Apart from the above described Vs, Big Data also come with a big dimensionality. It refers to the explosion of features or variables that bring new challenges to data analytics. Big Data implies fine-grained data, which can describe the same event with something much more precisely to support better decision-making .

3. CASE STUDY – ANALYTICS AND INFORMATION SYSTEMS IN MANUFACTURING

In the current section, we are going to discuss the application of Big Data Analytics in particular to Manufacturing Systems is discussed. A manufacturing system needs analytics to take decisions for operations at various levels and domains. For any information system , the complexity depends on total number of inputs and outputs as well as their relations. In manufacturing systems, several workers have investigated the impact of IT, such as mainstream computers, sensor networks, and obviously the Internet, on the development of information systems [2][14] In the following sections, we look into (1) how the scale and complexity of information systems is changing; (2) available hardware and software IT for this information systems; and (3) the requirements of IoT-based systems. As cloud manufacturing has been identified as the most promising paradigm for next-generation manufacturing systems, we pay our attention to the roles of Big Data Analytics in cloud manufacturing.

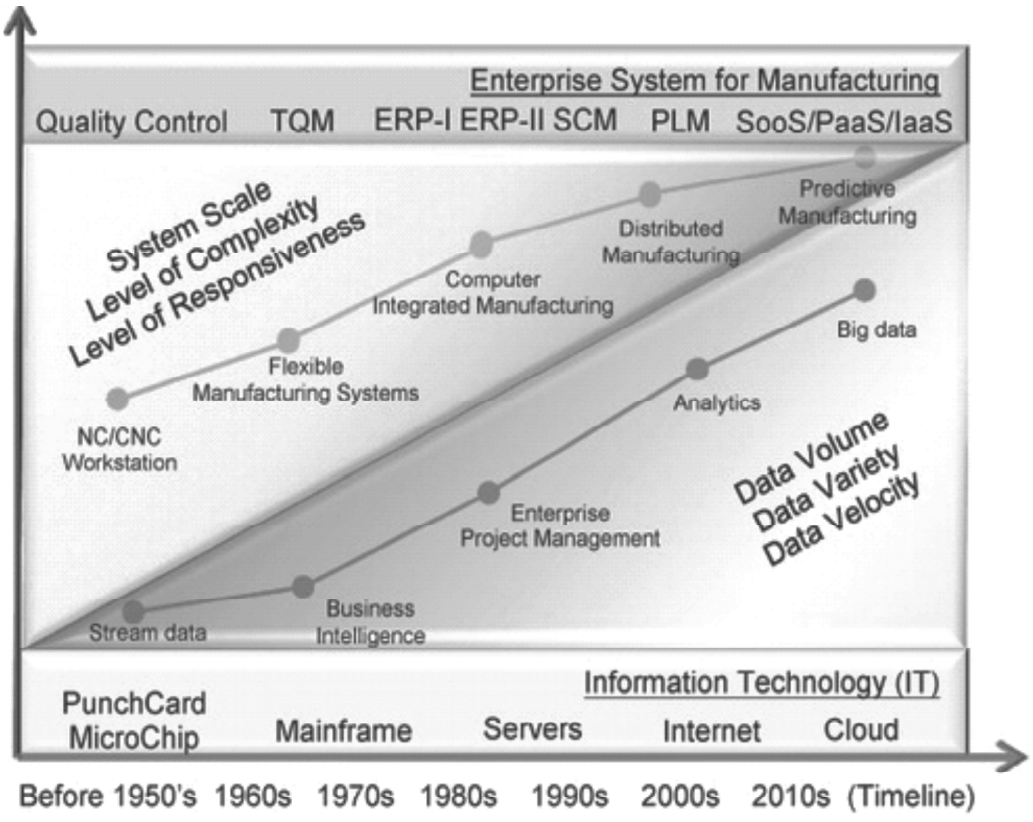

Fig. 2. Evolution of Manufacturing Technologies and Information Technology(IT).

The advancement of a manufacturing system can be measured by scale, complexity, and responsiveness of automation [2][8]. As shown in Figure 2, the levels of all these three matrices are increased continuously over time. The evolution of manufacturing technologies is classified into the phases of using Numerical Control workstations, Computer integrated manufacturing, flexible manufacturing systems, distributed manufacturing . Various software's that support these manufacturing technologies are Quality Control , Total Quality Management , Product Lifecycle Management (PLM), Enterprise Requirements Planning and Software. Also the these services of Cloud namely Service (SaaS)/ Infrastructure as a Service (IaaS)/Platform as a Service (PaaS). Correspondingly, the volume, velocity, variety of the data of different information systems has been increased tremendously from stream data in the digital era to big data today. IT hardware systems must be capable of processing data in a timely manner. Parallely, the computing environments have changed from mainframe, servers, the Internet, to today's Cloud.

Now it is possible to connect with people around the world with technology; also, It brings new possibilitiesto share knowledge via collaboration over the cloud [12]. Cloud technology will allow organizations to change their business models by catching new businesses, enhancing productivity, minimizing cost, accelerating deliveries. Also it helps in maximizing satisfaction of the customer and market share. Thus, the cloud concept was adopted by manufacturers as Cloud Manufacturing (CM). CM can be defined as a cyber-physical system; it offers on-demand manufacturing services with an optimized utilization of manufacturing resources. Cloud Manufacturing is a customer-oriented manufacturing model. Organizations benefit from the share-to-gain philosophy so that manufacturing resources and expertise from different resources are used to provide participants with the enhanced capabilities thus offering a very high level of customer satisfaction.

With fast growing wireless sensor networks and Internet of Thing (IoT), the data have become ubiquitous and easily accessible; thus it contributes to the BD manufacturing environment[5]. The information processing is becoming more and more powerful and flexible nowadays. Information systems can benefit from Big Data greatly in performing 5C functions namely, 'connection' with sensors and networks; 'content' to mine correlations and meanings; 'community' to share data and promote social interactions; and 'customization' to personalize products or services;'cloud' to store and provide data anytime and anywhere. Thus, Embracing Big Data in Information Systems is actually an expansion of conventional Information Systems.

Fig. 3. A sample Manufacturing Plant.

An enterprise system can continue to take decisions regarding operations involved in the product lifecycle from raw materials, about manufacturing processes, assembling, to final products and after-sales and services. However, the boundary of a manufacturing system with its business environment is becoming very vague for good reason. Any manufacturing system should provide value to its customers. This value stream may include product development and its supply chain, business relationships,etc. The capabilities of the Information System must be enhanced greatly in the sense that (1) relevant data in the cloud arrives not only from the enterprise itself, but also from other sources in IoT, including all participators in its supply chains; (2) Big Data management tools become essential to retrieve relevant data; and (3) all of the data utilizations are performed by connecting to services in the Big Data.

4. CHALLENGES OF BIG DATA IN MANUFACTURING

The business models for both information and communication technology providers and their customers, including manufacturing organizations have changed by Big Data. Big Data Analytics is helping manufacturing organizations to process huge data and gain global competitiveness for their business. In Big Data, all of the application tools, platforms, and infrastructure are connected and accessed as services over the cloud[14]. Big Data has a great impact on manufacturing enterprises. Any Enterprise systems relies on data to fine-tune supply chains, plan and schedule its operations at the shop floor, gauge consumer sentiment, and some go as far to say to make strategic plans based on, 'high-level analytics on large-scale datasets'.

However, Big Data Analytics and its application in Cloud Manufacturing are still at the budding stage. In the survey of over 500 large-scale companies made by TATA (2012), there were several interesting findings, including: (1) only a small no. of companies was using Big Data, even though the no. of these companies is rapidly increasing; (2) the biggest driver for using Big Data was to standardize the business processes and software tools rather than to minimize IT costs; (3) the largest Big Data users were the manufacturers who provide IT hardware for Big Data; (4) the majority of the organizations were reluctant to put their applications with sensitive data in the cloud; (5) enterprises assessed Big Data vendors mostly on their security, reliability, and uptime capabilities. Wegener and Sinha (2013) found that many executives did not think their enterprises were equipped to utilize BD. Among over 500 global companies, only 5% of them agreed that they had the right people, right intents, and appropriate tools for big data to obtain meaningful insights from the data and act upon it accordingly.

4.1. Protection of privacy of the data

Privacy is one of the important challenges faced by big data. It especially comes into picture when data are shared among industry sectors. In general, privacy is relied largely on technological limitations to extract, analyze, and to correlate sensitive datasets. However, the advances in Big Data Analytics makes it easy to extract and compare the data. Therefore, the big data analytics methods must consider the privacy principles and recommendations to ensure the safety of application over the cloud. Data provenance is another important challenge. It is hard to validate that every data source meets the required trustworthiness to produce acceptable results. It is required to consider data authenticity and integrity in developing Big Data Analytics tools. Implementation of Analytics requires a balance between opportunities and security assurance. For example, aircraft manufacturing is complex; it requires global technical collaboration over its life-cycle, while engineering data must be under strict control even in the cloud [1][14].

4.2. Other challenges

Different from the application of Big Data in other areas, Cloud Manufacturing operates on the manufacturing resources and their associated services; domain-services should be developed on the top of SaaS, PaaS and IaaS , such as Testing as a Service, Simulation as a Service, and Management as a Service, Production as a Service, Design as a Service. Besides the technical challenges, the applications of Big Data Analytics in manufacturing also face the problems of increasing financials costs, scarce solutions for integration of verticals, lack of workers with IT skills, and lack of SME focus by IT vendors (KPMG 2011). From the perspective of the hardware development, Zou, Yu, Tang, Chen, and Chen indicated there are the gaps between the required capacity of computation and the available capacities of the high-end computing machines.

5. DISCUSSION

Leveraging on abundant data to obtain smarter decisions requires new thinking. Big Data does not mean that enterprises had only 'small data' before. It means a radical shift of data environments in terms of volume, velocity, and variety. Big Data creates an architectural upheaval where systems, storage, and software are connected and managed. The driving force for Big Data is the software and platforms for infrastructure and analytics. Four

primary technologies to accelerate processing over huge datasets are *grid computing*, *in-memory analytics*, *in-database processing* and *Hadoop* [4]. Grid computing provides dynamic workload balancing and parallel processing for data management and analytics. In-database processing uses scalable architecture to reduce processing time for preparing and analyzing of data.

Of all, the significant architectures available to deal with Big Data Analytics are the Extended RDBMS and MapReduce/Hadoop. Hadoop is the primary infrastructure used to distribute, manage, and query data across multiple, horizontally scaled service nodes. It is an open-source product from Apache, and Not Only SQL databases do not require significant license costs of traditional systems; [3][5]. Apache Hadoop consists of two main components, i.e., (i) a Hadoop Distributed File System (in short, HDFS), which is a self-healing, high-bandwidth clustered storage, and (ii) MapReduce, which is fault-tolerant distributed. A no. of Hadoop implementations are applied in IT giants such as Google and Yahoo. Hegeman et al. designed a logical workflow based on MapReduce; it consists of three levels of data dependency, i.e., inter-query, inter-job, and intra-job.

6. SUMMARY

Cloud has started becoming the infrastructure for analytics services on pervasive and scalable data; More than 50% of large companies will adopt the cloud for their data management by 2016. Extracting knowledge and wisdom from huge data sets needs scalable and intelligent algorithms, and corresponding applications. Big Data and its tools have been developed and described to serve this purpose; Big Data has been used in predictive analytics for decades. However, Big Data Analytics is facing new challenges due to the rapid growth of data in terms of volume, velocity, and variety from the IoT.

Attention and Focus should be kept on the applications of Big Data Analytics in cloud manufacturing. Nowadays, the success of a manufacturing organization relies greatly on the advancement of IT to support and enhance the value stream. Big Data Analytics tools help an information system to capture, process, and use ubiquitous data from IoT effectively. It allows a manufacturing enterprise to capture business opportunities, to readily adapt to change and to deal with uncertainty promptly. However, the development of Big Data Analytics for cloud manufacturing is preliminary; intensive research efforts are in demand to address the concerns about integration frameworks, advanced Big Data Analytics tools, privacy protection, customized applications for SMEs, and other challenges. This reported work will be used as a guide for us in developing integrated Big Data Analytics tools for cloud manufacturing.

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