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(Review Article)

Research on architectural model and implementation method for smart manufacturing system of printing factory

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Abstract

In order to implement SMS(Smart Manufacturing Systems), it is needed to realize horizontal integration, vertical integration, end-to-end integration of the plant and establish an architectural model of SMS using CPS(Cyber-Physical System), industrial IoT, cloud computing, big data analysis, artificial intelligence techniques, etc. There are several reference architectures for industry 4.0 such as IIRA, RAMI4.0, SITAM, IVRA, IBM Industry 4.0, and LASFA, but there are advantages and disadvantages with each other, and it is needed to find the architectural model and implementation method that can be customized for use in cases of specific smart factories. Print production systems have characteristics of highly personalized customer requirements, mass production and complexity of production processes.

In this paper, based on the comprehensive analysis of the results of the SMS architectures, we build an effective SMS architectural model for the printing factory producing educational books and describe the success and experience through the practical process of studying, developing and building SMS.

Keywords: Smart Manufacturing Systems; Cyber-Physical System; IoT; Cloud Computing; Big Data; Digital Twin; Customer Relationship Management

1. Introduction

Printing is one of the ways in which digital information can be converted into a physical format [1].

The print production process has not yet been treated as a standard manufacturing activity due to its own unique characteristics: from the product's perspective, it simultaneously demands both product diversity and mass production; from investment's perspective, it is both capital-intensive and labor-intensive.

The highly variable and dynamic job mix with highly personalized customer requirements results in many different combinations of equipment, resources, print shop configurations and business philosophy. Such artisan (or craftsman) decision-making practice has been identified as one of the key reasons that the productivity growth of the print industry as whole is falling far behind other manufacturing industries [2].

Furthermore, the personalization and variability of the demand for educational books are now increasing.

Simulation based modeling can help to optimize the print production system at both strategic and operational level. It can help to determine optimal workflow, predict production bottlenecks, guide capacity planning, and incubate different print production paradigms without incurring material expenses [2].

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Smart manufacturing is a new breed of production concept attributed to flexibility, distributed decision, and self-feedback mechanisms, which eventually increase production efficiency and ensure fast adaptation to market conditions. These capabilities are realized with the state-of-the-art information technology (IT) advancements such as machine-to-machine (M2M) communication, industrial internet of things (IIoT), cloud, artificial intelligence (AI), and machine learning (ML) [5].

Smart factory is a manufacturing CPS that integrates physical objects such as machines, conveyers, and products with management information systems (MIS) such as manufacturing execution system (MES) and enterprise resource planning (ERP) to implement flexible and agile production [4].

Industry 4.0 employs reference architectures with different content, format, and purpose and there are many different scenarios and challenges for the implementation of Industry 4.0 systems. These different scenarios correspond to different use cases, which may also have different architecture requirements. There is therefore a clear need to find out and understand which reference architectures exist in this field and how they can be customized to use cases of specific smart factories, as well as which supporting technologies and tools are available [3].

Hence, we have developed and implemented a suitable SMS architecture model for the printing factory based on a comprehensive analysis of the results of studies on SMS architectures such as IIRA, RAMI4.0, SITAM, IVRA, IBM Industry 4.0, and LASFA.

2. Architectural Model and Implementation Method

The architectural model of the smart manufacturing system implemented in the printing factory producing educational books is shown in Figure 1.

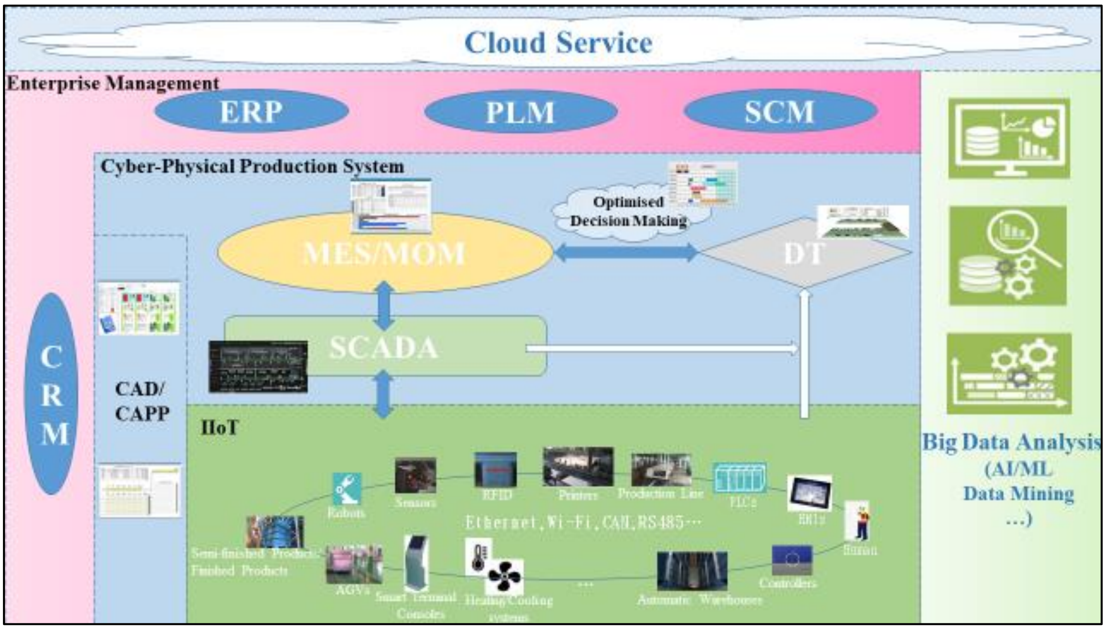

Figure 1 Implemented architectural model of SMS

The implemented structural model consists of four main parts: cloud service, enterprise management, virtual physical manufacturing system, big data analysis, and it reflects the horizontal, vertical and end-to-end integration of the factory.

Each boundary shows that the tangent parts are correlated with each other. For example, the enterprise management part shows an integrated and fused relationship with cloud services, cyber-physical production system, and big data analysis parts.

In the cyber-physical production system, we compare the results of cyber production and physical production using digital twin techniques and perform autonomous production management immediately respond to field changes by implementing a rescheduling strategy to minimize bias, and realize synchronization in cyber and real space.

The initial production schedule is designed to finish the production in the shortest time considering the initial printing plan, print and bookbinding equipment capacity, power conditions, semi-product capacity, etc. The schedule is modified and verified through cyber production using digital twins in cyber space and is commanded to the production site. The physical production system is produced by the production order according to the schedule, and the whole process of production is captured in real time through the IIoT to make a comparison with the initial production schedule.

Due to the changes in production and demand conditions, there is a significant difference between the initial production schedule and the production execution results of physical production. The construction of a reschedule is executed whenever the deviation between the schedule and the production execution results exceeds the allowable deviation.

Using digital twins, production site information is collected in real time, and synchronization between cyber production and real production is realized.

Things that constitute the IIoT of printing factory include various printers and production equipment of production processes, AGVs, robots, sensors, smart terminal interfaces, PLCs, RFID, automatic warehouses, semi-finished products and finished products. The RFID system was installed in the necessary places of the unmanned production process for publication production and unmanned vehicles to capture in real time the position information and property information of semi-finished products and finished products moving in the paper supply, cutting, printing and bookbinding processes.

The Big data storage and analysis process system integrates all the data related to the production of smart factory to build a large database, making predictions about the production, consumption and sales, and analyzing various indicators such as scale-up reproduction, net income, target index setting, quality assessment, cost objectives, reducing the cost criteria, reducing labour, and improving the quality, as the final goal. The structured data collected includes all MySQL data needed for production and management, whereas the semi-structured data contains csv, xml types of data, and the unstructured data are large tiff files generated at the technical organization stage.

To perform big data storage, we built a distributed file system based on Apache Hadoop 2.0 which integrates MapReduce and Distributed File System (HDFS) as a parallel distributed computing project, and implemented a NoSQL-style big data aggregation environment based on HBASE model.

On the other hand, the equipment health index assessment is performed by predicting the current capability state compared to the nominal capacity of the equipment using deep neural networks, process information such as production planning and production time of the relevant equipment, production data, plant operation, equipment operation, technical characteristics of the equipment, power consumption, various sensor data installed in the printer, etc. Deep learning takes as input planning information, production information, environmental information, such as planning amount, production time, production rate, bad rate, power consumption, frequency, temperature, humidity, etc., and generates a deep regression model to learn the training data so that the training bias is minimal and daily retraining is performed whenever new training data are generated.

In equipment health index analysis, the capacity status of each equipment is detailed to date according to the current production conditions, and the maintenance date of the equipment can be determined.

It also contributes to the implementation of the optimization of the whole plant by providing decision-making sections including scheduling by accurately diagnosing and predicting the current equipment capacity.

The SMS of the printing factory producing educational books significantly improved the productivity of the factory and also revolutionized the management activities.

3. Conclusions

This paper describes the development and application of architectural model for the smart manufacturing system of the printing factory producing educational books, based on the study and analysis of the smart manufacturing system architectures of the smart factory that emerged after the fourth industrial revolution.

The introduction of the smart manufacturing system in the printing factory has increased the production capacity by 2.5 times and saved 45.7 percent of labour.

In the future, we will further study the architecture and development of smart manufacturing systems to meet the diverse needs of customers and build more efficient smart manufacturing systems in the manufacturing industry.

Compliance with ethical standards

Disclosure of conflict of interest

All authors of the manuscript have no conflict of interests to declare.

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