Article

Design of Smart Factory Based on Asset Administration Shell

Guangjie Wu [1], Chengyue Wang [1], Xiaojuan Huang [1,*] and Quanbo Lu [1,2]

[1] School of Mechanical Engineering, Chongqing Three Gorges University, Chongqing, China
[2] School of Information Engineering, China University of Geosciences Beijing, China
* Correspondence: 1345179064@qq.com

Abstract: Smart factories face the opportunities and challenges brought by globalization and new technologies, which requires flexible and practical approaches to lean manufacturing and optimization. The asset administration shell (AAS) is expected to help factories better cope with new challenges throughout the life cycle. This paper proposes a methodological framework for building AAS for the whole lifecycle of a smart factory. Based on the AAS methodological framework, the theory study of smart factories is developed.

Keywords: smart factory; AAS; I4.0 component; smart manufacturing

1. Introduction

Smart manufacturing is an evolving topic. Its definition, application scope, research hotspots, and trends have been a hot topic in the field of industrial informatization research. Research and practice for the concept of smart manufacturing have emerged in recent years [1]. Smart manufacturing involves smart products, smart production, and smart services [2]. From the perspective of technical mechanisms, it is the integration of the human- information-physical system [3].

The whole lifecycle of smart factory includes the planning, design, construction, control, upgrading, and reengineering [4]. The whole lifecycle of a factory varies depending on the nature of the industry and the volume of the enterprise. The physical factory is constantly enriched, improved, and evolved throughout the process [5–7]. At each stage, companies face different management issues and technical challenges. People, equipment, logistics, processes, environment, and data in smart factory have to interface and interact with each other in different ways at different stages of the lifecycle. Different systems and models should integrate information technology and management processes [8,9].

The AAS of Industry 4.0 (I4.0) components is a shell management software that follows various standards to digitally describe the asset characteristics and technical functions of the components [10]. The basic composition of the AAS is "Inventory + Component Manager" [11]. It is a self-describing digital "asset specification". With the available AAS to query and read, the asset becomes manageable and operable.

The research on AAS construction methods and application examples for the whole lifecycle of a factory is a new field, and the current research results have the following limitations:

(1) The research in the field of manufacturing focuses on product data management and product information tracking. The research on the whole lifecycle of products is more, and the research on the whole lifecycle of production subjects is rare.

(2) The research mainly focuses on the perspective of the product lifecycle. The research for the process industry and manufacturing industries is limited.

(3) Although there are studies on AAS methods in the planning and design stages in the past, there are few studies on AAS construction methods based on simulation and machine learning.

Therefore, to fill the gap of the existing research, we propose the design of smart factory based on AAS. This paper studies the construction method framework of smart factory in various stages of manufacturing and conducts practical research in different industrial contexts. Finally, we will verify the applicability and effectiveness of AAS.

2. AAS

2.1 Architectural Framework for AAS

The I4.0 component is a special case of cyber-physical systems (CPS) technology applied specifically to plant production processes and production facilities [12]. The I4.0 component can express certain characteristics of CPS because they link physical objects in the actual production environment with virtual objects and processes. The I4.0 component can be entire production systems, individual devices, and components within devices. It consists of two basic elements: object and AAS. The object is surrounded by AAS, which is the I4.0 component, as shown in Figure 1.

It is additionally required that these objects must be managed as entities. Each object has a globally unique identity, attributes, and behaviors to represent itself [13]. The object represents a physical thing and its combination in a factory. It is a technical asset with a specific technical function, including a machine, an automated component, or a software platform. The object can be either a legacy system or a new system developed with modern technology. These objects should be integrated within the plant regardless of their type or history with many variations.

2.2 Conceptual Model of AAS

As shown in Figure 2, the AAS has the same framework as the digital factory asset class. It is divided into two parts: Header and Body [14]. The context of the asset application is specified in the Header. The two main logical structures of AAS are the catalog list and the component manager. On the one hand, AAS receives and records real-time data from the asset. On the other hand, AAS provides data and function services to the outside through consistent communication.

By combing the latest results of international standardization in the field of digital factory, a conceptual model of AAS is proposed. It is represented by a unified modeling language [15]. AAS constitutes three different observation perspectives of the I4.0 component.

(1) Hierarchy illustrates the scope of the technology assets represented by the I4.0 component.

(2) Lifecycle and value stream provide a lifecycle context for the storage of the I4.0 component asset data. The data for the asset must be organized in the form of a particular lifecycle stage.

(3) Architecture clarifies the functional architecture of the I4.0 component.

2.3 The Standards for AAS

All items in the AAS comply with standards. It lays a solid foundation for future system expansion and the internet of everything. Figure 3 outlines the standards and specifications that the characteristics of AAS and submodules need to comply with.

3. Smart Factory Based on AAS

Smart factory inherits the technological development line of digital factory. In the past, the understanding of the advancement brought by digital factory generally emphasized that the digital factory would accompany the whole lifecycle of a factory. In the process of factory planning, fine design, construction, operation, production, optimization, upgrading, and even demise, the physical factory has been continuously enriched, improved and evolved. However, in the smart manufacturing, the smart factory brings a more advanced connotation to the digital factory, including the simultaneous use of advanced sensors and the analysis of historical big data. It has ultra-realistic, multi-system fusion, and high precision for monitoring, prediction, and data mining. Smart factory will be able to rely on sensors as well as other data to understand its situation, respond to changes, improve operations, and add value.
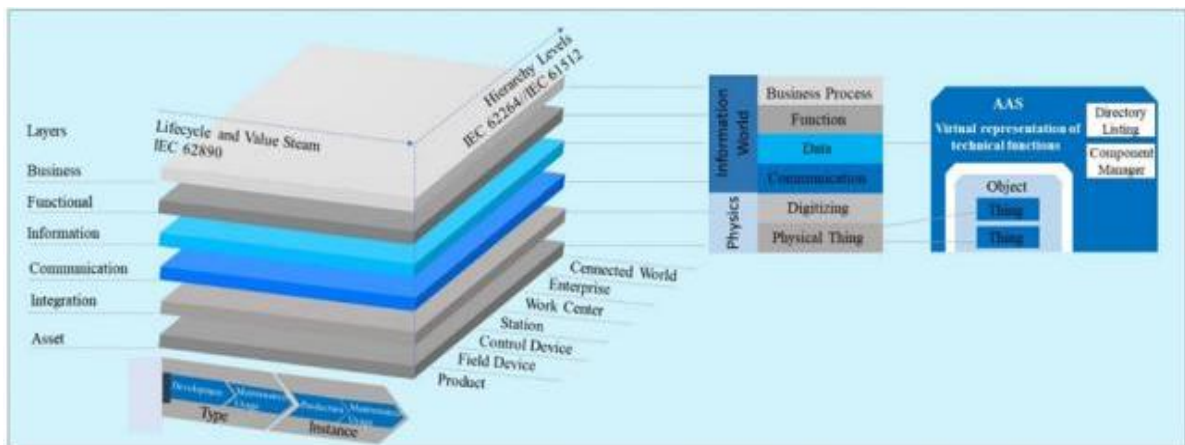

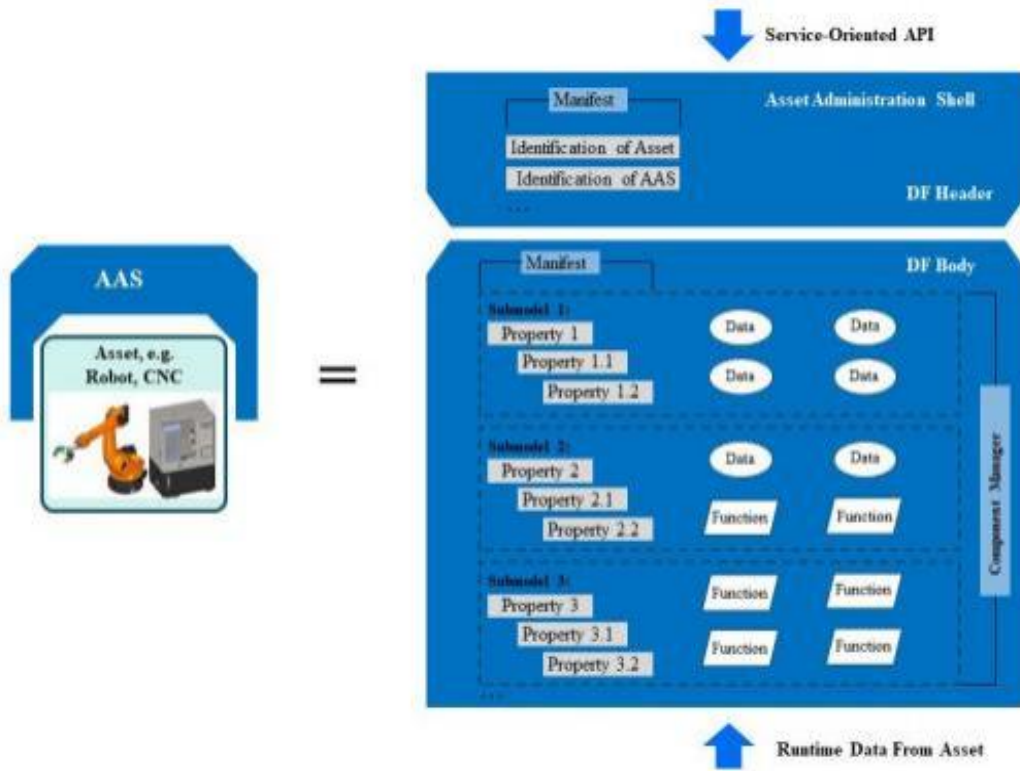
Figure 1. I4.0 component. [12]
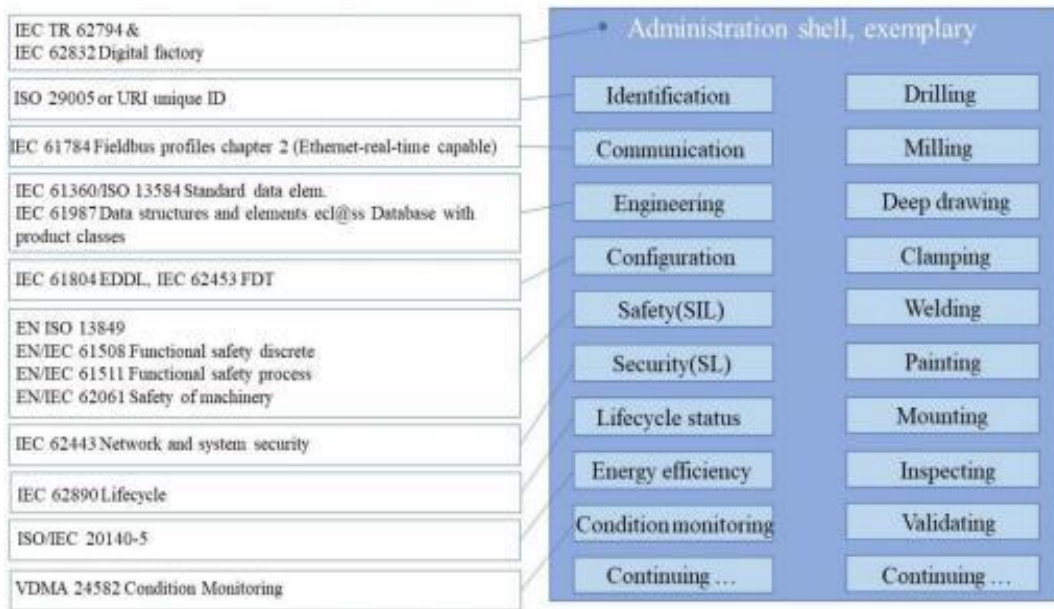
Figure 2. The structure of AAS. [13]

Figure 3. Standards for AAS.

A new generation of smart factory in smart manufacturing is a comprehensive process of evaluating and optimizing various technical solutions and technical strategies for the entire lifecycle of the factory. Combined with the modern management science perspective: wisdom comes from knowledge, knowledge from information, and information from data. The new generation of smart factory practice revolves around multiple heterogeneous industrial big data and realizes smart manufacturing through the application of big data. It advances the practice loop of the digital factory from the 1.0 stage of enhancing planning capability to the 2.0 stage of realizing smart manufacturing, as shown in Figure 4. Version 2.0 of the digital factory is the smart factory.

The methodological framework of AAS focuses on different stages of the whole lifecycle of a manufacturing factory. It includes AAS methods and AAS models. However, regardless of any stage, the framework of AAS should be built around "people, information model, and physical objects". It realizes two-way interaction of information between each element.

The components of AAS-based smart factory are shown in Figure 5, including the physical real factory, AAS model, and production process data (e.g., production equipment data, measurement instrument data, production personnel data, and production logistics data).
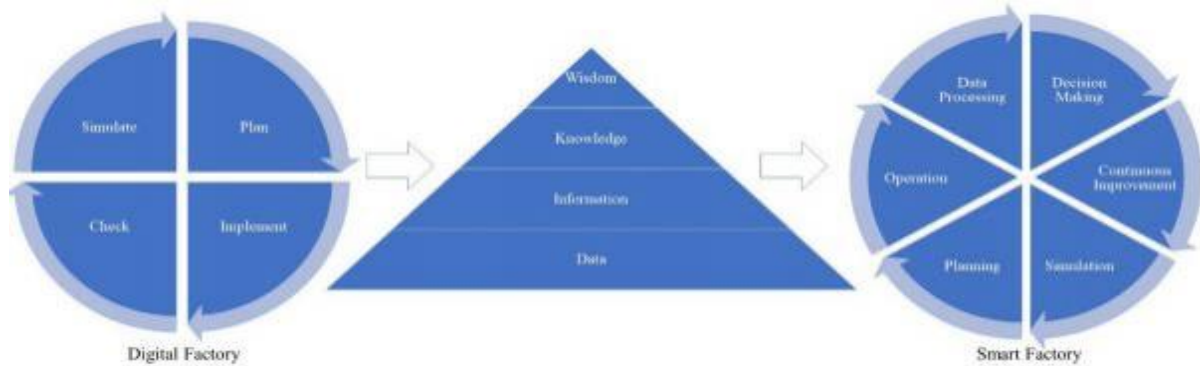

Figure 4. The practice loop of the digital factory.

Figure 5. AAS-based smart factory.

The information technology infrastructure supporting the mapping relationship of AAS includes industrial Internet, mobile Internet technology, and cloud platform. AAS will achieve project investment savings and accelerate start-up time in the planning and construction phase of the plant. The application scenarios include planning simulation, construction management, digital delivery, and enterprise process assets. In the production control stage of a factory, it will realize the fine control of products and manufacturing processes. The application scenarios include environmental safety, production management, equipment maintenance, and personnel training, which improve the economic efficiency of an enterprise.

4. Conclusions

Through the above research results, we can see that building AAS between the physical world and the information world will be beneficial to all aspects of the whole lifecycle of the manufacturing industry. With the support of various new technologies (e.g., industrial IoT, simulation, machine learning, and lightweight chips), the construction method and application model of AAS are feasible for practice in the manufacturing industry. Through the theory and application study of AAS, this paper demonstrates that AAS is expected to bring benefits and values to enterprises. The exploration of AAS for the manufacturing industry is still in its initial stage. The potential value of AAS has not been fully explored. Therefore, in the future, the construction method and application of AAS is a research hotspot.

Smart Factory based on AAS will achieve real-time collection of production line data. Through the internet of things and augmented reality, they will develop intelligent factories for closed-loop management of the whole life cycle (e.g., product design, process design, production management, production monitoring, and equipment maintenance). They will break the gap between the physical world and the data world, realize intelligent production covering the whole life cycle, and effectively improve product research and development and production efficiency.

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Conflict of Interest

There is no conflict of interest.

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