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Challenges of production microservices

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Abstract

Current production systems use monolithic software solutions. This causes a lack of flexibility, scalability and prevents direct communication between network nodes which is fundamental to face challenges of highly personalized mass production. In order to overcome these drawbacks, the introduction of a service-oriented architecture (SOA) more specifically microservices in production are a promising approach. SOA enables developers to distribute applications in a number of small services which communicate via an integration layer e.g. an enterprise service bus. This paper proposes a data-driven approach for creating a SOA, based on microservices in an assembly focused production.

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1. Introduction

Global megatrends such as globalization, urbanization, demographic change, growth of population and sustainable development are not only influencing societies around the world, but also have great impact on manufacturing enterprises and lead to a paradigm change in all production factors. This includes revolutionary changes in energy and material consumption, staff and capital circulation as well as massive demand movements towards emerging markets and developing countries. It is expected, that by 2025 developing countries will account for half of the global consumption [1].

Thus, addressing various markets will be far more a key challenge than facing demand problems. Products for developed countries need to be highly individualized, while products for emerging markets need to be adapted to regional needs including functionality, design and costs. In addition, there is a trend to shortened innovation cycles. This leads to an increasing complexity of the markets as well as a rise of product variants while quantities per product and variant are decreasing [2].

The proposed solution for these challenges from an IT perspective is the concept of service-oriented architectures (SOA) and microservices. While a SOA addresses challenges of manufacturing enterprises, their implementation introduces

new challenges. Among these challenges are the architecture design in terms of size of the microservices or their orchestration and integration. Thus, this paper presents an approach of how to overcome challenges of IT architecture design and implementation in industrial production environments to benefit from microservices.

2. Challenges in Production Systems

Information and communication technologies (ICT) will be a key enabler for the described challenges of manufacturing enterprises, where most of the innovations will take place. A propagated solution addressing rising market complexity as well as rising complexity within companies by ICT is the smart factory, the next evolutionary stage of the fractal factory. Cyber-physical systems (CPS) can build decentral and autonomous networks – like fractals – to self-organize and self-optimize. The level of autonomy and decentralization rises with increasing complexity [2,3].

To enable these developments, manufacturing IT is undergoing a fundamental change from the traditional automation pyramid of monolithic systems to service-orientation, also described as Everything-as-a-Service (XaaS). This paradigm describes that everything, no matter if physical or virtual, is offered as a service and originates from the three

main cloud computing service layers Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS) [4]. Table 1 summarizes and the following chapters describe the ongoing changes in manufacturing IT.

Table 1 Comparison of traditional and emerging manufacturing IT

Traditional manufacturing IT	Emerging manufacturing IT
Hierarchical	Non-hierarchical networks
Centralized	Decentralized
Software suites	Services, Apps
Monolithic	Fine-grained services
License fees	Pay-per-Use
Complex integration	Open standards
Delayed data	(Near) real-time data
Roll-out within months/years	Deployment within minutes

2.1. Traditional manufacturing IT

Traditional manufacturing IT is characterized by a hierarchical structure defined in ISA-95 and often depicted as the automation pyramid [5]. The automation pyramid is divided in three levels: the operational shop floor level, the tactical manufacturing execution system (MES) level and the strategic enterprise resource planning (ERP) level on top. Various planning and control tasks are performed on each level [6].

Tools on each level of the automation pyramid are usually centralized large software suites which require a significant investment in license fees. In addition, they are often monolithic and stick to self-defined interfaces instead of using open standardized interfaces and communication protocols. Therefore, the development and maintenance of interfaces between various systems requires a high effort. With each new version of a system, all corresponding interfaces need to be updated because they are proprietary to the respective software suites. Due to this effort, a holistic vertical and especially horizontal integration is usually not realized. This lack of real-time data caused by the missing integration often requires short-term and expensive intervention to production control. Furthermore, the process to introduce new software suites is very inflexible and time-consuming, taking months to years depending on the use case specifications [2,6,7].

2.2. Emerging concept for manufacturing IT

Today, the manufacturing IT is undergoing fundamental changes enabled by technologies such as cloud computing and associated concepts. The traditional automation pyramid is dissolving and manufacturing IT is moving towards service-orientation and app-orientation [4,8].

Software suites will be divided by functionality into services and apps, decentralization offered by distributed computing approaches like edge, fog computing concepts and cloud platforms. These services and apps can be non-hierarchically orchestrated in networks, where communication between services based on open standards will become a key factor for success. This overcoming of hierarchical structures also allows for communication of real-time information [6,9].

Many manufacturing companies have noticed this shift to service-orientation and have started to build their own cloud-based platforms. Examples are the Bosch IoT Suite, GE Predix or Siemens Mindsphere. However, most of these platforms are tailored around the products and services offered by the company and lack interoperability with other platform providers. In contrast, there are platforms such as Virtual Fort Knox [10] or the Fraunhofer initiative Industrial Data Space [11] following a federative approach to enable independent software vendors to participate in the ecosystem and to prevent vendor lock-in effects.

3. Microservices

To give an introduction to the concept of microservices, we compare it in the following first to the most obvious alternative: the monolithic architecture.

3.1. Monolithic Architecture

The phrase monolithic is used to describe a software application consisting of one piece. Traditional manufacturing IT, as introduced in section 2.1, uses this typically. The architecture is designed for running solely on one computational instance. This may run multiple processes which are distributed across multiple CPUs but all share the same operating system and hardware.

If the system reaches a capacity peak, it needs to be duplicated completely. This process might be executed automatically by a continuous deployment system. The main drawback is the lack of flexibility. For example, if a number of users is reached that cannot be handled by one instance, a monolithic system lacks the required horizontal scalability. Instead, it has to be scaled vertically.

3.2. Service-Oriented Architecture

Generally, a microservice architecture is a SOA, utilized as introduced in section 2.2. A service in a SOA is a software component delivering one predefined functionality matching one business activity and its specific results. The service is self-contained which means that it does not rely on external resources. All processing required by this service is performed in itself. It includes all required resources like databases etc. To consumers using the service it appears as a black box to be accessed only via predefined interfaces. It may itself require underlying services providing a certain sub-functionality [12]. A service which relies on a set of services is also called aggregated service [13].

3.3. Microservice Architecture

Microservices refer to a new software architecture. We are aiming to present an overview of the properties of this architecture. The core concept is a fine-granular decomposition of an application into such microservices. While SOA refers to the general idea of encapsulating functionalities into separate services, microservices additionally specify the scale of this functionality as small [14].

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