Service Composition in the Cloud-Based Manufacturing Focused on the Industry 4.0

Marcos Pisching, Fabrício Junqueira, Diolino Filho, Paulo Miyagi

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Marcos A. Pisching[1,2], Fabricio Junqueira[2],
Diolino J. Santos Filho[2] and Paulo E. Miyagi[2]

[1] Instituto Federal de Santa Catarina
Rua Heitor Villa Lobos, 222, Lages, SC, Brazil
[2] Escola Politécnica da Universidade de São Paulo
Av. Prof. Mello Moraes, 2231, Cidade Universitária, São Paulo, SP, Brazil
{marcos.pisching, fabri, diolinos, pemiyagi}@usp.br

Abstract. The emerging Industry 4.0 concept, also called fourth industrial revolution and understood as smart factory, is based on integration of both Internet of Things and Cyber-Physical Systems. In smart factory, these two concepts are converging to the Internet of Services, which uses the cloud-based manufacturing for creating, publishing, and sharing the services that represent manufacturing processes, and could be offered by virtual enterprises. Therefore, any dispersed partner can meets the market demands according to their skills, capacities, and availability. This paper presents a survey about service composition in a cloud-based manufacturing over the Industry 4.0. To achieve it, the concepts and characteristics about the service composition based on cloud-manufacturing over the Industry 4.0 are presented, and then the advanced researches about it are summarized. After it, the main research challenges over these issues are shown. Finally, discussions on service composition are reported to contribute for the future researches.

Keywords: Cloud-Based Manufacturing, Cyber-Physical Systems, Industry 4.0, Internet of Things, Service Composition, Virtual Enterprises.

1 Introduction

The Industry 4.0 is focused on creating smart products, procedures and processes. It was first presented in 2011 at Hannover Fair and launched in April, 2013 [1], [3]. This concept has meeting the smart manufacturing industry concerns that are dealing to spark design innovations and bring new products to market faster, and additionally, they are looking for satisfying the individual customer desires. In the Industry 4.0 this behavior changes the production concepts from mass to individualized production. Objects, sensors and actuators should communicate and exchange information among them all the time [2]. These tasks are realized by two concepts, the Cyber-Physical Systems (CPS) and Internet of Things (IoT) [1], [2], [3], [4].

In the Industry 4.0, also referred as smart factory, the CPS and IoT concepts are converging to the Internet of Services that widely uses the cloud-based approach for creating, publishing, and sharing the services [1], [2], [3], [20]. In this context, the services represent manufacturing processes, which could be offered by virtual enterprises (VE). Thus, any dispersed partner around the world can meets the demands according to his ability, capacity, and availability. These issues have been gained force at worldwide industrial sector, and its complexity implies on the demand of collaborative and smart services, which should be available and shared on the Internet infrastructure [1], [4], [20].

Service composition is one of many concerns in the Industry 4.0. For example, the customer could require one virtual service, and then the virtual system must set a composition of services, in a way to comply with the customer specific demand. This research is centered on service composition and how can it be possible in a way to offer smart services and how it can integrate the real systems to the virtual systems, to contribute for Industry 4.0 expectations. This paper presents a survey about service composition in a cloud-based manufacturing over the Industry 4.0 context, for a future perspective of a collaborative and integrated environment, on which VE could be established to provide services and goods to the customers. It could help any enterprise regardless of size, but small and medium-size enterprises (SMEs) could be more competitive by joining business and knowledge.

2 Benefits from Cloud-based Engineering Systems

In the Industry 4.0 the end-to-end engineering and the vertical and horizontal integration can have a significant increase by the extensive use of CPS and IoT. Consequently, it is expected that the number of projects, data and services over the Internet infrastructure should have an exponential growth. Therefore, the cloud-based engineering systems can benefit the emergent Industry 4.0 in a way to offer infrastructure, platforms, and software among the partners [1] and also contributing to the development of SMEs [1], [2], [3]. By these resources, the services and data could be available for any partner regardless of the platform and operational system. The cloud-based technology could be decentralized, and it is favorable for the deployment and sharing of services among the member of projects. In the worldwide context, where the service demands should rapidly increase, the stakeholders must be prepared to improve the ICT to answer the demands in a short time. The cloud-based infrastructure could be scalable and dynamic to attend the entrepreneur needs faster. In addition, these systems could support the service composition based on service-oriented architecture (SOA) for the establishment of VE, where SMEs could be favoured to the design of new products and, in the same time, to become faster in the answers to market fluctuations [9]. The Industry 4.0 and VE require more flexible environment and need autonomous system reconfiguration to support the market concerns. Then, according to [15], cloud-based manufacturing should comply task as service oriented, customer centric, and demand driven manufacturing, in a way to enable industrial control systems, service composition, and flexibility [8].

3 Fundamental Concepts

3.1 Industry 4.0

The Industry 4.0 concept, also referred as the fourth industrial revolution [5], integrated industry, or smart factory [4], is centered on network and Internet architecture [1], on which is possible to integrate the virtual world with the real world by using Information and Communication Technology (ICT). In the smart factory, all the relevant "things" involved in the manufacturing processes could be recognized, and then the hardware and software can automatically behave, with less human intervention, to perform all the tasks in a production line. It also depends on Cyber-Physical Systems (CPS) and Internet of Things (IoT) concepts. Its main purpose is to improve the efficiency and productivity of industrial processes by the smart automation environment and by the industry integration [1], [2]. Accordding to [3] in the Industry 4.0 context the products can control their own manufacturing process, and additionally, the customer should be more involved in the creation processes of new products. This project has been leading by German government, German industries, and German Research and Development [2]. However this term is little know in the world, it has been spreading and being the issue in some technology conferences, and research and development [1], [3].

3.2 Cyber-Physical Systems and Internet of Things

The Cyber-Physical Systems (CPS) and Internet of Things (IoT) are the basis of Industry 4.0. The Fig. 1 shows the relation of CPS and IoT with the Industry 4.0. The CPS are related with the integration of computation technologies with physical processes [6]. The CPS are based on a structure composed by embedded systems (ES) and physical environment, on which are expected the ubiquitous computing that provide information anytime and anywhere [1]. Communication technology such as distributed application and service provision, and embedded system technologies such as robots, control systems, sensors and actuators are converging in a way to offer a distributed and embedded web-based system represented by services.

On the manufacturing, the CPS have been used at shop floor tools and equipment to integrate the manufacturing processes and to enable the machine-to-machine communication [7]. Additionally, the CPS infrastructure enables the communication between real and virtual systems, and vice-versa. By the virtual systems is possible to design, model and simulate products that should be exchange to real world to be produced. On the other way, the physical processes for manufacturing products could be visualized by a virtual environment such as three-dimensional environment or augmented reality environment.

The IoT is a concept that is also based in the ICT, which uses the Internet infrastructure. It consists of sensory and smart object interconnection to offer connectivity of devices, systems and services. Its main purpose is to connect everything including resources, information, objects, people and machines to create the Internet of Things and Services [1]. In the IoT each object must be addressed with a unique identification that enable the interaction and cooperation with neighbours to reach common goals.

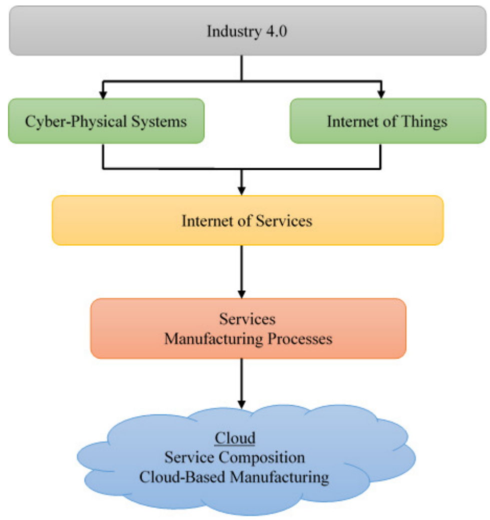

Fig. 1. The Industry 4.0 and its relation with CPS and IoT in a cloud-based manufacturing. Industry 4.0 depends on CPS and IoT technologies. These two concepts are converging to the Internet of Services that provide a set of services, which represent manufacturing processes. A cloud-based manufacturing is used to compose a set of services to offer solution for VE.

Both, CPS and IoT resources, could be virtualized as services, and then deployed over a cloud-based infrastructure, on which is possible to store, exchange, share, and process data. Furthermore, the stakeholders could deploy and share manufacturing processes as a service. All this resources can be used in a collaborative and integrated environment (CIE) to model and design goods and services by VE, and may be favorable for the SMEs and start-ups, in a way to facilitate design innovations and provide new products for an increasingly sophisticated, dynamic and demanding market.

3.3 Service Composition

In the context of manufacturing, all the objects, features and resources that represents their states, information, and mode operations are considered as services [10]. These services can be described, published, located, and invoked over a network, which purpose are to perform actions as answers from requests between service consumers and providers [11]. Services could be implemented on a single or on a large number of servers [11], and over the cloud-based technology. Such services, when working alone, could be more difficult to perform the actions according to demands. Therefore, the combination of exiting and available services from different enterprises, which is called service composition, can perform both simple or complex tasks [11], [12].

In the Industry 4.0, CPS components, hardware and software are represented as services. When it is published in a collaborative environment they could be used to compose an integrated service, which aim to solve problems of common interest [12], [13]. The Fig. 2 depicts a single situation, where the stakeholders or partners, such as SMEs, can deploy and publish their virtual services on a cloud-based infrastructure in a way to establish virtual enterprises, which the main purpose is centered on a collaborative work to provide solutions according to the customers demand. Therefore, the customer could request a service by a virtual environment, and then a background system over the cloud should verify the availability of services and the best way to compose it to solve the customer need.

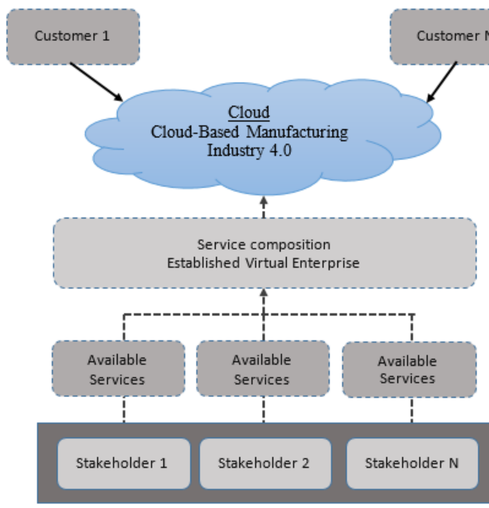

Fig. 2. Stakeholders publish their CPS components as services to provide a common solution in order to establish a VE to answer a specific market need.

4 Research on Service Composition over the Industry 4.0 Concepts

The Industry 4.0 platform is in initial stage, hence the researches on this field must have many issues to explore and one of them is the service composition based on CPS and IoT concepts.

Based on CPS, [12] propose a dynamic manufacturing resource aggregation (MRA) architecture, on which they consider a virtualization model and describe in detail the implementation process of the manufacturing resources and a dynamic service composition.

In the [16] the CPS resources are related as components, for further modelling for complex and flexible process for smart environments. The authors present a process meta-model and use Unified Modelling Language (UML) to represent component composition using object-oriented approach, and then it is used to model process component and its composition.

For a cloud-manufacturing implementation focused on customer centric solutions, the [15] present an overview about cloud manufacturing, and show the current issues over the architectures, models and framework, for further exposure about the potential impact and future work. They also present the relation of service composition with the cloud-manufacturing systems, on which is presented a review about methods and implementation considering service composition in VE and virtual marketplace, for further presentation of model, framework, infrastructure, and architecture of cloud-manufacturing for flexible, cooperative and collaborative virtual enterprises.

Based on VE establishment, the work [14] adopt the everything-as-a-service concept to propose a service-oriented platform for on-demand virtual enterprise. The suggested platform supports flexible integration of networked resources and help the formation of VE considering trusted service composition, data service centric business collaboration, and business process utility. Considering collaborative and integrated environment, a modeling of service composition by interpreted Petri net for system integration is presented in [18], on which is proposed a coordinated and collaborative control of a dispersed productive system.

A widely approach about service composition based on ontology was realized in [17]. The authors present a method based on algorithms, on which automatic service composition is studied to decompose the requirements, the rules to determine the relation among the services, and the algorithms for composing services.

Associated to the new paradigms such as cloud computing and Web of Things, [19] report an overview about the lifecycle of web services composition (WSC) and present issues about standards, research prototypes, and platforms, which is assessed using a set of criteria. They show the state-of-the-art of WSC, and present a generic model for the lifecycle from it, which is used to compare with different prototypes using the defined criteria.

These studies show general issues and concerns around the service composition such as architecture, models, and methods that could be explored and applied on Industry 4.0.

5 Discussion on Service Composition for Industry 4.0

In the Industry 4.0 is expected a large growth of the objects and services available over the web due its worldwide trends involving the growing adoption of CPS, IoT and services.

Service composition, which is also applied in the smart manufacturing industry, is one of the essential problems of service-oriented computing [12]. In [15] the author points to the concerns over the automation and control, business model, information and resource sharing, distributed system simulation as services.

The research [11] points to the problem around the composability, adaptive, autonomic composition, quality of services, and service governance, management, and administration.

The [16] suggests a decentralized and distributed workflow across several orchestration peers in a way to increase the availability of the workflow process. They also work on a process component repository and a semantic domain-model for the classification of process components. Additionally, they will investigate the agent-based technology to find appropriate process composition.

The SMEs have been demonstrating significant importance around the economic growth of the European Union, on which several of them are consolidated and new companies have being created [9]. According to [9] these SMEs have been found difficulties to meet demands and react to the business changing due their manufacturing limitations, interoperability, and its lack of collaborative capabilities. It could be improved by SOA, which has been used to undertake inter-enterprise collaboration [13] by the orchestration and composition of services to join the SMEs in a interconnected network to form a virtual enterprise.

According to [17], subsequent research will extend the ontology approach for supporting the service composition in various domains. To [18], the integration and coordination of dispersed productive system is a problem that need investigation. In [19], web services composition has been an active sector for research and development, and activities including standardization, research, and system developments have been produced.

Considering the recommendation from [1], [3], [4], all these issues also need attention and could be exploited over the Industry 4.0. Additionally, issues like integration of CPS focused on collaborative, dynamic and smart services should be considered on smart industry researches.

6 Conclusions

The Industry 4.0 project promises to break-thru the boundaries of the conventional industries by the Information and Communication Technology (ICT). In addition, it is expected the increase of the number of members on the production chain in a collaborative environment, on which their location is indifferent and all the resource could be accessed by ubiquitous systems from any place of the world. In the same way it is expected that all the objects involved on the production processes can be available as services, and that they could communicate and exchange information among them.

The Industry 4.0 expectations and its complexity caused by the large number of interconnected machines, products, processes and people could increase the challenges and expand the opportunities for the research fields such as data security, standardization, and services interoperability. The SMEs may gain force on the Industry 4.0 by the virtual enterprise establishment. The shared skills, knowledge and resources as services over the cloud-manufacturing context, should leverage the business potential and improve the customer satisfaction. Although, strategies and methods should be adopted to improve the service composition among thousands of objects, services, and business.

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