STUDY ON THE SERVILIZATION OF SIMULATION CAPABILITY

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ABSTRACT
Manufacturing capability (MC) servilization is a key to realize on-demand use, dynamic collaborative work, and circulation of manufacturing resources and capability in the cloud manufacturing (CMfg) system. This paper emphasizes the servilization of simulation capability (SC), which is a very important kind of MC. According to task demands and characteristics of complex product's simulation process, concepts and state of the art related to MC were systematically analyzed and summarized firstly in this paper, then a conceptual model of SC were presented, A application model of SC service life-cycle in CMfg system is proposed. Then the framework for simulation capability servilization is investigated, as well as several key issues involved in the servilization process such as elements of simulation capability, modeling and decriptiion of simulation capability, and so on. Finally, an application example analysis of SC was presented.

Keywords: cloud manufacturing, manufacturing capability, simulation capability, servilization

1. INTRODUCTION

Cloud manufacturing (CMfg) is a new service-oriented, highly efficient, lowly consumption knowledge based, and intelligent networked manufacturing model (Bohu Li and Lin Zhang *et al*. 2010). It is combined with advanced manufacturing and information technologies organically (e.g. cloud computing, the internet of things, semantic web, and information system integration)in order to achieve virtualization and servilization of manufacturing resources and capability, CMfg provides users with application services which are on-demand using, safe and reliable in the whole life-cycle of products through network (Bohu Li, Lin Zhang *et al*. 2010). CMfg aims to achieve agile, service-oriented, green and intelligent manufacturing, is a new phase of networked manufacturing, and is the materialization of service-oriented manufacturing (Lin Zhang and Yongliang Luo *et al*. 2011). Therefore, CMfg can provide theoretical and technical supports for the transformation from production-oriented manufacturing to service-oriented manufacturing.

Manufacturing capability (MC) servilization is one of the most important innovative points of CMfg, however. Because of MC is a complex concept and its correlative research is less, as a result there is no clear definition currently. At present, there are two different understandings on the concept and connotation of MC, some people argue that MC reflects the performance of enterprise from a macro points of view, i.e., Skinner first proposed the MC in 1969, he holds that MC includes many elements such as cost, delivery time, quality, and the relationship between these elements. MC reflects the completion of manufacturing objective, and it is a performance level of the standard which is pre-sat by working organization (Mattias Hallgren. 2006). Guan (2004) commented that MC is the core part of enterprise innovation capability, it is conversion capability of results which meet market demand, design requirements of product and mass-produced. The relationship between MC and enterprise performance is discussed from the perspective of achieving low operating costs and high product quality (Siri Terjesen, Pankanj C. Patel *et al*. 2011). The other comment that MC is a integration of manufacturing resources based on microscopic pint of view, i.e., Richard (1973) considered that capability includes knowledge, skills, and experience of enterprise. MC reflects the performance of completing setting function based on manufacturing resources in order to support the operation of enterprise activities (Cheng Yun, Yan Junqi. 1996) Keen(2000) commented that MC is the integration of intangible resources and tangible resources, where the tangible resources include labor, capital, facilities and equipment, simultaneously, and the intangible resources include information, procedures, equipment and the organizational system. Khalid(2002) concluded that MC is the effective integration of related resources in the process of achieving expected target task. Cheng (2009) gave the definition that MC is a set of elements involved in the implement process of manufacturing enterprise's strategy. Zhang Lin (2010) commneted that MC is an intangible and dynamic resource in CMfg model, it is the subjective condition of production –related goals.

Combined with above views about MC, several problems are systematically summarized as follows:

- The current research about MC have been widely studied from a management point of view, because mostly based on qualitative analysis, lack of supports for quantitative description on MC;

- Lack of the logical relationship analysis between construction elements of MC

In this paper, is considered as a subjective condition, what manufacturing enterprises needed to complete one task or objective. It is a intangible and dynamic resources form. And it is a kind of capability which can be represented in the manufacturing activities. MC including design capability (DC), simulation capability (SC), product capability (PC), and many other capabilities related to life-cycles of complex products. MC is tightly linked to manufacturing activities and manufacturing resources, it can't be reflected without concrete activity tasks and resources elements. According to task demands and resources characteristics of complex products' simulation process, this paper studies MC based on simulation. In order to comprehensively understand SC, concepts and state of the art related to MC were systematically analyzed and summarized firstly, then a conceptual model of SC was presented. An application model of SC service life-cycle in CMfg system is proposed, and the key technologies involved in each process were investigated. On this basis, a new simulation capability servilization (SCS) framework is presented, several issues related to SCS are discussed in detail.

2. THE CONCEPT AND CONNOTATION OF SIMULATION CAPABILITY

SC is an important kind of MC in CMfg system, is a simulation process, which reflects a capability of complete a simulation task or experiment supported by related resources and knowledge. Through SCS, it can not only realize the function sharing of resources, but also share the experience and knowledge in the simulation process, such as simulation flow, simulation data, experience of simulated staff, and so on.

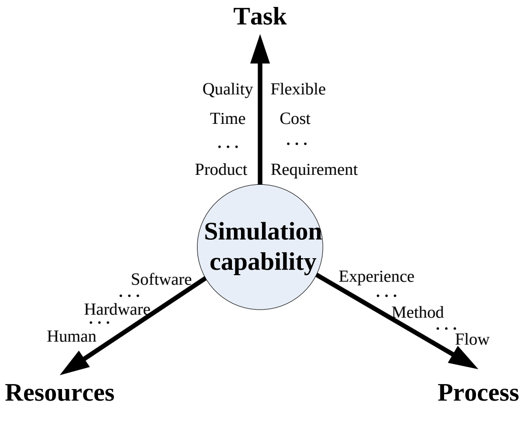

Fig.1 The conceptual model of simulation capability

The conceptual model of simulation capability is illustrated in fig1, which primarily consists of three dimensions:

1) *Resources dimension(R)*

SC is the integration of all kinds of simulation resources related to perform some tasks or activities, such as simulation software, simulation equipment and so on. Resources are the foundation of forming SC; it is the subject of SC servilization as well. Resources can be divided into two kinds, one is subject resources, which is the carrier of SC performance, for example, the subject resources of software's SC is the simulation software. The other is auxiliary resources such as material, which is support for product and related goal. In addition, a SC possibly refer to several subject resources

2) *Process dimension(P)*

SC is a kind of activity process; it contains a knowledge set generated in the implementation process of task and goal realization, such as constraint condition, simulation method, and simulation experience and so on. In addition, knowledge is the effective carrier of procedure representation.

3) *Task dimension(T)*

It contains two aspects information, one part is about the simulation task, and the other part is about the completion of the simulation task target, which include many objective factors and evaluation of user satisfaction factors, elements, i.e., delivery time, cost, quality, innovation, service, et al. This dimension is the most important selection basis for SC users in cloud manufacturing service platform.

The relationship among resources dimension, process dimension and task dimension is investigated as follows, resources is the basic of achieving SC. Task dimension shows us the result of SC, it is the most important basis for user optimize selecting in CMfg system. Process dimension is the method of SC's forming.

3. SIMULATION CAPABILITY SERVICE LIFE CYCLE MODEL

As shown in figure 1, the life cycle of simulation capability service can be divided into the following four parts:

(1) Simulation capability publication (SCP)

SCP is a servilization process of SC; it is the basic of cloud manufacturing service platform to realize on-demand use and sharing of simulation capability. It combines the characteristics of simulation resources with simulation capability classification in the CMfg model. Elements of SC are extracted and analyzed firstly, and the unified semantic description model of SC is presented. Secondly, in order to achieve the formal description of SC, the existing services description language will be expanded or improved, then SC will be released in the form of service in CMfg system. It will support the trading and distribution of SC for users through network. Some key technologies involved in this process, such as simulation capability classification, simulation capability modeling, manufacturing capability description language expansion and so on.

(2) Simulation capability discovery (SCD)

SCD is responsible for achieving semantic searching and dynamic composition of SC services in CMfg system. According to the characteristics of SC, such as relative, complexity, dynamic and so on, in order to reflects multi-dimensional attributes of SC fully and clearly, all kinds of SC description information should be classified, fused and normalized firstly, and then construct the ontology of SC to support semantic search. The ontology can improve searching accuracy. At last SCD can support the sharing of SC through the network. The process of SCD includes several key technologies, such as domain ontology construction, semantic matching and dynamic composition of SC, services of SC sharing and so on.

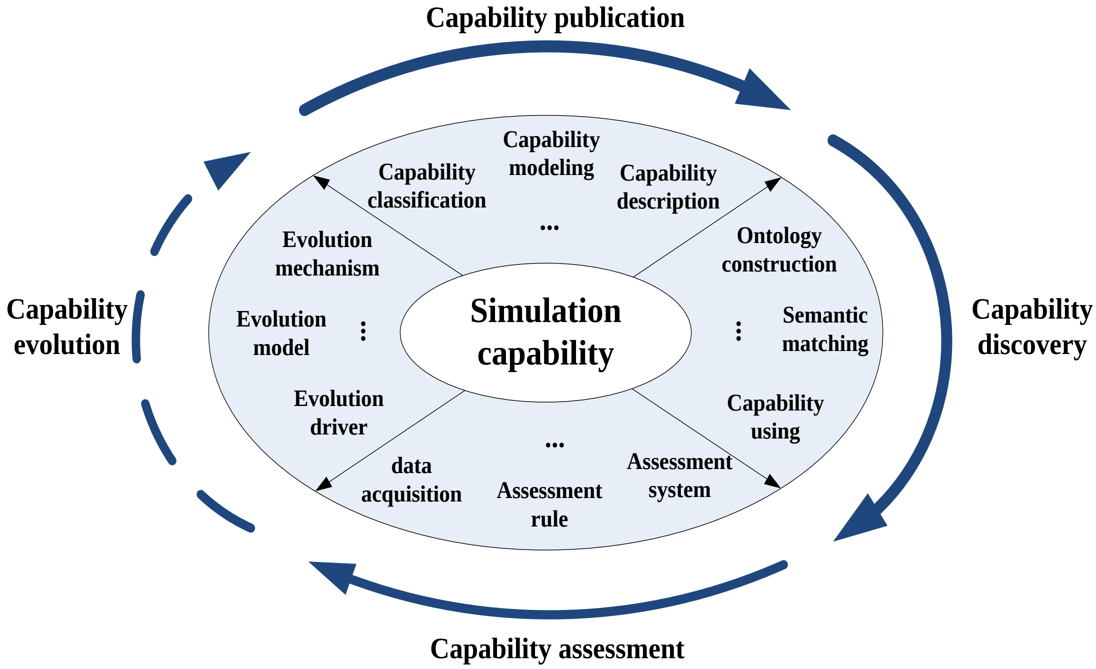

Fig.2 The life cycle of simulation capability service

(3) Simulation capability assessment (SCA)

Combined user feedback with operation of the SC, SCA will realize the comprehensive utility evaluation of simulation capability. Due to the complexity and dynamic of SC, how to measure SC is an important issue of SCS, but in order to achieve the assessment of SC, we need to provide comprehensive assessment system establishment and suitable assessment methods based on description system and evaluation factors of simulation capability, where the assessment system should be level and systemic, it can reflect the overall characteristic of simulation capability , and all level and dimensions attributes which contains quantitative and qualitative. The assessment methods of SC should take full account of dynamic changes during the process of the SC’s using. Some key technologies involved in this process, such as capability assessment system construction, SC assessment of data acquisition, SC assessment method, operation monitoring of SC and so on.

(4) Simulation capability evolution (SCE)

It is a response and adjustment process of manufacturing enterprises or systems in the face of changing external environment. On the basis of enterprise evolution theory and dynamic capability theory, driver attributes of simulation capability evolution is systematically analyzed in the CMfg mode firstly, combined with assessment index system of SC, form, process and mechanism of simulation capability evolution are deeply discussed from the qualitative point of view, and then an empirical analysis on the process of SCE is done by mapping the qualitative to quantitative. SCE will provide support for dynamic maintenance and intelligent update of SC to CMfg system. Key technologies of SCE include evolution driving factors, evolution mechanism and method of simulation capability, evolution model construction, evolution procedural knowledge representation and so on.

4. THE FRAMEWORK OF SIMULATION CAPABILITY SERVILIZATION

SCS plays an important role in the process of achieving on-demand use of SC. The process of SCS is shown in fig3, it can be divided into the following five parts:

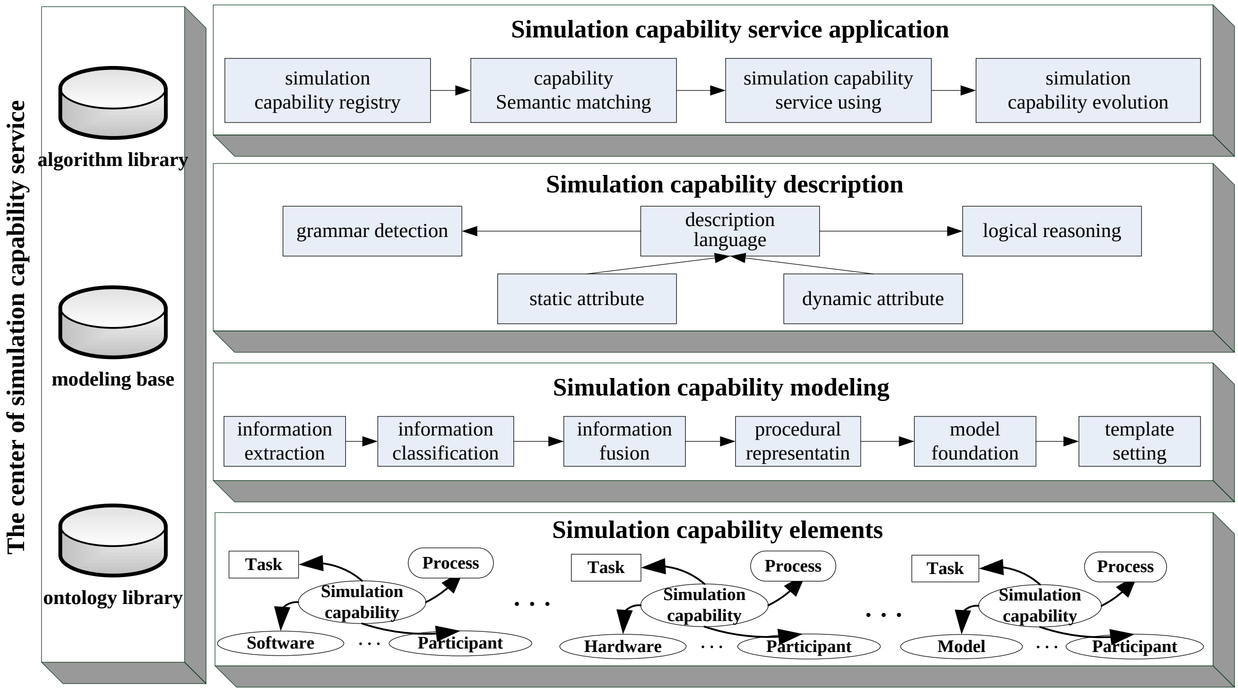

Fig.3 The framework of simulation capability servilization

➢ **Simulation capability elements**

Most of the current researches about capability elements refer to the performance of manufacturing capability. SC elements mainly contain various resources and related assessment factors in the construction process of SC, it is a comprehensive and integrated reflection of SC, and will provide support for construction and formal description of SC model. In order to achieve on-demand use and dynamic collaborative of SC, the display content of SC oriented to users should be analyzed and classified firstly. Then according to the actual requirements related to product and goals, elements of SC will be summarized. For example, SC elements can be divided into six parts ,as shown in fig4: major resources, product and business, participator, process knowledge, SC assessment information, enterprise integrated information. And each part is also consisted by many related elements in detail, e.g., process knowledge contains design model, experience knowledge, simulation method and so on.

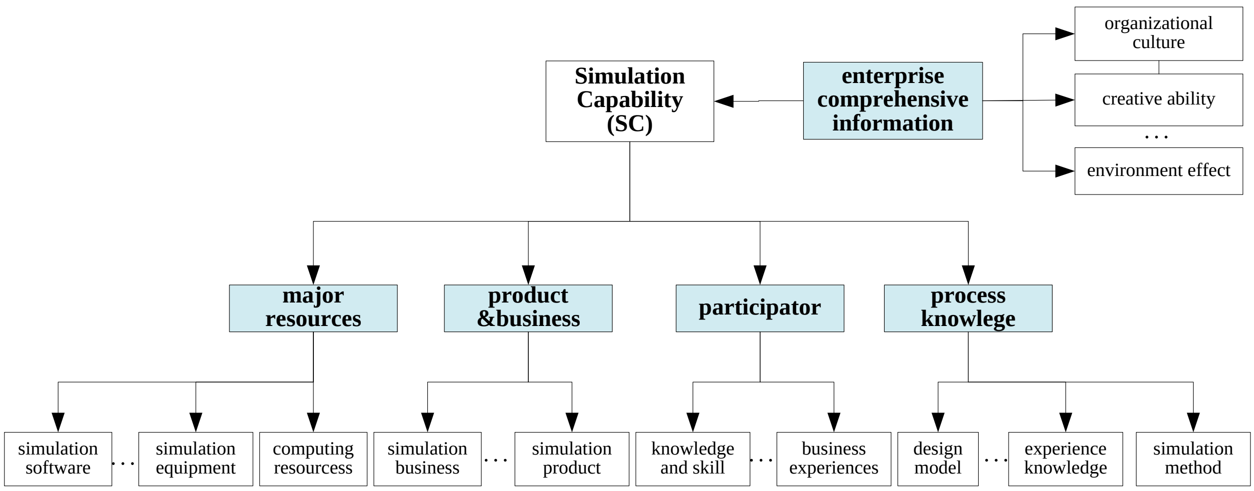

Fig.4 Elements of simulation capability

➢ **Simulation capability modeling**

According to the characteristics and connotation of SC, combined with the above introduction about SC elements, description model of simulation capability (DMSC) is abstractly represented. The transformation from qualitative to quantitative elements of SC is realized. And related key technologies involved in the model as shown in fig4, such as information extraction, information classification, information fusion, process representation, SC description template construction and so on.

The model can be divided into two parts as follows:

$$DMSC=(T, R, P, K, E) + fun(T, P, R, K, E)$$

In above description model, the first part is a four-quad, where T is the simulation task and the objective needed to realize a simulation activity. R is simulation resources elements involved in the simulation process, i.e., hard-resource (including simulation equipments, materials) software, et al). *P* is the participants involved in the simulation process, i.e., the human resource in the simulation resources elements including personal and organization. *K* mainly includes all kinds of knowledge possessed by resources elements and experiences accumulated in simulation process, i.e., production flow, burden scheme, et al. *E* is reflects the comprehensive information of enterprise, such as organizational culture, creative ability and so on. The second is SC evolution function - *fun (T, P, R, K, E),* it expresses the logical relationship between each elements of SC, for instance, the completion of task will be affected by enterprise reputation and organizational culture.

- **Simulation capability description**

Based on the above simulation capabilities model, in order to achieve SC servilizaiton, we need to select a proper way to realize the formal description of SC, as so far the existing service description language include web ontology language (OWL), OWL for service (OWL-S), simple HTML ontology extension (SHOE), can't fulfill the actual requirements. According to the above problems and resources characteristics, many extended service description languages are proposed, for example, OWL-SP is presented based on OWL-S by adding dynamic logical operator. Due to the complexity, uncertainty and knowledge of SC, existing service description languages are not able to meet the requirement of SC servilizaiton. Based on the grammar and lexical of existing service description language, characteristics and servilizaiton requirement of SC were systematically analyzed and summarized, then achieved the expansion of service description language, expanded content main includes the description of the formation of SC, the logical relationship between the elements and related reasoning.

- **Simulation capability application**

It is responsible for the application of SC servilizaiton. On the basis of above proposed methods and related technologies, a prototype of SCs system will be developed, its main functions include SC servilizaiton publication, capability service semantic matching, SC transaction and assessment, SC evolution and so on. Then SC can be provided to user in term of cloud services which are stored in CMfg system through the network. In addition, corresponding methods are taken according to different simulation resources in order to achieve resources intelligent accessing to CMfg system. For example, virtualization technology is adapted to simulation software access, but to simulation equipment, related technologies of the internet of things will be used for that.

- **The center of simulation capability service**

The center of simulation capability service is the foundation of application related to SCS, it is responsible for field ontology library, modeling base and algorithm library. Due to knowledge is the basis of SC formation, so how to store the formal knowledge, is an important issue to SC servilization. Furthermore, description information of SC servilizaiton need to be stored and classified with related rules, it can provide support for user achieving on –demand use of simulation capability service.

5. CONCLUSIONS

MC servilization is a core of CMfg philosophy, and is the key to achieve on-demand use and dynamic collaborative of manufacturing resources and capability. This paper discusses the application process of MC services' life cycle in the complex product's simulation stage, and then elaborates the simulation capability servilization in detail. Simulation capability servilization is helpful to provide user with simulation capability service by network. In the future, a prototype of cloud service platform for complex product simulation will be developed according to above proposed methods and related technologies.

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