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A Method of Manufacture Resource Informatization in Cloud Manufacturing

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ABSTRACT

As a new advanced service-oriented networked manufacturing model, cloud manufacturing has been proposed recently. The informatization of manufacture resource is a core part for realizing this manufacturing model. Based on this problem, a kind of manufacture resource informatization method is proposed for resource virtualization. Firstly, this method puts forward an analysis view of abstract information elements from manufacture resource. Secondly, the entity-relation model is established according to relevant information elements which is mapped to relational model. Then, the relational model is transformed to the object-oriented model. Finally, based on the knowledge representation way of semantic web and production system, the object-oriented model is expanded to the agent model. A case study is given based on this method in the last section, through the case shows that the method can provide a design strategy for resource pool subsystem development in cloud manufacturing system.

Key words: Cloud manufacturing, information model, agent, semantic web, artificial intelligence

INTRODUCTION

In recent years, the next generation of Information Technology (IT) obtains fast development and widespread application, e.g., cloud computing and Internet of Things technology. At the same time, servitization is one of the development movements in modern manufacturing (Schmenner, 2009). The concept of integration between manufacturing and service gets comprehensive, rapid upgrade based on IT technology. Many manufacturing enterprises are changing from manufacturing products providers to manufacturing service providers for adapting the more dynamic market demand. Under this background, a new networked manufacturing model called Cloud Manufacturing (CM) was born (Li *et al*., 2010).

The basic idea of the cloud manufacturing is that collecting all manufacturing resources in a virtual resource pool, providing on-demand use of manufacturing services for all types of users. This model will provide the system integration platform for manufacturing enterprises and help them to move from production-oriented manufacturing enterprises to service-oriented manufacturing enterprises. It not only is the development of virtual manufacturing, agile manufacturing, etc., but also is the further reflection of manufacturing service concept. From the manufacturing system management perspective, cloud manufacturing will achieve the use of distributed resources and centralized resources (Xu, 2012). What's more, the cloud manufacturing more emphasizes on-demand service so that the manufacturing resources get efficient utilization which is also the embodiment of the sustainable manufacturing.

However, the core of cloud manufacturing is that distributed resources are encapsulated into cloud services, realizing information control and management integration based on cloud environment. Clients can use the cloud services according to their requirements. In order to develop the cloud manufacturing platform system, the first step is that concentrating all the manufacturing resources in a called resource pool as Virtual Resource (VR), namely manufacturing resource informatization. On the other hand, from the platform building view, the mainly model research of cloud manufacturing is about how to develop the design, simulation and process, etc., platforms. Such as the Cloud Simulation Platform which is developed by the Beijing University of Aeronautics and Astronautics (Li *et al.*, 2009). But as the most important part of the manufacturing life cycle, the manufacturing process which has not similar platform. One of the most important challenges is that how to make users access and use all kinds of manufacturing process equipment which is used like software resources in the computer virtual resource. For the purpose, based on the analysis of the resource characteristics in the field of manufacturing process, a manufacturing resource virtualization method is proposed which can provide development method for manufacturing process cloud system.

Related works: The virtualization research of manufacturing resource is limited in the published literatures, especially about cloud manufacturing. Liu and Shi, (2011) described an approach of Machining Services (MS) description modeling. And a semantic network of MS description consisting of the core ontology and the extendable ontology was established. Using the method a large number of heterogeneous manufacturing services description problems on the Internet were solved etc., Yin *et al.* (2011) proposed an outsourcing resources semantic description framework based on Web Service Modeling Ontology (WSMO) for the outsourcing service demand manufacturing model. And they established the ontology modeling for outsourcing resources in the study. In order to support a virtual service environment for cloud manufacturing Ren *et al.* (2011) proposed a cloud manufacturing resources virtualization framework and relevant technologies of cloud manufacturing resource virtualization were analyzed. The study also pointed out that the resource virtualization about cloud manufacturing could realize resource sharing, obtaining higher resource utilization rate and reduce energy consumption. What 'more, the problems including condition perception of manufacturing equipment, Internet of Things and access adaptation to cloud manufacturing service platform are mentioned by elaborating and analyzing the cloud characteristics in the literature 6 (Li *et al.*, 2012). Based on the analysis of Human-Computer Interaction (HCI) technology, Ma *et al.* (2011) proposed the research framework of ubiquitous HCI for cloud manufacturing. In our previous published study in the JDCTA (Wang *et al.*, 2012), our focus on the information model for manufacturing resources which was comprised by capability information and service information. Then, aiming to the requirement for expressing semantic information, ontology and web ontology language were used to construct the information model. In this study, we will continue to research how to transform the information model into data structure from the database system development point of view. So, the purpose of this study is how to transform the manufacturing resource to agent model in order to realize database development.

METHOD OF MANUFACTURING RESOURCE INFORMATIZATION

Hierarchical structure of manufacturing resource informatization: The cloud manufacturing resource pool is one of the characteristics of cloud manufacturing which gathers all kinds of dispersed manufacturing resources in the virtual pool. And it is the basis of the concept of "integration of distributed resources" and the concept of "distribution of integrated resources".

In this study, we put the orient-manufacturing process cloud platform development as the background; the proposed manufacturing resource informatization architecture consists of four layers. Figure 1 shows the hierarchical structure including resource E-R model, resource relational model, resource object-oriented model and resource agent model which is the target model.

The first layer is the manufacturing resource information model which is described by the E-R model. The second layer is resource relational model which is the Logical Data Model (LDM) of resource information. The LDM is the foundation of realizing manufacturing resource information structured storage and operation, etc. The third layer is the Object-Orient Data Model (OODM) which is the interim model in the architecture. The OODM is prepared mainly for resource agent model because our agent model is based on the object-orient technology. The fourth layer is the Resource Agent Model (RAM) which is the resource agency model in the resource pool. Resource Agent Model is the performer or operator to realize resource discovery, resource matching and combinatorial optimization of resource when the cloud manufacturing performance. All layers of conversion principle are described in the following.

Conversion principle: The above model reflects the basic pattern of the proposed method in this study, The main features is to construct the information model based on resource information elements and based on the relational database as the data storage medium, eventually expanded to agent model, the conversion principle is shown in Fig. 2.

In the conversion course of the model, the analysis information model is the foundation; the present manufacturing resource classification is based on physical property which have caused that the resource description can't use a unified framework for expression. Oppositely, in this study, we proposed a new idea to classify the resource which is from the demand view not from the resource itself to abstract resources.

To illustrate our new point of view, we use the shaft manufacturing demand as an example to explain it. For example, as shown in Fig. 3, if A manufacturer just wants to let the other maker help complete its keyseat process (namely, demand 1), then he just need find related equipment

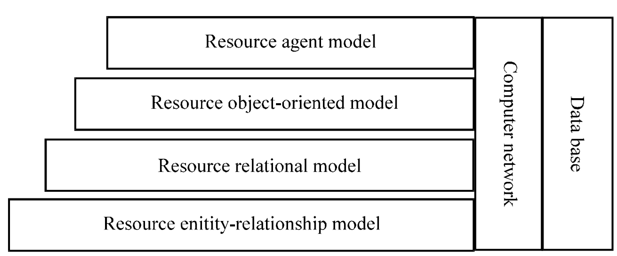

Fig. 1: Architecture of manufacture resource informatization

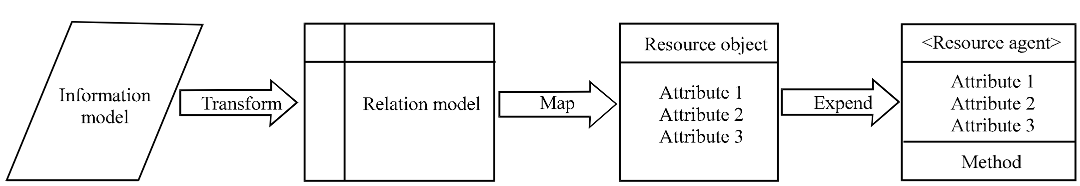

Fig. 2: Data model conversion workflow

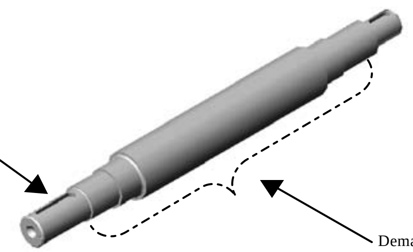

Fig. 3: An example for shaft manufacturing demand

which can process keyseat. So the corresponding resource providers need to publish related equipment resources which can process the keyseat. If B wants the shaft as a part for assembling to other parts or mechanical (namely demand 2), then just need to find the resource provider who can produce or customize shaft, then the corresponding resource providers only need to describe its capacity that he can complete the fact of production shaft and there is no need to describe its internal related manufacturing resources completed the shaft production.

However, from the platform development view it is very important for platform developers to consider whether describe resource itself or resource provider manufacturing capacity. Different demands need to know corresponding manufacturing resources or manufacturing capability statement for manufacturing resource nodes (node). So, the manufacturing node connotation includes the description of the manufacturing resources and manufacturing capacity and the description of the node itself information description, the formal definition as following:

$$MRN = (MR, MC) \tag{1}$$

where, MRN denotes manufacture resource node; MR denotes manufacture resource; MC denotes the manufacture capacity of resource provider.

Based on the viewpoint, process resources are corresponding to the process level demand in the cloud manufacturing. Mechanical processing equipment resources information should be consider to process level demand and need to describe manufacture resource information, the information model frame diagram is shown in Fig. 4.

In the resource information, a process equipment resource node includes five attributes. Through the above information model we can structure the E-R model about process equipment resources. Based on the E-R model and relation model optimization, the equipment resource node relation pattern can be expressed as the following sets:

- Resource info (ID, Name, Provider, Add, Feature, Max L, Max ϕ, Precision)
- Service info (ID, Service time, Process time, Service price)
- Expand info (Material data, process drawing, other info.)

Equipment resource information is stored in the relational database based on the relational model. Through the expansion of object technology (Garcia *et al*., 2004), some attributes are mapped to the object attribute. In our study, we use UML (Prat *et al*., 2006) to represent object model, as shown in Fig. 5. The map schema is that table mapping into class, field mapping

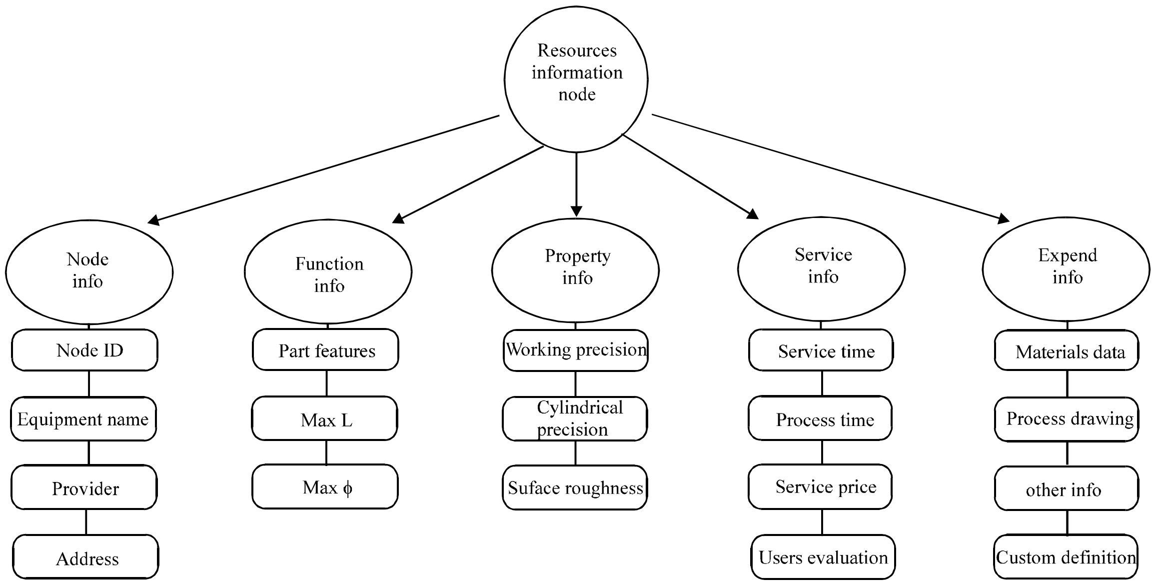

Fig. 4: Information model of processing equipment resource

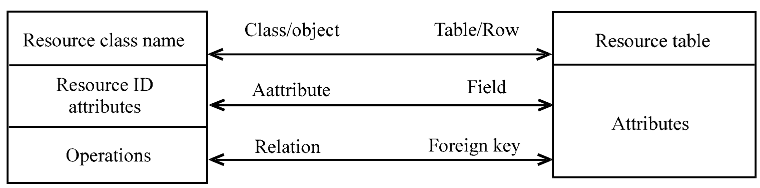

Fig. 5: Mapping diagram of the object model and the relational model

attribute, domain mapping for class attribute value scope, the relation between tables mapping into relationship between classes according to circumstances, respectively.

For the tables without any relation to other tables which is mapped for independent classes and the class have not any relations with other class, the table name is mapped into class name, each field mapping for class attribute, field name as attribute name, the main key maps for the id attribute.

The object-oriented model is expanded from the attribute and method. This approach is supported by a number of OO implementation frameworks, such as JADE. Classes are also used to represent the internal state components of an agent. Each object is added semantic ID attribute which will make resources has the only mark in the semantic web. The semantic web framework is show in Fig. 6. Semantic network is through the concept and semantic relation to express a kind of knowledge network diagram. In this study, the semantic network framework between part characteristics and process equipment is contracted through the process relationship. There are only included part characteristics and equipment resources corresponding relation in Fig. 6 but in actual construction system more relationship can be modified according to demand. On the other hand, response method is constructed by production system which grammatical structure is as follows:

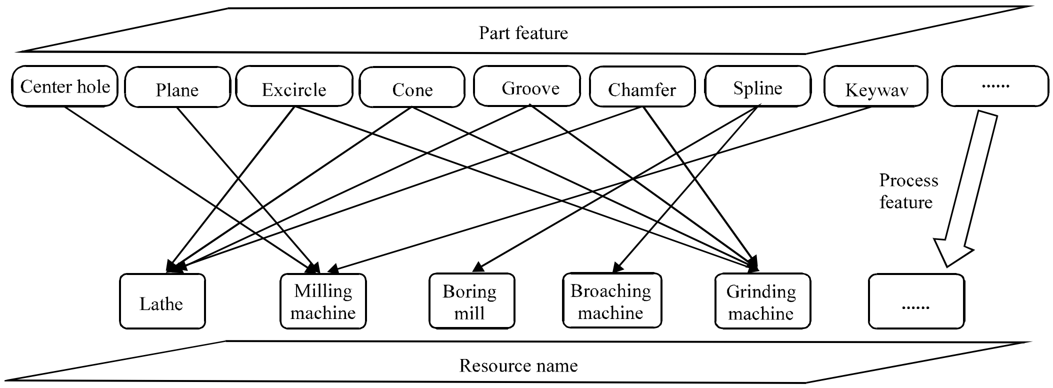

Fig. 6: Part feature and processing equipment semantic relationship

- R1: IF P1 THEN Q1
- R2: IF P2 THEN Q2
- R3: IF P3 THEN Q3

where, (R1 R2 R3) denote the Response number; (P1 P2 P3) denote the produce type premise, used to produce type is pointed out that the available conditions; (Q1 Q2 Q3) is a set of conclusions or operation, used for pointed out that when the premise the indicated conditions are met, the conclusion should be or should response operation. More produce type are put into the object-oriented model using the object-oriented language (such as Java) will make the object model has the autonomy, thus forming agent.

Through the two aspects of expansion, the agent can be expressed in the database management system according to the resource provider of information modification and Agent has the autonomy in the software world.

Case study: Hypothesis that now there are three ordinary lathes CA616 needing to set up resource agent model, Assume that the owner are three universities: Chongqing University, Xinan University and Chongqing Jiaotong University. These university lathes provide process level services and only provide machining cylindrical, inner round, cone part characteristics, respectively. According to the above method framework, we can determine the relevant information model elements and the relational model can be constructed as Table 1 according to these information nodes. As shown in the table, the resource name is CA616. The provider and address can be obtained from the owners. According to the resource information model in the Fig. 3, the lathe information elements can be extracted from the owners, for example, the feature, process size, plan precision, surface roughness and so on (Table 1).

According to the relation table it can be converted to object-oriented model, then establish common lathe agent model. After analysis of the sources that lathe can process parts characteristics, parts characteristics and ordinary lathe the corresponding relationship between semantic can be set up. On the other hand, the system preset series of response condition for resource providers release time setting:

Table 1: Relation model data of CA616 lathe

ID	Resource name	Provider	Address	Feature	Max L (mm)	Max radius (mm)	Z maximum range (mm)	Plan precision (mm)	Cylindrical precision (mm)	Surface roughness (Ra um^{-1})	Service time (day)	Process time (h)	Service price (Yuan h^{-1})	User rating
1	CA616	Chongqing University	Chongqing University	Excircle	750	610	default	0.014/300	0.027/300	1.6	2013.02-2013.05-15	default	30	3
2	CA616	Xinan	Xinan University	Inner University	500	450 circle	default	0.014/300	0.027/300	1.5	2013.03- 12	default	25 2013.05-	1
3	CA616	Chongqing Jiaotong University	Chongqing Jiaotong University	Cone	700	610	default	0.014/300	0.027/300	1.6	2013.02-2013.05-21	default	40	5

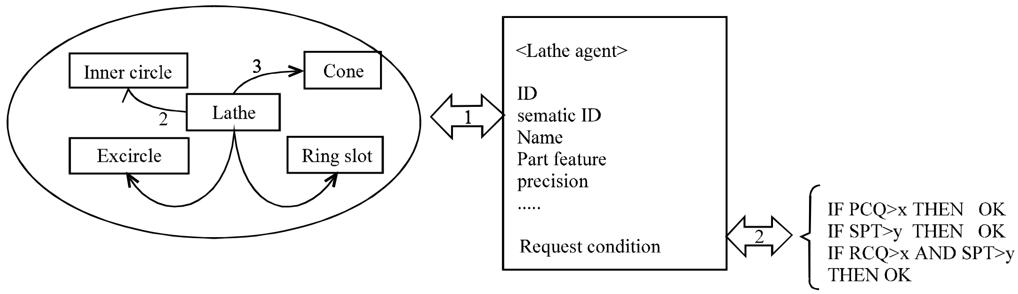

Fig. 7: Overview of lathe agent model component

- R1: IF Parts characteristics quantity (RCQ)>x THEN Response service request (OK)
- R2: IF Service price total (SPT)>y THEN Response service request (OK)
- R3: IF RCQ>x AND (SPT)>y THEN Response service request (OK)

Figure 7 is the finally model of lathe agent. Of course, there are other corresponding ways to customize set according to the produce mode.

The above case justly assumes that constructing three kinds of same equipment resources, in fact there are existed more other types of resources. But according to this method, the system developers can rapid analysis and construction of the similar resources and establish the resource agent model.

CONCLUSION

In this study, we analyzed the cloud manufacturing platform development for manufacturing process and draw the manufacturing resource information is the most important work to realize this platform development. From the perspective of database development, a method about manufacturing resource informatization is proposed. This method target model is to build agent resources model. In order to realize the agent model, we put forward from the resource information model, resource relational model, object-oriented model to agent model conversion method. Finally a case analysis how to use this method to analyze, create resource agent model. The next step we will carry out demand and resource matching method based on the agent model.

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