Research on the Cloud Service Description Model for Cloud Service Composition in Cloud Manufacturing System

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Abstract. Cloud service description is the foundation of cloud service composition in cloud manufacturing paradigm. Through unified encapsulation and description, cloud services in cloud manufacturing service platform can provide effective cloud service information for cloud service composition. This paper puts forward the requirements of cloud service description and modeling in cloud manufacturing paradigm. Based on the general ontology construction method, the core ontology and extensible ontology of cloud manufacturing service are constructed by extending OWL-S. On this basis, a formal description model of cloud manufacturing service is established, which supports the implementation of cloud service description method based on OWL-S for cloud service composition.

1. Introduction

The cloud Manufacturing (CMfg) [1] is a new networked manufacturing paradigm that can achieve product development, production, sales, use and other life-cycle integration of related resources, which can provide standardized and shared manufacturing services with advanced information technology. One of the key aims of CMfg is to realize the added-value of cloud service (CS) through cloud service composition (CSC) [2], i.e. existing CSs are assembled into a composite CS to serve the complex manufacturing task. In view of the diversity and complexity of CSs and requirements, as well as the dynamics and heterogeneity of cloud manufacturing environments, a premise and difficulty in achieving the intelligence and automation of CSC is a comprehensive description of the CS. In the actual process of CSC, the CS provider should be able to accurately describe the CS, and CS requesters also need to accurately describe their own needs. Then the CS satisfying user’s special requirements can be effective positioned, so as to achieve a variety of operational requirements in the process of CSC.

With the introduction of various advanced manufacturing paradigm, more and more researchers begin to study the modeling or the description specification of advanced manufacturing resources and its description methods by employing the technology of STEP, OWL-DL, OWL-S, and so on [3-5]. However, the above researches lack a unified and complete definition of manufacturing resources and concrete description of resource capability. The established manufacturing resource model is not enough to support the special needs of description of CS in the complex environment. Thus a rich and standardized description of CS cannot be provided. Therefore, in order to implement the CSC in CMfg paradigm, the corresponding CS description language (such as SHOE, DAML + OIL, OWL-S, etc.) is
needed to be selected to realize the digital description of the CS to support the optimal configuration and other operations based on the knowledge for CS. In this paper, the CMfg service ontology and the formal description model are constructed by extending OWL-S to implement the CS description based on OWL-S for CSC.

2. The Extensible Ontology and Description Model of CS

CS description is a basis for a series of operations of CS inquiries, discovery, matching, composition and so on. The current description of the service language is WSDL, OWL-S, etc. But the WSDL-based description language is based on the grammar, there is no semantic-related information. OWL-S is an ontology description language that can describe the semantics of the service and can be reasoned based on the inputs, outputs, preconditions, and effects of service.

Although OWL-S can provide a good support for the semantic description of service, it is necessary to extend the description of CS to meet the needs of CMfg environments in view of the complexity of CS. In this paper, CS model is divided into two parts, i.e. core and extensible. On the basis of OWL-S description for service, the ontology description of manufacturing resources, manufacturing capability, quality of service (QoS) and correlations among CS[2] are added to form the core concept ontology of CS (see Figure 1).

![Figure 1 The Core Ontology Model of CMfg Service](image)

3. The Core Ontology and Description Model of CS

This section will respectively investigate the ontology and description model of CloudServiceProfile, CloudServiceModel, CloudServiceGrouding, manufacturing resources, manufacturing capability, QoS and correlations among CS for the extensible description part of CS.

3.1. CloudServiceProfile

CloudServiceProfile inherits the function of the OWL-S Profile and describe CS in detail. CloudServiceProfile describes the basic information of CS, including the name of CS, CS provider's information, and the description text of CS. In addition, CloudServiceProfile describes function information and interface semantics of CS, which can be expressed as follows.

$$S_i = (DO, hasInput, hasOutput, hasPreconditions, hasEffects)$$

For simplicity, the above expression is denoted by $$S_i = (DO, I_i, O_i, P_i, E_i)$$, where $$DO$$ is the domain ontology model that $$S_i$$ belongs to. In this paper, it assumed that all the concepts come from the same ontology. $$I_i = \{I_1, I_2, \cdots, I_n\}$$ is the input set and $$O_i = \{O_1, O_2, \cdots, O_m\}$$ is the output set of $$S_i$$, and $$n$$ and $$m$$ are the number of input parameters and output parameters, respectively. $$I_i$$ and $$O_i$$ can be expressed as triples $$I_i = \langle \text{concepts, properties, values} \rangle$$ and $$O_i = \langle \text{concepts, properties, values} \rangle$$, $$P_i = \{P_1, P_2, \cdots, P_r\}$$ is the preconditions of $$S_i$$, and $$E_i = \{E_1, E_2, \cdots, E_v\}$$ is the execution effects of $$S_i$$.

3.2. CloudServiceModel

The CloudServiceModel is the process model of CS, which describes how the internal flow of CS work, that is, the concrete implementation process of the cloud manufacturing task. CloudServiceModel detailed describe the basic information and semantic information of each
operation contained in CS, such as operating name, parameter, corresponding Grouding mapping file, semantic information of operation, etc.

3.3. CloudServiceGrouding

CloudServiceGrouding describes how to invoke a CS, including CS access protocols, message formats, ports, etc. CloudServiceGrouding is mainly employed to describe the data interface in detail for CS, and indicate the specific communication protocol and the used message during the exchange of information with CS data, including protocol and message format, serialization, transmission and location.

3.4. Manufacturing resource ontology

There must exist one or more manufacturing resources with a certain capacity play a role in any manufacturing process. Manufacturing resource is a kind of resource form with physical presence and static transmission medium, such as processing equipment, simulation software, model, knowledge, data documents and other objective physical resources. Manufacturing resources can be divided into soft resources, hard resources, and other related resources. The manufacturing resource description should be extensible. This paper only gives the description of some commonly used ontology (see Figure 2).

Definition (manufacturing resource model). The formal description of the manufacturing resource ontology is defined as:

\[ \text{CMfgResource} = \{ \text{Soft-resource(software, knowledge, human, \ldots \ldots )}, \text{Hard-resource (manufacturing equipment, computing, material, \ldots \ldots )}, \text{Other related resources (training, information consultation, storage, transportation tools, \ldots \ldots )}, \ldots \ldots \} \].

3.5. Manufacturing capability ontology

Manufacturing capability refers to the subjective conditions that the manufacturing enterprise needs to complete a certain goal. It is an invisible and dynamic resource form. It is a kind of capability to implement manufacturing activities combining with the elements of manufacturing resources, such as the design ability of the enterprise, simulation experiment capacity, production capacity, management capacity, maintenance capacity and other invisible resources. Manufacturing capacity itself has a certain degree of fuzziness and uncertainty, and it is difficult to measure by accurate values. At the same time, each manufacturing process has a different set of manufacturing capability attributes, even if the same manufacturing process, the description of the manufacturing capacity is not the same. So
here the described the manufacturing capacity only reflects the capacity of manufacturing-related functions. The partial extensible model of manufacturing capability ontology is shown in Figure 3.

![Figure 3 The Extensible Model of Manufacturing Capability Ontology](image)

**Definition (manufacturing capability model).** The formal description of the manufacturing capability ontology is defined as:

\[
\text{CMfgCapability} = \{\text{Design capability}(\text{design experience, \ldots}), \text{Simulation experiment capability}(\text{computer precision, \ldots}), \text{Product capability}(\text{productivity, \ldots}), \text{Management capability}(\text{business concepts, \ldots}), \text{Maintenance capability}(\text{performance testing, \ldots}), \ldots\}. 
\]

### 3.6. QoS ontology

At present, the evaluation of quality of service is mainly based on the measurement of QoS standards. QoS of the whole service composition flow can be obtained through establishing an effective quality of service evaluation model. Zeng [6] gave evaluation standard including the execution duration, execution price, success rate, availability and reputation. Literature [7, 8] gave more classification of QoS, such as security, economic, robustness, integrity, accuracy, inter-operability, etc.

Although there exists the qualitative description of the QoS in the ServiceProfile of the OWL-S specification, however the OWL-S specification does not provide a detailed definition of the classes and attributes that can measure QoS. CSs meeting the quality requirements cannot be queried well. Therefore, according to a certain logical order, this paper presents the top-down three-layer semantic ontology of QoS for CS. The partial description of QoS ontology is as shown in Figure 4, including parameter description layer, parameter attribute layer and parameters attribute measurement layer.
Figure 4 The Extensible Model of QoS Ontology

(1) Parameter description layer
This layer mainly describes the concept of common parameters included in QoS. At present, the following QoS parameters are commonly used: time, cost, reliability, availability, reputation, etc.

- **Time**: time takes for the CS to complete the requested task. Time is an important measure for QoS. The shortening configuration time means that the result of the CS operation can be obtained in a shorter time.
- **Cost**: it means the cost of the CS to complete the requested task each time.
- **Availability**: it means the probability that a CS will be available for a certain period of time.
- **Reliability**: the probability that CS executes successfully.
- **Reputation**: the user’s evaluation and satisfaction of the CS.

(2) Parameter attribute layer
This layer mainly describes the attributes of each parameter of QoS, such as generality, domain, aggregation, correlation affection, direction, weight, etc.

- **Generality**: it indicates the characteristics that QoS parameters have in most cases.
- **Domain**: it is specific QoS attributes in a specific area, such as the delivery speed of a courier company, QoS of the airline, and so on. The domain attributes of QoS are generally developed by domain experts based on experience, and there is no uniform standard or specification.
- **Aggregation**: it means that a QoS parameter is composed with two or more parameters together. For example, time is composed by the response time, execution time and delay time.
- **Correlation affection**: it indicates that QoS is affected by the correlation among CSs. When there is some kind of correlation among the CSs, the QoS value of the CS may be increased or decreased on the basis of the default value.
- **Direction**: it means the effect on the evaluation of QoS preferences for different QoS parameters. For example, if the CS execution time is shorter, the higher the QoS value.
- **Weight**: it indicates the different importance of QoS parameters that users consider due to the need.
(3) Parameter attribute measurement layer

This layer mainly provides a way for attributes of QoS parameters to be measured, including values, types, ranges, units, etc.

- Value: it means the value of QoS parameters. The value can be real, interval, language and so on.
- Type: it means the data type of the QoS parameter, which may be digital, text, string, and so on.
- Unit: it means the unit of QoS parameters. For example, units of time are seconds, minutes, etc.
- Scope: it means the range of value that a user can accept for a QoS parameter.

Definition (QoS model of CS). The QoS model of the CS can be defined as a multivariate array:

\[ q = \{q_1, q_2, \cdots, q_n\}, \quad q_i = \{(P_{i1}, M_{i1}), (P_{i2}, M_{i2}), \cdots, (P_{im}, M_{im})\}, \]

where \( q_i \) represents the \( i \)-th \( (1 \leq i \leq n) \) QoS parameter of the CS, \( P_{ij} \) represents the \( j \)-th \( (1 \leq j \leq m) \) parameter attribute of \( q_i \), and \( M_{ij} \) represents the \( j \)-th parameter attribute metric.

3.7. Correlation ontology

For any two CSs, according to the influence of correlation among CSs to QoS, the correlation between two CSs is defined as

\[ Correlation(S_j, S_i) = \langle CoC, BuC, StC \rangle, \]

where CoC, BuC, and StC denote composable correlation, business entity correlation, and statistical cooperate correlation, respectively.

The partial description of the correlation ontology model is shown in Figure 5. Specific description of the correlation between the CSs is discussed in detail in our previous work [2], so here we no longer give unnecessary detail.

![Figure 5 The Model of Correlation Ontology](image)

**Definition (correlation ontology model).** The formal description of correlation ontology model can be defined as:

\[ Correlation(S_j, S_i) = \{CoC(ExactCom, SubsumesCom, Plug-inCom, CrossCom), BuC(PCC, JCC, BCC, VCC), StC(never, sometimes, often, sure)\} \]

4. Conclusion

This paper mainly put forward the demand of CS description and modeling for CSC in CMfg system. Based on the ontology construction method, the core ontology and extensible ontology of CS were established on the basis of OWL-S description. The ontology of CloudServiceProfile, CloudServiceModel, CloudServiceGrouding, manufacturing resources, manufacturing capability, QoS and correlations among CS were given respectively. On this basis, the formal description model of CS was given.

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