OWL-S based Service Composition of Three-dimensional Geometry Modeling

Jiangning Yu¹, Hongming Cai¹ and Fenglin Bu¹
School of Software, Shanghai Jiao Tong University, Shanghai, PR China
E-mail: yujne@yahoo.com.cn; hmcai@sjtu.edu.cn; bu-fl@cs.sjtu.edu.cn

Ailing Liu¹ ²
Shanghai Waigaoqiao Shipbuilding Corporation, Shanghai, PR China
E-mail: y_lal@126.com

Abstract—This paper proposes an OWL-S framework for distributed CAD system based on the combination of semantic web service and CAD technology. Service ontology mapping mechanism is analyzed in detail and semantic model is built with the study of the correlation across the geometry modeling service. On the purpose of accommodating the design pattern of network modeling, this framework supports the service composition of three-dimensional geometry modeling and achieves further integration of service information. At last, a case study from the developed prototype system shows the feasibility and flexibility of this method under distributed CAD environment.

Index Terms—three-dimensional geometry modeling, geometry service, service composition, OWL-S, CAD

I. INTRODUCTION

In the web service based network environment, the development trend of three-dimensional geometry modeling is the integration of CAD technologies and web applications. The integrated system is to realize the packaging and orderly invoking of web service, and improve design efficiency and interoperability. Consequently, the geometry modeling services need to be released freely to provide adequate information for the requirement of uniform interacting mode and integrating heterogeneous systems.

The concept of Web Services for CAD (WSC) aims at interoperation with CAD systems using Web Services [1]. This structure is divided into service Layer, CAD adaptation layer and CAD APIs layer. The service layer provides the access interfaces with WSDL, the adaptation layer packages the XML description of CAD model information for service invoking, and the bottom layer transforms the model data to an identifiable format for CAD system. Parallel WSC [2] is an improved system based on WSC. It uses parallel web services to share assembling information. Through constructing a WSC Master to request WSC node service, it accomplished the assembling of CAD model parts. But it still belongs to a static model information processing method. In the process of modeling, the relationship between model data and structure has been built, so it cannot support the dynamic operations of modeling. Based on this, the architecture of three-dimensional geometry modeling proposes a mixed solid model for characterization which separate the data manipulation and model display, thus it encapsulates modeling operations into web services. The research of web service based knowledge CAD system [3] presents the method of saving model data in the CAD designing process and parametric modeling with WSIF architecture in order to achieve the goal of knowledge reuse.

According to related researches mentioned above, these structures all use web service as the user interactive mode. They semantically package discrete functions, and provide a loose coupling and reusable graphic modeling interface. After being released on internet, it can be accessed through a standard internet protocol in system. This kind of access will be achieved through a self-contained and self-described application program. Before the semantic web comes up, the distribution of geometry modeling services is discrete and unordered, so the access of service must be based on the one-on-one binding to the local operation. This dramatically decreased the service discovery variance and the service access efficiency. After semantic web has been proposed, the ontology can describe static resources as well as a dynamic operation or service. This enabled users to locate, select, use and compose the web based services. This technology provides more flexibility to the web service based CAD system. By releasing the services to semantic resources, the simple services can be recombined and reused. It will enhance the service based information interaction and knowledge sharing.

II. RELATED WORKS

A. Model Data Exchange

The conventional CAD data formats are designed for single-user mode, such as STEP, IGES, DXF, etc. The system has integrated the geometric information, constraint information and engineering information of the product model. Through parameter, feature or historic modeling, it can simulate product design process. As the model structure is often complicated, the saved model document is usually too large for model rendering and display. And it doesn’t have the scene elements either.
Virtual Reality Modeling Language (VRML) [4] is the web language used for virtual scene creation. X3D [5] is an extended technology based on VRML. The main task is to encapsulate VRML function in a light, scalable core. The Web 3D technology creates static 3D models, and adds behavior to these models, which constitute a visual interactive scene [6].

In order to achieve the interaction of CAD data in network environment, there is a need to convert the specific data format to a browser-knowing data format. For example, the conversion from STEP data to VRML is based on the following steps: EXPRESS Language to C++ Language mapping, solid surface triangulation, boundary representation and surface representation, then C++ interface to VRML interface mapping [7].

**B. Distributed CAD System**

Distributed CAD research is mainly in the field of distributed collaborative design. In this mode, distributed at different locations, product designers and others involving in the network use a variety of computer-aided design tools to conduct collaborative activities. Each user in the activities can feel the presence of other users with different levels of interaction. Research in this direction experienced network communication, distributed computing and computer supported cooperative work. After a simple process of combining CAX/DFX technology [8] and web technology, in recent years, it turns to some deep, core technology issues. Service-oriented CAD system architecture asks user to connect CAD system applications through public web service interfaces. With service invocation at the clients, it achieves the interoperation of visualization application in the internet environment.

**C. Semantic Technology**

Semantic web service mainly contains three technology subjects: Ontology Web Language for Services (OWL-S) [9], Web Service Modeling Ontology (WSMO) [10] and WSDL-S [11]. A comparison is shown in Table I.

<table>
<thead>
<tr>
<th>Item</th>
<th>OWL-S</th>
<th>WSMO</th>
<th>WSDL-S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service</td>
<td>General</td>
<td>Web Service</td>
<td></td>
</tr>
<tr>
<td>Semantic</td>
<td>From Semantic Service Description to Web Service</td>
<td>Web Service to Semantics</td>
<td></td>
</tr>
<tr>
<td>Interaction Model</td>
<td>Description Logic</td>
<td>Framework Logic</td>
<td>No Model</td>
</tr>
</tbody>
</table>

OWL-S and WSMO are similar in terms of semantic matching and information extraction, but the interactive mode is different. OWL-S is already a W3C recommendation. It is mainly a logic description using process model. WSMO is mainly a framework description using a mediator meaning that WSMO service ontology is more suitable for the concept modeling. WSDL-S is an extension of present web service standard, you can use different semantic language to mark the web service, but still comly with WSDL specification. So the expansion is limited. That way if you need to use the original service in a composition mode, new rewritten WSDLs must be provided [12][13][14].

For the layer of service implementation, OWL-S provides rich semantic interfaces. OWL-S FLOWS define the combination rules for the web service [15]. In addition, OWL-S does not care about the specific service type. The current service matching engine is established based on WSDL. After replacing the release standard of service, the loose coupling logical framework still can be used. Comparing with the other semantic technology, it is more suitable for the service composition application of three-dimensional geometry modeling.

**III. OWL-S FOR CAD**

OWL-S for CAD (OSC) provides a solution for OWL-S based CAD system. The ontology framework of OWL [11] provides a people-oriented understanding of the semantics and this creates the framework of the description to be customized and shared. Various Web CAD site should use a basic set of classes and attributes for the statement and description of ontology. Thus it calls local CAD engine interface to respond to the requested ontology service which integrates web service resources in accordance with service process by OWL-S Process technology. OWL-S provides rich semantic interfaces which can both describe a simple web service, and a complex combination of multiple services [16].

For composite services there should be an interactive session between the user and provided services so that the user can make a choice and provide conditional information. Modeling services use this information and save model data into VRML coordinate index node in the form of XML. The VRML model is used to be transferred into the X3D scene rendering model by VRML to X3D Translation [17] which can bring a user-friendly internet environment for the interaction of geometry scene data.

In the prior research, most of them focused on the web service based encapsulation of CAD interface. OSC uses web service ontology described by owl to establish ontology service model. Basic framework as shown below: The same as WSC framework, the under layer is service encapsulation layer. But in OSC framework, the packed services should be fundamental and static so that they can be used for the upper ontology service mapping and service composition. From the CAD design perspective, model elements define the data and conditions during service invocation. Service correlation determines service composition approach, which is the integration from a lower level to the top.

An OWL-S service [18] is described by: ①Service Profile describes the information of service organization, functions and characteristics of properties (Service Parameter, Service Category), etc. ②Service Model describes the work nature of geometry modeling service as a process. The main entity type of process ontology is the process. ③Service Grounding is the mapping from the abstract definition to the concrete realization of the service description which specifies the details of how to
access services, including protocols and message formats, serialization and positioning. The owl-s service is a further abstract of design process and will be reflected to the effective service hierarchy. As the original atomic service being combined, it ultimately provides more advanced modeling services for the network environment. The following figure shows the OWL-S for CAD framework. The left side is geometry modeling service hierarchy and the right side is service encapsulation architecture.

![Figure 1. OWL-S for CAD Framework](image)

IV. GEOMETRY MODELING SERVICE

A. Modeling Elements

On the basis of overall design, the task of three-modeling is to draw the specific model structure according to the established principles to reflect the functions to be achieved. In general, the abstract working principle into a certain model needs to determine material, shape, dimensions, tolerances, and disposal method of the structure. Among them, the material, size, tolerance of the components is model data. The shape of components is model structure. The processing mode is operating condition.

1. (1) Model Data

To build a model you need to know the basic data including absolute position, relative positions, dimensions, tolerances. (Used only as identification, not data processing)

2. (2) Model Structure

Model structure is mainly for the expression of three-dimensional geometry model and the physical shape characterization of structure and the correlations between entities. The correlations include the direct and indirect correlations. The solids contacted with the surface have the relation of direct correlation. For example, gear and shaft have a consistent centerline with the inner surface and the outer surface fitting together. The indirect correlations include location correlation and motion correlation. Location correlation indicates the relative position of entities, such as the car position relationship between two parallel axles. Motion correlation indicates the probable movement locus in the scene. For example, the movement locus of cutting tool should be parallel to the centerline of the principal spindle which illustrates the indirect correlation.

3. (3) Condition

Condition is also crucial for the modeling process. A model with full information not only need the model data and structure, but also need to identify the modeling constraints and rules, such as the scene rendering and illumination conditions.

Therefore, from the service encapsulation perspective, geometry modeling services should include the operations of the three modeling elements which provide the input and output of model data, form the basic model structure and build the scene conditions in modeling process. The encapsulated operations should contain the data, structure and condition elements.

B. Five-Stage Modeling and Service Correlation

CAD design guidelines require the analysis of product functionality to get the product model design. The modeling process of a product is subject to five-stage design process.

Stage 1: Make the analysis of the basic functions of the product to determine the structure and the surface features of the shapes.

Stage 2: Determine the physical location and the connection relationship of the shapes.

Stage 3: Link the body surface and other surfaces together to form the basic parts of a product.

Stage 4: Assemble the product parts to each other to form the main components.

Stage 5: Determine the space constraints and the dimension conditions of installed products components.

Through the analysis of three-dimensional geometry modeling elements and modeling process, we have the five stages of modeling service, which are defined for different service layers from S1 to S5.

S1: The service sets SKETCH, CURVED SURFACES, PRIMITIVES accept the inputted model data and generate entities. Although here a sketch model is two-dimensional graph, but its type in the system is still the type of entity which can be used for other entity operations. The output of surface modeling and primitive modeling is an entity type.

S2: The service set FEATURE creates the features of the model. The service set TOPOLOGY operates on the entities through the Boolean operator and form the link between different surfaces to create a product part.

S3: The service set TRANSFORMING repositions the model structure by coordinate transformation, mirror or rotation.

S4: The service set ASSEMBLING assembles the parts through their matching relationship to form components.

S5: The service set SCENE RENDERING adds light, shadows, transparency effects and other conditions to the product model components.

These services in accordance with relationship of the entities can provide a complete service system as shown in Fig 2.

Following the procedure idea of CAD design procedure, modeling operations should have parameters with uniform type. That is the type of a model which is defined as the solid type. First the CAD meta-model is...
constructed by the sketches, the basic entities and the surface modeling set. Then the meta-model data as actual parameter and the model type as formal parameter can be passed to the topological operation, feature operation and transform operation to construct a solid model that is used for the final assembling and Scene.

As shown above, without using the composition of service, S2 design tasks need to use the \{S2, S1\} set of services, S3 design tasks need to use \{S3, S2, S1\} set of services and so on. The more high-level the services are, the higher the complexity is. S5 design task need to use all of the lower layer services. The purpose of service composition is to combine lower layer services in accordance with the designing task forming a new service for the invocation by the high-level service. It will reduce inter-service invocation between different service levels. As shown in Fig 4.

![Figure 2. Service Correlation](image2)

**C. Service Hierarchy**

Making analysis of modeling elements and ascertaining the layers of service system will be useful. It contributes to network visualization environment to help providing common and standard functional modeling services that will greatly enhance the efficiency and consistency of the distributed design environment. However, due to different design tasks, companies may generate more advanced modeling services based on the use of common services. Different service parameters and conditions will allow service providers to provide many services with similar features but different parameters. Complex modeling using basic services repeatedly will be bound to result in information redundancy and waste of resources. Therefore, design companies combine the atomic services to provide a higher level of functional services to network environment. It will further optimize the network service resources and improve the design efficiency. For example, a car model designer may use different parts service to complete the wheel modeling. However, these parts service can be combined as the wheel part service for the vehicle designers to use. They no longer need a decomposition of the design task and use those lower layer services. The following diagrams represent the optimization result of the composition of five-layer service system.

![Figure 3. Service Hierarchy without Composition](image3)

![Figure 4. Service Hierarchy with Composition](image4)

**Higher layer services make the composition of lower layer services. Functionally the combined service has an inclusion relationship with the lower layer service. The design tasks at each level only use the peer service, not access to the cross-layer service, thereby reducing the frequency of using underlying service, while improving the functional requirements of design process. Under the premise that without affecting the complexity of design tasks, the underlying service will be more standardized, and the functionality of advanced service will be more centralized.**

**V. ENACTMENT**

**A. Ontology Service**

Ontology model of three-dimensional geometry services includes service description, product description, input, output, preconditions, effects, access conditions, service quality, and safety parameters and so on. In OWL-S, a service is described by Service Profile, Service Model and Service Grounding [19]. The service profile presents the basic information of ontology service. The service model describes service definitions. The service grounding supports the ontology service.

![Figure 5. Ontology Service Framework](image5)

1. **Service Profile**

   First, it describes the basic information of service provider including serviceName, textDescription and contractInformation. The service provider is mainly CAD design companies.
Second, it describes the function of service. Mainly contains IOPE: Inputs, Outputs, Preconditions, and Effects. Inputs, Outputs are the data flow of service. Preconditions, Effects are the status flow of service. OWL-S can define the conditional expression of Outputs and Effects. Until some conditions are satisfied, the Outputs and Effects could be generated.

Third, it can describe the category and the QOS information of service. Service profile defines the performance attribute by serviceParameter, describes the classification by serviceCategory.

(2) Service Model

Implement the CAD design process based on web service can be seen as an ordered invocation of geometry modeling services. As these functional services are combined and mapping into ontology, the ontology service is produced. It is seen as the process. Service model describes the internal processes of these services.

It is the rules of OWL-S. The operated object of modeling service is model entity. The data of model structure is saved as the VRML nodes in XML. In the procedure of service interaction, the XML document is parameter and its type in owl is string.

In service model, Processes are connected to the IOPEs in service profile. The object case of IOPEs is created in Service Model, through these definitions: hasParameter, hasInput, hasOutput, hasPrecondition, hasEffect [20]. Here is an example of the IOPEs definition of Topology Service showing in Table II.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Inputs</th>
<th>Outputs</th>
<th>Precondition</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topology Service : BooleanCut</td>
<td>Shape1, Shape2</td>
<td>Shape3</td>
<td>Shape1 and Shape2 intersect</td>
<td>Shape1 is cut by Shape2</td>
</tr>
</tbody>
</table>

OWL-S’s Process is divided into three categories: Atomic Process, Simple Process and Composite Process [21]. An atomic process is a description of a service that expects one message and returns one message in response. A composite process is one that maintains some state, each message the client sends advances it through the process. Simple process is an abstract concept. An atomic can realize a simple process, and a composite process can collapse to a simple process. Atomic process is the process that cannot be divided. Each atomic process has grounding information that describes how to access the process. Composite Process consists of a number of atomic processes and service processes. OWL-S’s ControlConstruct defines the implementation order of each sub-process. The ControlConstruct are Sequence, Split, Split+Join, Unordered, Choice, If-Then-Else, Iterate, Repeat-Util and so on [22].

In terms of CAD design, when the service is request, an operation is triggered. So we will rarely use choice or if-then-else control construct. On the basis of five-stage modeling service, the composite process occurred inside one stage should use split or other unconditional construct. But during cross-stage composition, the composite process must use the sequence construct. That is caused by the service hierarchy, as advanced functions are generated on the basis of fundamental functions.

(3) Service Grounding

The grounding of a service specifies the details of how to access the service. Service grounding refers to the service access protocol, message format, port and so on. It packed abstract description of input and output in the atomic process into a network message. The grounding concept is similar as binding concept in WSDL. OWL-S uses WSDL to describe the specific information, so it is necessary to implement concept mapping between OWL-S and WSDL.

B. Service ontology mapping

Service ontology mapping includes two aspects. On one hand, the description of modeling service using WSDL is syntax description. It describes the input and output but doesn’t describe the service preconditions. In the result, the discovery and matching of the modeling services require human intervention. However, using OWL-S can add semantic description to the original modeling service, in particular, the grounding description will let computer automatically find and match the corresponding service. On the other hand, the OWL process can describe logic relations in the service access process, which means with OWL logic syntax fine-grained sub-services can be combined and optimized into coarse-grained service resources for a re-release. Consequently there are more and more provided services, but the use of them will be increasingly simple because service functions are integrated.

According to W3C specifications, mapping WSDL to OWL [23] should keep to certain standards. Therefore, service ontology mapping of three-dimensional geometry modeling should satisfy specific conditions. As shown in Table V. Specifically, the atomic process corresponds to modeling service operations. Both inputs and outputs of OWL-S atomic process correspond to modeling service messages. The type of inputs and outputs (OWL class) corresponds to the abstract type in WSDL that is taking WSDL as a class of specific operation definitions including definitions of parameters and types using in modeling service. OWL uses RDF/XML to encode abstract service. With the mapping specifics and logical relationship, a number of WSDL services are packaged into an OWL resource to be re-released.

<table>
<thead>
<tr>
<th>WSDL</th>
<th>OWL</th>
</tr>
</thead>
<tbody>
<tr>
<td>operation</td>
<td>atomic process(one-to-many)</td>
</tr>
<tr>
<td>message body</td>
<td>inputs/outputs set</td>
</tr>
<tr>
<td>message part(abstract type)</td>
<td>owl class</td>
</tr>
<tr>
<td>wsdl binding</td>
<td>owl grounding</td>
</tr>
<tr>
<td>xml schema</td>
<td>description logic</td>
</tr>
</tbody>
</table>
C. Service composition

The development trend of semantic service is simplification and automation. The basic unit of service composition is the scattered atomic service. OWL-S ontology model contains four parts: service name, service description, service provider, and service URL. The mapping from web service to ontology service and composition need the definition of the process. It converts old services to new descriptions, validates and caching ontology, then executes service process. For the purpose of using OSC for ontology service composition to construct geometry model on internet, the system need to define the interface for the service requestor to access. OWL-S APIs [24] has two important interfaces, OWL Ontology and OWL Knowledgebase. OWL Ontology represents the stored information in a single file. The model of RDF data can be loaded on OWL Ontology. Only ontology object can be used for composition.

Table IV. Service Composition Pseudo-code

<table>
<thead>
<tr>
<th>Service Composition</th>
<th>Service Execution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create a CADService Sequence(List, URI);</td>
<td>Class RunCADService{</td>
</tr>
<tr>
<td>Create an Ontology;</td>
<td>Dim CADService;</td>
</tr>
<tr>
<td>Create a CADService from URI;</td>
<td>Dim CADOperation;</td>
</tr>
<tr>
<td>Create a Composite Process (URI);</td>
<td>RunCADService();</td>
</tr>
<tr>
<td>Create a Sequence Construct;</td>
<td>Create an OWLKnowledgeBase;</td>
</tr>
<tr>
<td>Put the Sequence into Composite Process;</td>
<td>Read a CADService from the URI of Owl;</td>
</tr>
<tr>
<td>Foreach (Size of Services){</td>
<td>Get the Process of the CADService;</td>
</tr>
<tr>
<td>Get CADService from the List;</td>
<td>Create an empty ValueMap;</td>
</tr>
<tr>
<td>Get Process from the CADService;</td>
<td>Set the input Parameters;</td>
</tr>
<tr>
<td>Create a Perform Construct;</td>
<td>Create an Execution Engine;</td>
</tr>
<tr>
<td>Put the Process into Sequence;</td>
<td>Get the Result;</td>
</tr>
<tr>
<td>Create Profile;</td>
<td>System.out.println(Result);</td>
</tr>
<tr>
<td>Create Grounding;</td>
<td>}</td>
</tr>
<tr>
<td>Return CADService;</td>
<td></td>
</tr>
</tbody>
</table>

VI. Prototype System and Experiment

A. Prototype system

The following figure shows the architecture of the prototype system.

The overall framework for the system is Client/Server architecture including three parts: the application program interface, the client and the server-side.

System execution engine is based on CAD core engine which provides the basic interface for graphic modeling. The interface will be used for the encapsulation of web service. Server-side is based on OWL-S framework. At the beginning encapsulated services are unordered in the network environment, so the service's process model and the semantic logic input and output should be matched through the description mapping from WSDL into OWL. Then services are deployed in the bus of server-side which connects service registry and service matching engine with OWL-S virtual machine [25]. The client is distributed web CAD set which custom the matched service to generate and view the design models.

The prototype system uses CAD engine interfaces to implement the encapsulation of modeling operations and releases services with service publishing tool (Axis). Each web service will be deployed on the server-side, and be accessed by internet browser with the mode of SOAP binding, HTTP, etc. At the client, WSDL documents are mapping into corresponding owl document, execution process is defined with OWL process sequence mode combining atomic process services. The output result is saved in VRML nodes as string type. The core of user system uses VRML to X3D exchanger to render VRML nodes into X3D scene model. The prototype system UI shows as bellow.

B. Case study

Take a 3D desk modeling process as an example. Use Opencascade6.3 as the CAD engine. The basic implementation of modeling operations is through Dynamic Link Library (DLL). The process mainly consists of four steps.

1. Create leg primitives. Use Cone, Cylinder, Sphere in Primitives set.
3. Copy leg one and translate. Use Copy, Transform operations in Transforming set.

Figure 6. System Architecture based-on OWL-S

Figure 7 UI of the Prototype System
(4) Finish desk modeling.

The geometry modeling services describe these different kinds of activities in the design case. We start with creating instances of the atomic process. Define the used web services as atomic processes. The decision what is a composite process can be further refined into a combination of atomic processes. Therefore decide what are the inputs and outputs for each of the atomic processes. The following diagram is an example of service publishing for the atomic process which defines the input and output parameters.

![Diagram](image)

Figure 8. an Example of Service Publishing

Service model is the core for OWL-S based service. Along with start of the process, the atomic processes PrimitiveCone, PrimitiveCylinder and PrimitiveSphere make up a composite process. The ControlConstruct signs before and after are Split and Split+Join. These service processes belong to the S1 layer in five-stage service system. The control construct sign between the TopologyFuse process and Transforming process is Sequence. The two service processes belong to the S2 layer and S3 layer respectively.

![Diagram](image)

Figure 9. Service Model

Based on the definition of composite process, ontology mapping and service composition of the three-dimensional geometry modeling is a transition process from the old description into the new description. The owl-s engine will verify and buffer the ontology object to execute the process. As shown in Fig.8, the PrimitiveCylinder service is written in WSDL. For the semantic service composition it is rewritten in OWL based on the mapping rules. A fragment is shown as following. It describes the service ID: CylinderService, the service atomic process: CylinderProcess.

![Fragment](image)

Figure 10. an OWL Fragment

In the above case, the use of OWL-S to implement a distributed CAD system, not only achieve the main mechanism of Web Service for CAD, but also has advantages of the semantic expansion and service composition. The prototype system verifies the feasibility and flexibility of the framework, encouraging the development of distributed CAD system under semantic web environment. However, present study mainly focused on the realization of applications in the service composition. Along with the development of semantic web technology, further research can focus on the discovery and matching of geometry modeling services, semantic constraint model and the test method to perfect the system functionality.

VII. CONCLUSION

Semantic web service, built on the open standard, introduces a new computing concept by enabling different clients to access their services. Users and software agents should be able to discover, invoke, compose, and monitor Web resources offering particular services and having particular properties, and should be able to do so with a high degree of automation if desired. According to the current development situation of distributed CAD systems under internet environment, this paper provides a solution to three-dimensional geometry modeling from the semantic web aspect. It establishes an OWL-S based service composition framework and defines the service model. By studying the mechanism of mapping modeling service into semantic ontology, it proposes service composition application of the ontology resources in a procedure way, thereby the problems of scattered resources and service integration difficulties existing in current service-oriented distributed CAD systems can be solved effectively. In the end, a practical example and the prototype system demonstrate the implementation process of composition application of OWL-S based modeling services.
Further study should be focus on the following point: (1) Adding semantic annotation to the geometry modeling services to assist service discovery and service matching. (2) For the automatic ontology service discovery and invocation, there is need to create a series of upper ontology. (3) For the scene modeling and model data interaction, service work flow and data base support are needed. Although the current prototype system did not address these issues, further work should focus on them.

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Jiangning Yu was born in 1986; he received his BS degree in School of Mechanical Engineering in 2008 from Shanghai Jiao Tong University, China. He will receive MS degree in School of Software in 2011 from Shanghai Jiao Tong University, China.

He won the 1st prize of National Robot Contest in 2006, China. He published the paper “Knowledge-based web service environment for 3D visualization” in Journal of Advanced Materials Research (EI indexed) in 2010. In the same year, he got the award, “Excellent Teaching Assistant”, for the course of Modeling of Enterprise and Information System.

He is currently studying in Information System Technology Laboratory as a postgraduate student in Shanghai Jiao Tong University, China. His research interests include Geometry Modeling Technology and Service Oriented Architecture.

Hongming Cai was born in 1975, he received his BS degree in Aircraft Structural Strength Design in 1996, and received his MS degree in Machinery manufacturing automation in 1999 and Ph.D. degree in Aerospace Manufacturing Engineering in 2002 from Northwestern Poly-industrial University, China. His research interests include Computer Aided Design and Computer Graphic, Information Integrated Technology. He served as postdoctoral research fellow at the Computer Science and Technology Department of the Shanghai Jiao Tong University, China during the period of November 2002 to September 2004. And he served as visiting professor at the Business Information Technology Institute of University Mannheim, Germany during the period of August 2008 to July 2009. The visiting scholarship was appointed and sponsored by Alfred Krupp von Bohlen and Halbach Foundation, Germany.

Dr. Cai is currently an associate professor in School of Software, Shanghai Jiao Tong University. Dr. Cai is a director of China Engineering Graphics Society, and he is a member of ACM and a senior member of China Computer Federation.

Fenglin Bu was born in 1961; he received his BS degree in School of Material Engineering in 1982 from Shanghai Jiao Tong University, China. He received his MS degree in School of Material Engineering in 1995 from Shanghai Jiao Tong University, China. He got the 3rd prize for Process in Science and Technology of State Education Commission in 1998, China. He got the 2nd prize for Process in Science and Technology of Shanghai in 1999, China. He is currently an associate professor in School of Software, Shanghai Jiao Tong University. His research interests include Product Modeling and Automation Design.

Ailing Liu was born in 1976; she received her BS degree in School of Automatic Control department in 1998 from Huazhong University of Science and Technology, China. She received her MS degree in School of Software Engineering in 2010 from Shanghai Jiao Tong University, China. She is currently an Assistant Minister in IT department of Shanghai Waigaoqiao Shipbuilding Corporation.