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Developing Semantic Business Model for VO Construction on Semantic Grid

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Abstract: This paper combines semantic web technology with business modeling and yields semantic business model that is semantically described in terms of roles and relationships. The semantic business model can be used to discover grid services by means of automation tools. The gap between business goals and grid services is bridged by role relationships and compositions of them, so that the virtual organization evolution is supported effectively. Semantic business model can support virtual organization validation at design stage rather than at run-time stage. The designers can animate their business model and make initial assessment of what interactions should occur between roles and in which order. The users can verify whether the grid service compositions satisfy business goals.

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0 Introduction

Grid computing is a new field concentrating on flexible, secure, coordinated resource sharing among dynamic collection of individuals and institutions. Initial research on grid computing focused on hiding the heterogeneity of computational resources and providing large-scale data and computation systems. As grid computing has evolved, it continues to be about bringing resources together, but the emphasis has shifted from the earlier view to the notion of virtual organization (VO) that are formed dynamically by individuals and institutions with common interest. A virtual organization comprises a set of individuals and/or institutions having direct access to computers, software, data, and other resources for collaborative problem solving or other purposes. The grid is a support where virtual organizations will evolve with the changing business goals and the shared services[1, 2].

Although the advantages of the VO are well known at the conceptual level, but most researches focus on the interoperability of grid services, little effort is put on the business requirements for VO. The practical application is still far from the expectations. VO planning and creation are still difficult[3]. One of the obstacles is the lack of appropriate business model for VO construction. The purpose of such a model is to specify requirements of VO. VO construction spans three phases: planning, design, and implementation. By planning, the customer describes the desired service. Business model is used to describe resources management, task allocation, and support business process management that aims at monitoring operations on a business process level[4].

Current business modeling approaches focus on just a few aspects of business processes. None of the existing languages provides the expressiveness and degree of formal semantics necessary for the representation of the business knowledge[5].

Workflows need to work within a structure of organization and local constraints. VO needs to perceive the condition of the environment and actions accordingly, and needs to be more adaptive by providing a structure. A natural way to conceptualize organization is as roles and relationships. A role is an encapsulated business entity that is situated in some environment and is capable of flexible, autonomous action in that environment in order to meet its business goals[6, 7].

The discovery of a grid service means that a published grid service matches user's requirements. The concept "match" means that the description of a published grid service is sufficiently similar to that of the user's requirements. Existing researchers focus on semantic description of grid services, but the requirements of VO construction lacks of semantic information. It is difficult to satisfy the need for semantic matching[4, 8]. In addition, the process of VO planning, configuration, and maintenance are themselves a candidate respectively for tools and for automation that require the application of Semantic Web technologies.

Our idea is to combine semantic Web technology and Business modeling in order to semantically describe business model. The virtual organization structure, its constituent partners, orchestrating process, and constrains are explicitly specified to semantically specify the requirements of VO, to prepare necessary control structures for the formed VO, and to monitor the behavior within the VO during its lifetime.

1 Semantic Grid and Business Model

The service-oriented architecture is well suited to grid applications that allow different stakeholders to retain ownership of their own content and processing capabilities, and to allow others to discover, transparently access and process relevant content wherever it may be located in the grid under the appropriate conditions. HU Chunming *et al* proposed a web service-based grid architecture within the open grid service architecture (OGSA) framework, and workflow technology is used to model the task of the grid application and its requirement on resource and services[9].

In the grid environment, shared resources and users typically span different organizations. Thus the demand on semantic description and an effective and efficient search support for grid services is becoming increasingly significant. Semantic grid makes use of semantic web technology to support the automated discovery, substitution, composition, and execution of grid services. Ye Zhang *et al*[4] have proposed semantic grid node framework to build up a semantic description and representation for grid services. They have also developed a semantic based search and reasoning engine for the grid services registration and discovery for grid node selection using an ontology-based matchmaker.

Kou Yue *et al*[10] apply ontology theory to describe semantic information so that a uniform understanding between provider and consumer can be obtained in concepts, and the resource efficiency can be promoted remarkably. S. Majithia *et al*[11] also present an architecture to facilitate automated discovery, selection, and composition of semantic grid services, which distinguish it from other work in this area. They distinguish between different levels of abstraction of loosely coupled workflows to facilitate reuse and sharing, and allow users to specify and dynamically refine a high-level objective that is then translated into a workflow. It should be possible to carry out "what-if" analysis in an efficient manner when some sub-processes are changed.

L. M. Camarinha-Matos identifies some major open research challenges for virtual organizations. One of them is modeling, administration, and management of highly distributed business processes and roles[3]. Business Process Management (BPM) is an approach to manage the execution of IT-supported business operations. However, BPM does not provide a uniform representation of an organization's process space on a semantic level, the degree of mechanization in BPM is still very limited, creating inertia in the necessary evolution and dynamics of business processes. M. Hepp *et al*[5] propose to combine semantic Web and BPM and yield one consolidated technology that is called semantic business process management, which supports both agile process implementation and querying the business process space by logical expressions.

Currently, in VO development process, business knowledge is frequently tacit, embedded in practice and experience rather than explicitly recorded and its associated semantics are in an implicit fashion, providing poor mechanisms for sharing this knowledge with other grid services, which makes sharing and adaptation extremely difficult. Managers and other business experts cannot quickly determine whether a specific process can be composed out of existing atomic processes, nor can those stakeholders query the process space within their organization. Thus, checks for feasibility (prior to the launch of new VO or services) or compliance are still to be done manually by business analysts. In addition, it is impossible to use machine reasoning in order to identify potential side effects of modifications. Also, process improvement should be conducted for global process optimum, not only for local process optima; however, this cannot be achieved without a proper representation of business model[1,5]. To support the creation of virtual organizations, the research on semantic business model is required. Semantic business model can be used to specify the VO requirements, divide the work between the roles, and support to monitor the ongoing operation of the virtual organization.

2 Semantic Business Model

One important aspect in VO construction is the specification of the business goals, structure, activities, and constrains. The key concepts underlying business model are role and relationship. We use the concept of role as a means to encapsulate the business goals, constituent partners, activities, and constrains. Roles are: ① clearly identifiable business entities with well-defined boundaries and interfaces; ② situated in a particular environment-they receive inputs related to the state of their environment and they act on the environment; ③ designed to fulfill specific business goals; ④ autonomous-they have control both items over their internal state and over their own behavior; ⑤ capable of constructing hierarchical structure. Roles can serve as building blocks to construct complex VO on the basis of reuse and extension. Another important modeling block is relationship that describes an association between roles. It includes three kinds of relationships between roles: "Responsibility-Assignment", "Take-Part-In", and "Satisfied-By"[7]. First of all, we give the role specification.

A role specification provides domain-specific information and includes the following parts: Category, Global-goals, Constituent Partners, Activities, Orchestrating process, and Behavior.

The category contains four attributes: Domain, Name, Synonyms, and Abbreviations. Domain gives the area of interest of the role. The synonyms attribute contains a set of alternative characteristics of Name. Abbreviations attribute is a set of short forms of Name. Roles take part in business process by their activities. The Global-goals (including functional goals and non-functional goals) give the reason for existence of the role. Constituent Partners is a set of roles that cooperate with each other in order to achieve local business goals of the role and are regulated by the Orchestrating process.

Activities are described at three levels: syntactic, semantic, and operational.

Syntactic Properties: Activities are syntactically described by the following attributes: name, mode, input, and output. The activity's mode has one of the values In, Out, In/Out, and Out/In. Depending on the mode, each activity has input parameters, output parameters, or both. A parameter has a name and data type associated with it. XML Schema data types can be adopted as a canonical type system for input and output parameters.

Semantic Properties: The semantics of Activities is crucial to discovering grid services on the semantic grid. Semantic properties defined for Activities include Precondition, Post-condition, and other domain specific properties.

Operational Properties: We propose to provide Activities with Scenarios as operational properties that can be used as interpretation of Activities to understand role function and to validate business model. In addition, scenarios can also be used to validate whether the discovered grid service satisfies business goals, and be used to conduct regression test when the developer/provider change the grid service implementation, leaving the interface unchanged. In that case the user may not be aware of the change made, while such a change can influence the behavior of the system. If it is indicated that Activities of a role satisfy business goals (Φ) by testing based on Scenarios (S), we write the case as $S \models \Phi$, otherwise $S \not\models \Phi$. There exist relationships among Scenarios of different role specifications. The Scenarios of low-level role specification is designed based on Scenarios of high-level specification[12]. Due to the limited space, we don't discuss them in detail.

In the role specification, Behavior describes another kind of semantic information of Activities by using formalisms like finite state transition system. Generally speaking, not all the activity sequences are permitted.

There exist activity restrictions that specify the possible activity patterns. An activity may require going through a pre-requisite activities. Behavior is used to determine valid order of Activities.

A business process can be decomposed into a hierarchy of sub-business processes. When properly "orchestrated", a combination of various processes taking place at different roles of the organization will lead to the achievement of the global goal of the organization. The Orchestrating process governing an organization has to capture aspects of collaboration at multiple levels. The Orchestrating process carries information about the expected participant roles, activities, and the expected collaborative order between participants. The Orchestrating process is a logically central element that can be used to establish and monitor interoperability between independent participants, and can be verified. Because the Orchestrating process is the critical part of the VO and may vary over time, it is important that the Orchestrating process should be explicitly represented and available to both the application and the user.

The semantic business model includes relationships between roles. In order to validate, manage business model and to support discovery and composition of grid services by means of automated tools, the relationships should be defined rigorously.

Definition 1 (role description) A role description is a tuple $D=(\theta, \Phi, C)$, where θ is a set containing signatures of role description; Φ is a set of functional goals (activities) and constrains; C is the context of Φ including global-goals, orchestrating process, constituent partners, and so on.

Role description is used to define role specification.

Definition 2 (scenario) A scenario for a role activity is a pair (M, V), where M is a transition system structure $(W, w_0, \rightarrow)$; V is a valuation function: V: $F \rightarrow W \rightarrow S$, F is the set of formulas over θ (e.g. pre-condition and post-condition), S is the sort of a given formula f.

Scenario can be used to validate business model or to test the VO.

Definition 3 (role specification) A role specification is a tuple $R=(D, B)$, $D=(\theta, \Phi, C)$, B is a set of scenarios, and $B \models \Phi$.

Let us distinguish between what we shall call simple role specification and composite role specification to facilitate reuse and sharing. If a role specification only contains business goals, and it dos not include constituent partners and orchestrating process for achieving business goals, it is called simple role specification. If a role specification contains constituent partners and orchestrating process, it is called composite role specification.

A role specification with semantic information can be used as requirements to compare published grid services with semantic information by means of automated tools.

Definition 4 (γ-relationship: responsibility-assignment) Let $R_1=(D_1, B_1)$ and $R_2=(D_2, B_2)$ be role specifications, $D_1=(\theta_1, \Phi_1, C_1)$, $D_2=(\theta_2, \Phi_2, C_2)$. γ: $R_1 \rightarrow R_2$ means that Φ_1 is global-goals of Φ_2, and $B_1 \models \Phi_1 \Rightarrow B_2 \models \Phi_2$, $B_2 \not\models \Phi_2 \Rightarrow B_1 \not\models \Phi_1$.

γ-relationship describes the decomposition of high-level business goal, and answers the question "why a role exists".

Definition 5 (β-relationship: take-part-in) Let $R_1=(D_1, B_1)$ and $R_2=(D_2, B_2)$ be role specifications, $D_1=(\theta_1, \Phi_1, C_1)$, $D_2=(\theta_2, \Phi_2, C_2)$, B_1 and B_2 are scenarios of R_1 and R_2 respectively. β: $R_1 \rightarrow R_2$ means that: the constituent partners of R_2 contain R_1; Φ_1 is sub-goals of Φ_2, and $B_2 \models \Phi_2 \Rightarrow B_1 \models \Phi_1$, $B_1 \not\models \Phi_1 \Rightarrow B_2 \not\models \Phi_2$.

β-relationship can be used to trace how a role cooperates with others.

Definition 6 (λ-relationship: satisfied-by) Let $R_0=(D_0, B_0)$ be a simple role specification and $R=(D, B)$ be a composite role specification, $D_0=(\theta_0, \Phi_0, C_0)$, $D=(\theta, \Phi, C)$, B_0 and B are scenarios of R_0 and R respectively. λ: $R_0 \rightarrow R$ means that: $\Phi_0=\Phi$ and $B \models \Phi \Rightarrow B_0 \models \Phi_0$.

λ-relationship helps stakeholders to trace how the global goal is achieved.

Let $R_0=(D_0, B_0)$, $\{R_i=(D_i, B_i) \mid i \in \mathbf{N}\}$ and $R=(D, B)$ be role specifications, R_0 be a simple role specification only containing business goals, and there exist $\{\gamma_i: R_0 \rightarrow R_i \mid i \in \mathbf{N}\}$ and $\{\beta_i: R_i \rightarrow R \mid i \in \mathbf{N}\}$. If there exists $\lambda: R_0 \rightarrow R$, then R_0, R, $\{R_i\}$, $\{\gamma_i\}$, $\{\beta_i\}$, and λ constitute an organization structure, written as $R_0 \rightarrow_\lambda R\{R_i \mid i \in \mathbf{N}\}$. Organization structure is specified at several levels of functionality or granularity in a consistent way and can be used to describe department, team, or whole organization.

Definition 7 (semantic business model) A semantic business model is pair $S_B=(O, L)$, where O is a set of role specifications at different abstract levels, L is a set of relationships between roles.

The different roles at different abstract levels can be traced by relationships or relationships composition. A role itself is a partner in a high-level role, hence leads to a hierarchical model structure. Figure 1 is an example of semantic business model.

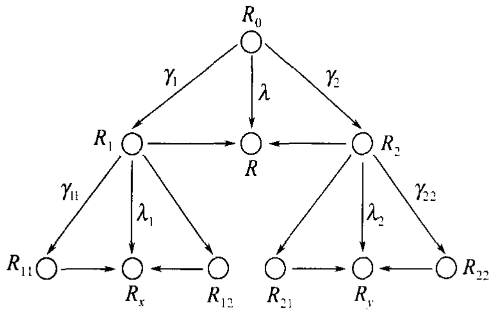

Fig. 1 Semantic business model

In Fig. 1, R, R_x, and R_y are composite role specifications. R_0, R_1, R_2, R_{11}, R_{12}, R_{21}, and R_{22} are simple role specifications, it only contains business goal. When constructing VO is based on grid services, the lowest-level simple role specifications (e. g. R_{11}, R_{12}, R_{21}, and R_{22}) can be used to compare with published grid services. The composite role specifications (e. g. R, R_x, and R_y) contain business processes at different abstraction levels. The semantic information of role specification supports effective discovery of grid services by means of automated tool.

3 Conclusion

Virtual organization on semantic grid offers significant enhancements to our capabilities for collaboration, and has exciting ambitions in e-Science, e-Enterprise, and e-Business. This paper shows that the full richness of the VO vision requires the semantic business model that are given well-defined meaning to specify requirements of VO, maps them to a collection of grid services and supports to monitor the execution of grid services according to business model. This paper combines semantic web technologies with business modeling and results in semantic business model that can be used to discover grid services by means of automation tools. The gap between business goals and grid services is bridged by role relationships. The semantic business model supports VO validation at design stage rather than at run-time stage. Validation can be undertaken with two views. The designers can animate their business model and make initial assessment of what interactions should occur between roles and in which order. The users can verify whether the grid service compositions satisfy business goals.

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