OntoEdu: Ontology-based Education Grid System for e-Learning

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Abstract *Based on several new technologies, such as ubiquitous computing, ontology engineering, semantic web and grid computing, this paper proposed a flexible educational architecture for e-learning, which is called OntoEdu. The core of OntoEdu is educational ontology. It is divided into five parts: user adaptation, automatic composition, education ontology, service model and content model. At the meantime, the grid-based design is also proposed, which realized the concept reusability, device and user adaptability, automatic composition, function and performance scalability. The simple OntoEdu1.0 implementation indicates that OntoEdu architecture is viable and flexible.*

Keywords *e-learning, Education, Ontology, Grid Computing, Semantic Web*

1. Introduction

Technologies has been enhancing Education all the time, and new technologies ware always first utilized by education, especially with the emerging of computer related information technology[1]. Network education (including distance education and distance learning), or e-learning has come out for several years with the computer networks emerging. Wireless and mobile computing has resulted in the mobile education or m-learning [3, 4]. With wireless and mobile advantages, it is very promising to realize anytime, anywhere, anyway, any device learning and instructing. However, it will take a long time and too much work to get the goal. One obstacle is about the technology, it means a lot of technologies must be considered, such as mobile computing, ubiquitous computing, semantic web, ontology [2, 5] and other technologies. Another is the engineering implementation of application system, which means adding mobile computing technology into old e-learning system, and modifying old system need a lot of work: redesign architecture and re-implementation m-learning system. At the meantime, too large amount of universities will update their systems and much more educational resources will be ported to new systems. It need too more work! Every time new technology is utilized by education, it is always necessary to waste a lot of additional work. And with the educational resource increasing, the updating work will be more and more.

In a short word, any new technology will enhance education, new function will provide better education service, but it will result in too much work to modify and update the old system. How can we abandon the waste? Some technologies are needed: Content Reusability， Code Reusability, Function Scalability, Function Scalability, Device Independence, Context Adaptability, User Specific Adaptability, Performance Scalability.

In order to overcome these obstacles, many researchers have spent much more work [1, 2, 6-10]. According to [2], drawbacks of current education system from AI and ED point of views are listed as follows:

1. There is a deep conceptual gap between authoring systems and authors.
2. Authoring tools are neither intelligent nor particularly user-friendly.
3. Building an IIS requires a lot of work because it is always built from scratch.

4. Knowledge and components embedded in education system (ES) are rarely sharable or reusable.
5. It is not easy to make sharable specifications of functionalities of components in ES.
6. It is not easy to compare or cross-assess existing systems.
7. Communication amongst agents and modules in ES is neither fluent nor principled.
8. The authoring process is not principled.
9. There is a gap between instructional planning for domain knowledge organization and tutoring strategy for dynamic adaptation of the IIS behavior.

Reference [2] claims that what we need to overcome these drawbacks is ontology-based architecture and appropriate ontologies, that is, the introduction of ontological engineering. Ontology and other technologies have been or have being studied by many researchers and a lot of results have been achieved, but there is not an overall architecture and far more than practice. To get above goals, this paper will propose flexible education architecture based on ontology technology, Grid technology, Semantic web technology, it is called OntoEdu---Ontology-based Education Grid System for e-Learning. This architecture realized the concept reusability with ontology, Device and user adaptability with ubiquitous computing, Automatic Composition.

The remainder of this paper is organized as follows: Section 2 introduces some new technologies; section 3 presents the logical architecture; section 4 gives the implementation design of OntoEdu. Finally, experiments and conclusions are given in Section 5.

2. New Technologies Introduction

This section will introduce some new technology simply, detailed information can be found in related references.

2.1 Ontology

An ontology is an explicit specification of a conceptualization [16]. The term is borrowed from philosophy, where an Ontology is a systematic account of Existence. For AI systems, what "exists" is that which can be represented. When the knowledge of a domain is represented in a declarative formalism, the set of objects that can be represented is called the universe of discourse. This set of objects, and the describable relationships among them, are reflected in the representational vocabulary with which a knowledge-based program represents knowledge. Thus, in the context of AI, we can describe the ontology of a program by defining a set of representational terms. In such an ontology, definitions associate the names of entities in the universe of discourse (e.g., classes, relations, functions, or other objects) with human-readable text describing what the names mean, and formal axioms that constrain the interpretation and well-formed use of these terms. Formally, an ontology is the statement of a logical theory.

In OntoEdu, ontology is used to describe the concepts of education platform and their relations. The OntoEdu ontology includes two kinds of ontology: content ontology and activity ontology. Educational ontology is the core module to control other components. With ontology, OntoEdu can learn knowledge from education specialist and information specialist and then, automatically compose service system in terms of user request---called automatic composition.

2.3 Semantic Web

The vision of the semantic web aims to have distributed data and services defined and linked in such a way that they can be used by machines not just for display purposes, but for automation, integration and reuse of data and services across various applications.

Automatic Web service discovery: automatic web service discovery involves the automatic location of Web services that provide a particular service.

Automatic Web service invocation: Automatic Web service invocation involves the automatic execution of an identified Web service.

Automatic Web service monitoring: Once a web service has been invoked, one may want to know the status of the service.

Automatic Web service composition: This task involves the automatic composition and interoperation of Web services to perform some task, given a high-level description of an objective.

2.4 Grid Computing

Grid computing is a services-oriented architectural approach that uses open standards to enable distributed computing over the Internet, a private network or both. This approach can help research organizations and universities aggregate disparate IT elements such as compute resources; data storage; devices, instrumentations and sensors; and filing systems to create a single, unified system and address fluctuating workload requirements.

At its core, grid computing enables devices—regardless of their operating characteristics—to be virtually shared, managed and accessed across an enterprise, consortium or workgroup. Although the physical resources that compose a grid may reside in multiple locations, users have seamless and uninterrupted access to these resources. This resource virtualization provides the necessary access, data and processing power to rapidly solve complex business problems, conducts compute intensive research and data analysis and engage in real-time, on demand research. Grid computing helps to promote the efficient utilization of technology resources and fosters the creation of cost-effective, resilient IT infrastructures that are adaptable to change [11].

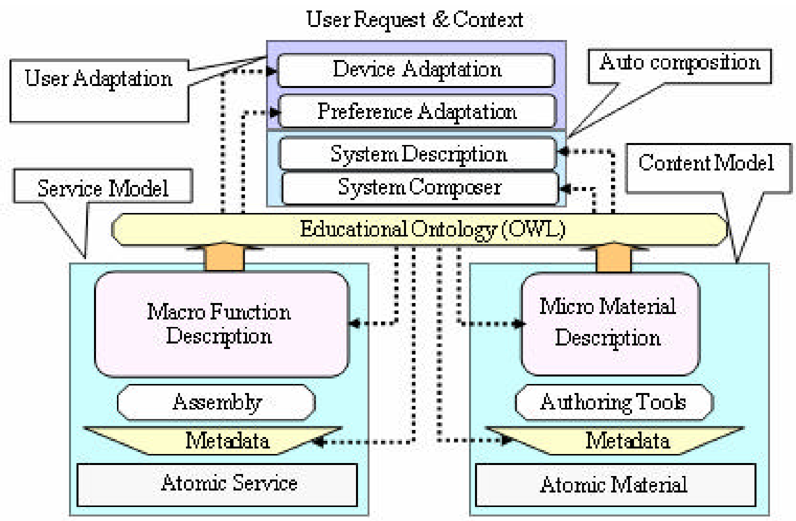

Figure1 Logic Architecture of OntoEdu

3. Architecture Design of OntoEdu

Based on ontology and semantic web technology, we proposed more flexible network education architecture, called OntoEdu (depicted as figure 1). This section will only give a rough description of the OntoEdu architecture, and its Grid design will be depicted in next section.

As indicated in figure 1, OntoEdu includes five components: user adaptation, auto composition, education ontology, service model and content model.

3.1 User Adaptation

This part receives parameters from user and completes some adaptation transformation. Three functions are completed by this part: receive the user request and context/preference, complete device adaptation, and do preference adaptation. The user request includes mainly the parameters input by keyboard, mouse and other input devices. User context includes three major components of the cliente: hardware platform upon which software is executing, the software platform upon which all applications are hosted, an individual application, such as a browser. The user context and preference can be transferred to server by CC/PP protocol.

Device Adaptation module is an interface between human and Auto Composition module. One function of device adaptor is getting inputs from human, which are called physical inputs, and then translating them into logic inputs which can be understood by program module (machine understandable). Another function of device adaptor is translating the logic outputs, which are pure data without presentation format, into physical outputs whose format is matched with the given device. Preference adaptation means the interface adaptability in terms of the user's preference.

3.2 Automatic Composition

Automatic Composition part is responsible for the task creation according to the user request, which is received from User Adaptation. This part includes two components: System Description and System Composer. The function of System Description is to create a function description according to user's request. Traditionally, the function description is created by hand. But in OntoEdu, it will be created by reasoning from OntoEdu ontology. And the function can be easily described using OWL-S language. The role of System Composer is to implement the function description in terms of web services published by grid system. This work has been initiated in [12].

3.3. Education Ontology

Ontology can be understood as either the descriptions about some domain or as the specification of the things that make up a domain. Although there are quite a few philosophical problems about these alternatives, we will, as good constructivists, simply assume that ontology is a collection of descriptions about a domain. This collection of descriptions generally includes elements that provide categories, measures, and criteria, specify ways in which place, time, and change are specified, indicate the ways in which things can be composed and decomposed, and the relations among all of these and the beliefs and other mental states about them. In education all of these are important. We will focus on the automatic composition of the function user requested. Inspired by [2, 13, 14, 15], we design educational ontology as follows:

Level 1: A structured collection of terms. This level is also called conception model, whose goal is the description of domain terms and its relations. Two kinds of ontology are included in this level: activity ontology and material ontology. Activity ontology gives the activity model about instructional task, such as examination process, homework process and etc. Material ontology gives a formal and semantic description of material organization according to education or learning standards. From this level, the function description on user request can be extracted by reasoning.

Level 2: A metadata level description of terms. In this level, all terms in level 1 are described in detail. The parameter and function of every activity are described with a metadata model. These activities can be composed into a more complex function according to the user request. The metadata level of activity can be described with OWL-S, which is a process model to express activity. On the other hand, the material ontology of this level describes the detailed information of education-related materials. At present, some standards on learning resource have been making, but without an ontology agreement till now.

Level 3: An executable infrastructure of educational functions. This level is called service model which can run the function described in level 1. At this model, all services used in education system will be invoked with URI and completed. Some systems, such as axis, have supported this kind of mechanism. In OntoEdu, we use axis to publish service and complete function for user.

In OntoEdu, the education ontology is distributed in several modules of the whole system. The level 1 and level 2 are general called education ontology and the level 3 is referred to service model which is described as following.

3.4 Service Model

In order to raise the traditional Web-based distributed learning to a new high level achieving a true dynamic model, we considered the following requirements according to [14]: Open architecture and interfaces, High interoperability for information exchange, Flexibility, Accessibility, Durability and Reusability, Compatibility with other systems.

In OntoEdu, all educational services are organized as hierarchy: the bottom services are atomic services, which are self-described and can not be divided into smaller operations; the higher level services are composed with the lower level services. All the learning objects, contents and applications are built as services with XML front end and described with some generally available terms such as metadata which must be in education ontology so that service requesters are able to search and map these services to their needs.

3.5 Content Model

This model is the same as the service model except for replacing service with content. This part is omitted.

4. Grid Design of OntoEdu

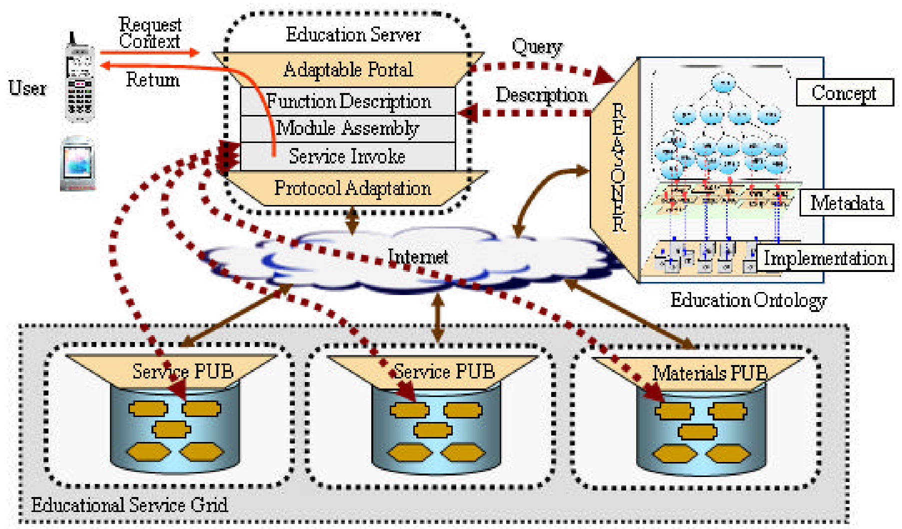

Figure2 Grid Design of OntoEdu

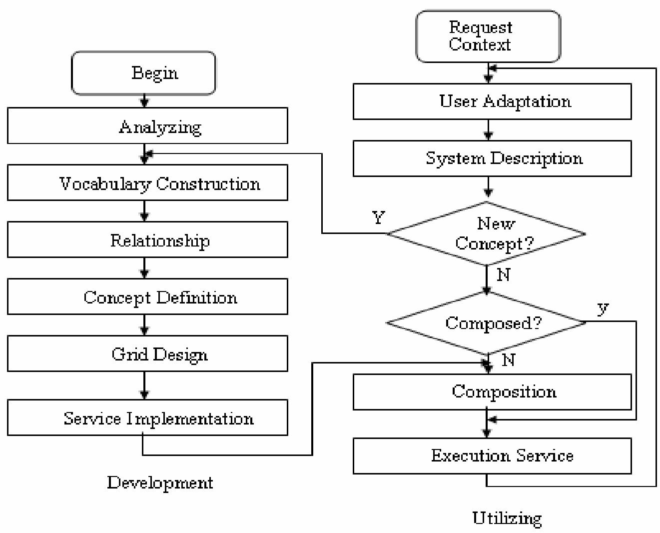

Figure 3 Optimized Workflow of OntoEdu

In this section, a more detailed design is proposed based on Grid computing technology. The Grid system of OntoEdu is depicted as figure 2. In this design, the grid system includes three parts: Education Server, Service Grid and Ontology System. As described in section 3, the Education Server includes User Adaptation, System Composition; the Service Grid is responsible for register, publish and execute the education service (including content service); Ontology System is responsible for the query to ontology and get the function description according to user's request.

The work flow of grid system is as following.

1) The user, with any device at any place, accesses the Education Server and sends the specific request and context to Education Server. The context contains specific information of the client device. The user request can be a few concepts which describe a special request.
2) The Education Server receives the user request and queries to Ontology System and gets the returned function description; and then composes into the target system according to the function description

(such as OWL-S description). In the target system description, the requested function is decomposed into macro and atomic services.

3) The reasoner in Ontology System executes query and inference operation with Education Ontology, and returns the result to Education Server.
4) Education Server executes target system. Every service in target system is delivered to Educational Service Grid. The Educational Service Grid allocates the proper Server and runs the requested function and returns result to Education Server.
5) Education Server collects all the results and transforms these results into the proper format according the device context.
6) User client receives the result and gives a perfect display.

From above statements, every user request will resulted in a workflow of 1-6. In fact, some steps can be optimized. For example, once a request is executed, the same request need not flow the whole six steps (re-composition can be canceled). The optimized workflow is depicted as figure 3.

5. Experiments and Conclusion

5.1 Experiments

OntoEdu is a complicated engineering which involves some to be researched technologies, such as ontology engineering, semantic web, ubiquitous computing and grid computing. At present, we have only built a frame platform with Apache Cocoon, Apache Axis, Racer and Tomcat. Education Ontology is described with OWL, educational service is described with WSDL and published with OWL-S. OntoEdu1.0 is a simple version of grid system of OntoEdu. With OntoEdu1.0, new services can be added to system with convenience and the client can be utilized with GPRS handheld, PDA or PC.

Based on ontology, ubiquitous computing, semantic web and grid computing, we proposed new flexible education architecture, called OntoEdu. With OntoEdu, it is easy to add new function, adapt according to user context and compose new function dynamically. Implementation of OntoEdu1.0 indicates that OntoEdu architecture is viable and flexible.

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