A Design of Ontology Context Model in Ubiquitous Learning Environments

Dae Jea Cho[1] and Myoung Woo Hong[2]
[1]Department of Multimedia Engineering, Andong National University
[2]Division of Computer Information, Woosong Information College
Andong-city, Gyeongsangbuk-do
KOREA

Abstract: - This paper describes the conceptual architecture and ontology-based context model for providing context-aware learning services in ubiquitous learning environments. If ubiquitous computing environments have been realized, it can lead to ubiquitous learning. In ubiquitous learning environments, various embedded computational devices will be pervasive and interoperable across the network for supporting the learning, so users may utilize these devices anytime anywhere. An important next step for ubiquitous learning is the introduction of context-aware learning service that employing knowledge and reasoning to understand the local context and share this information in support of intelligent learning services. In this paper, we assume that a school was equipped with ubiquitous computing environments. We present context-aware manager based architecture to support user-centric ubiquitous learning services, and describe a ontology based context model for intelligent school spaces.

Key-Words: - Ubiquitous Learning, Ontology Context Model

1 Introduction

The vision of ubiquitous computing technology means to provide invisible computing environments so that a user can utilize services at any time and place [1]. If the vision was to be realized, users could utilize learning services while moving because, in ubiquitous learning environments, various embedded computers, to support learning activities, are provided everywhere and these tools are connected to one another through the network. Also, by introducing context-aware technology, intelligent learning services can be provided on the basis of the context. In order to construct user-centric, ubiquitous, computing environments to provide intelligent learning services like this, it is necessary to design both architecture which can support context-aware services and a context model which can describe context information. Thus, on the assumption that ubiquitous computing environments are constructed at every school, this study suggests conceptual architecture led by a context-aware manager that provides learning services applying context-aware technology. Besides, this study designs an ontology-based context model which describes context information through OWL-DL(Web Ontology Language-Description Logic).

The second chapter introduces studies about context-aware computing and a context model based on ontology as a related work. The third chapter suggests a conceptual model of ubiquitous learning architecture to support context-aware learning services. The fourth chapter discusses an ontology model design concerning ubiquitous computing environments and context reasoning of this model. The final chapter shows conclusions and future work.

2 Related Works

2.1 Context-aware Computing

Schilit defines that context-aware computing is not only adaptable according to a place, a person and a group of objects, but also it is a software which can accept changes of objects as time goes by [2]. As the feasibility of context-aware computing in ubiquitous computing environments has been getting higher, the related studies have progressed. The Active Badge Project which is about phone switch applications developed a system which locates people through Active Badges attached to people and connects to the nearest phones to where they are [3]. Cooltown Project of HP aimed to construct a web which has people, things and spaces online and suggested a web-based context model in which each object has the corresponding web description [4]. ContextToolkit, by using an object-oriented method, has been providing framework and many reusable components in order to support quick manufacture of prototypes of sensor-based context aware applications [5].

2.2 Ontology-based Context Model

Ontology is a language to describe knowledge systematically; a typical and explicit specification about concepts and conceptualization, that is, it also defines concepts and relations required to describe meaning and information. OWL which has been developed most recently is an ontology language which defines classes and properties and also their relationships more clearly, acquiring consistency of concepts based on DAML+OIL. In particular, OWL-DL is based on description logics, which can be judged as TRUE or FALSE by First Order Predicate Logic and also can have inference ability in itself.

Research on ontology-based context models, which are able to share context information and reason context by defining contexts using these ontology languages, have been conducted. Ranganathan, et al. suggested the infrastructure that supports collection of context information from other sensors and supports delivery of appropriate context information through ubiquitous computing application [6]. Wang, et al. created context ontology which is known as CONON. It supports reasoning to find and correct inconsistent context information and reasoning as a means to draw farther context information [7]. Gu, et al. suggested an ontology-based model in intelligent environments as well as service-oriented context aware, middleware and architectures through OWL [8]. CoBrA project suggested the agent -based infrastructure for context representation, knowledge sharing, user's privacy control and developed COBRA-ONT, the ontology of pervasive computing environments supporting context awareness [9]. Especially, it suggested the methods to find the position of a person and support a context aware service in the smart room.

3 Context Aware Based Architecture in Ubiquitous Learning Environments

In ubiquitous learning environments, a conceptual ubiquitous learning architecture like Figure 1 to support services considering different contexts is designed and this is called *CALA* (Context Aware Learning Architecture). CALA architecture consists of *Personal Agent, Computing Entity, Physical Sensor* and *Activity Agent* centering on *Context-aware Manager* in the school space. This architecture supposes that a learning space is an intelligent ubiquitous school space where a ubiquitous computing environment is realized. Accordingly, all components of this architecture are connected to enable both wired and unwired networking, and exchange and share sensing information as well as context information through WiFi, Bluetooth, and Ethernet. Also teachers, students and administrative staff acting in a ubiquitous learning space wear a smart tag and a mobile device to be sensed by a physical sensor.

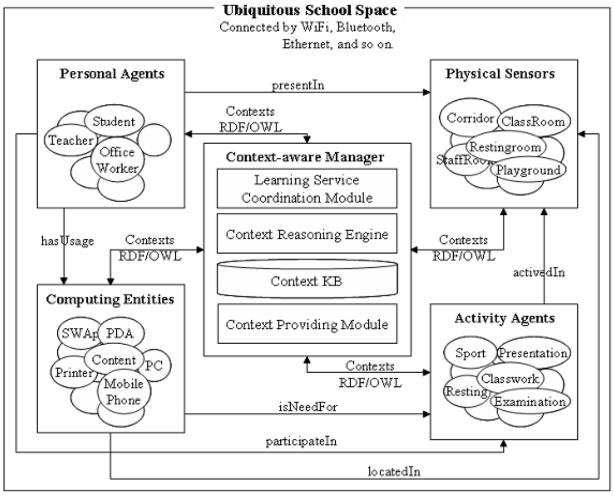

Fig.1. An outline of CALA, the architecture to support a context aware-based learning service

A Personal Agent is software to be operated in an individually owned-device and participates in learning activities and routine activities representative of students, teachers and administrative staff. A Personal Agent updates and manages owner's ID, name, e-mail, address, and so on. A Personal Agent also provides a context-aware manager with this information, describes it and keeps it as context information, and enables an activity agent, a computing entity and other facilities to share context information.

A Computing Entity includes mobile devices such as a PDA and a cellular phone, devices occupying a space such as a printer or a projector, software (for example, power points, editors, moving picture players, mp3 players, and so on.) as well as contents providing users with services. These are used by Activity Agents and people and are able to provide services through a characteristic function of devices and software.

An Activity Agent is software which controls learning activities such as lessons and examinations, and daily activities such as interviews, presentations and sports. An Activity Agent manages the information such as a schedule, a place, and a person and a computing entity as well as providing a context-aware manager with it. For example, a presentation agent is a sub-class of an activity agent, managing presentation activities, defining information such as time, place, a presenter, an audience, a related content and a facility of a presentation as well as transmitting it to Context-aware Manager.

A Physical Sensor is one arranged in the ubiquitous environment such as a classroom, a corridor or a lounge. It provides Context-aware manager with the information about its location, present temperature, lighting, and noise level. Mostly, a Physical Sensor can be used in perceiving a person through the existence of their smart tag.

The Context-aware Manger consists of a C*ontext Providing Module*, a C*ontext Knowledge Base*, a C*ontext Reasoning Engine* and a L*earning Service Coordination Module*. The Context-aware Manager controls a context module based on ontological reasoning, transforming a new context into a semantic place and updating a context module. Summaries about the role of the constituents as follows:

Context Providing Module. It obtains context information from various sensors, a person, an activity agent, and computing entity

Context Knowledge Base. It preserves and shares context knowledge on behalf of the personal agent, restricted by resource, and a computing entity.

Context Reasoning Engine. It reasons out the context, interpreting context information.

Learning Service Coordination Module. It coordinates and provides learning services based on context information through a user defined learning support rule.

4 Ontology Context Model about Ubiquitous Learning Environments

4.1 Proposed Ontology Context Model

Our ontology context model, which is a ubiquitous learning environment made by OWL-DL, is called *CALA-ONT* (Context Aware Learning Architecture ONTology). It consists of four top-level *class* and *sub-class*, and contains twelve main *properties* which describe the relations between *individuals* in top level class and its sub properties. An individual of a class, a real instance of ontology, is defined only in parts needed in explaining our ontology context model.

Figure 2 shows that we comply with XML, RDF Schema and OWL as a part of the CALA-ONT model and give a definition of four top level classes.

```
<rdf:RDFxmlns="http://www.owl-ontologies.com/Ontology1197601859.owl#"
xml:base="http://www.owl-ontologies.com/Ontology1197601859.owl"
xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:owl="http://www.w3.org/2002/07/owl#">
  <owl:Class rdf:ID="Person"/>
  <owl:Class rdf:ID="Place"/>
  <owl:Class rdf:ID="ComEntity"/>
  <owl:Class rdf:ID="Activity"/>
  <owl:Class rdf:ID="Person">
    <owl:disjointWith rdf:resource="#Place"/>
    <owl:disjointWith rdf:resource="#ComEntity"/>
    <owl:disjointWith rdf:resource="#Activity"/>
  </owl:Class>
```

Fig.2. A part of ontology expressions in CALA-ONT

The CALA-ONT model defines person (Person), places (Place), activities (Activity), and computational entities (ComEntity) in a top-level class. Figure 3 shows the relations between the classification of the CALA-ONT model and major properties through the graph.

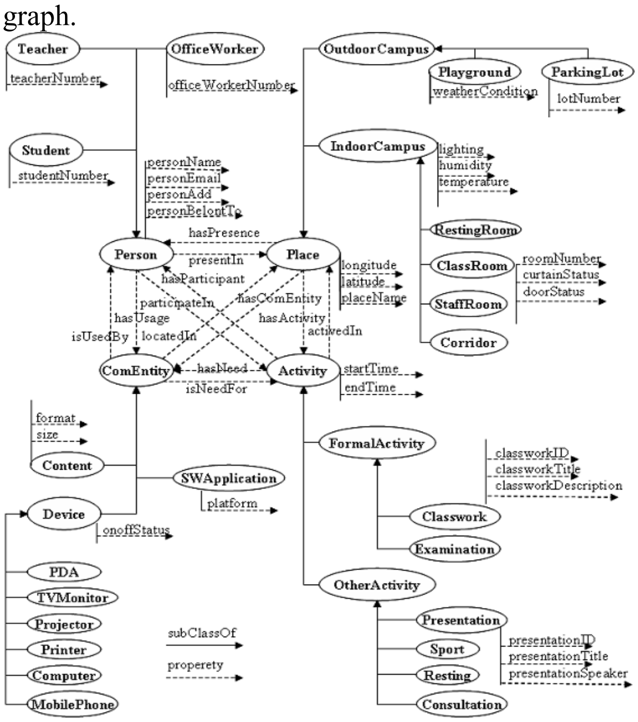

Fig.3. Graphic presentation about the classification of CALA-ONT model and its property

The class of a person, which defines the most general feature about a person, presents a student (Student), a teacher (Teacher) and an office worker (OfficeWorker) as its sub-classes.

The class of place, which defines the general properties about place, presents an outdoor campus (OutdoorCampus) and an indoor campus (IndoorCampus) as its sub-classes.

The class of an outdoor campus contains a playground (Playground) and a parking lot (ParkingLot) in its sub-class. The class of an indoor campus contains a classroom (ClassRoom), a staff room (StaffRoom), a resting room (RestingRoom) and a corridor (Corridor) in its sub-class. The class of an activity (Activity), which defines the general activities in the school, contains a formal activity (FormalActivity) and other activities (OtherActivity) in its sub-classes. The class of a formal activity also contains classwork (Classwork) and an examination (Examination). The class of other activities contains a presentation (Presentation), a sport (Sport), a resting place (Resting) and a consultation (Consultation) in its sub-classes.

The class of a computing entity (ComEntity) defines the general computing entities and contains a device (Device), SW application (SWApplication) and contents (Content) in its sub-classes.

Table 1 show twelve main object properties related to the top-level class.

Each property presents the binary relationship linking an individual in the domain to an individual in the range. For example, the property of PresentIn links an individual in the class of a person to a location in the class of place, which means someone is somewhere.

Table 1 Object property and its meaning

Domain	Porperty	Range	Meaning of the property
Person	presentIn	Place	someone is somewhere
	participateIn	Activity	someone is participating in some activity
	hasUsage	ComEntity	someone is using some computing entity
Place	hasPresence	Person	some place has one's presence
	hasActivity	Activity	some place concludes some activities
	hasComEntity	ComEntity	some place concludes some computing entity
Activity	hasParticipant	Person	some activity concludes someone as a participant
	activedIn	Place	some activity happens in some where
	hasNeed	ComEntity	some activity needs some computing entity
ComEntity	isUsedBy	Person	some computing entity is used by someone
	locatedIn	Place	some computing entity is some where
	isNeedFor	Activity	some computing entity is needed in some activity

4.2 Application of the CALA-ONT Model

4.2.1 Expression of the Context Information about a Person's Existence

The context providing module of the context-aware manager acquires context information directly from sensors, and expresses it by ontology. As a scenario, a student named Hong Yun-Sang makes his RFID badge perceived by the RFID sensor attached to the door, and enters the classroom. Then the RFID sensor makes his presence known to the context providing module, which expresses the student's presence in Class Room-1-1 through the property of present-in. Figure 4 shows the context information which is acquired according to the scenario, and the ontology expression corresponding to the information.

Context Information
(HongYunSnag, presentIn, ClassRoom_1_1)
Ontology Expression
<Student rdf:ID="HongYunSang">
<presentIn rdf:resource="#ClassRoom_1_1"/>
</Student>

Fig.4. Ontology Expression of a Person's Existence

4.2.2 Context Reasoning

The context reasoning engine has functions to interpret context information and reason new contexts: ontology reasoning and rule-based reasoning. Ontology reasoning of the context reasoning engine can be expressed in the first order predicate logic as shown in Figure 5.

- subClassOf: (?A rdfs:subClassOf ?B), (?B rdfs:subClassOf ?C) -> (?A rdfs:subClassOf ?C)
- inverseOf: (?P owl:inverseOf ?Q), (?X ?P ?Y) -> (?Y ?Q ?X)
- finctionalProperty: (?P rdf:type owl:FunctionalProperty), (?A ?P ?B), (?A ?P ?C) -> (?A = ?C)
- transitiveProperty: (?P rdf:type owl:TransitiveProperty), (?A ?P ?B), (?B ?P ?C) -> (?A ?P ?C)

Fig.5. Expression of Ontology Reasoning in the First Order Predicate Logic

The rule-based reasoning is reasoning new contexts based on information about various other contexts. This rule is to combine much information about various contexts using Boolean Algebra, and if the result is true, to define the information about the new contexts. For example, figure 6 shows the rule that one new context is reasoned from the information of two other contexts. The information of two contexts connected using AND on the left of -> of the rule corresponds to the ontology expression of fact 1 and fact 2, and the reasoned context information on the right of -> of the rule corresponds to the ontology expression of the result.

Rule
(?Person, hasUsage, ?ComEntity)
AND (?ComEntity, locatedIn, ?Place)
-> (?Person, presentIn, ?Place)
Fact 1
<Student rdf:ID="HongYunHo">
<hasUsage rdf:resource="#PDA_1004"/> </Student>
Fact 2
<PDA rdf:ID="PDA_1004">
<locatedIn rdf:resource="#ClassRoom_1_1"/> </PDA>
Result
<Student rdf:ID="HongYunHo">
<presentIn rdf:resource="#ClassRoom_1_1"/> </Student>
Fig.6. Example of Rule-Based Reasoning

5 Conclusion

This study supposes schools are ubiquitous learning environments, and has proposed CALA architecture and the CALA-ONT model. The first proposal focuses on a context-aware manager to provide learning service according to the context changes of learners' environments, and the second expresses school environments by ontology. The study also suggests possibilities of providing context reasoning and context-aware learning service by using architecture and ontology. In these two aspects, this study is distinguished from the preceding studies which concentrated on learning contents and designed ontology. First, the subject of the study is school in which practical learning activities are taking place. Second, this study has designed context models based on ontology using OWL-DL and has expanded them making them reusable. Though the ontology models suggested by the study didn't express all the objects and contexts, the models could be modified and expanded given the possibilities of reuse. This study has yet to apply varied and standardized methods to context reasoning and context-aware learning service, which will be a task of a future study along with verification of many other relevant things.

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