Adaptive and Context-Aware Scenarios for Pervasive Technology-Enhanced Learning System

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Abstract *With the proliferation of mobile devices, pervasive learning has become a new wave in technology-enhanced learning. One of the key problems to solve in this area is to adapt learning content and services according to a learner's needs and wants to different learning contexts at the workplace. Specifically, we are interested in integrating context-aware corporate learning and working activities to acquire some knowledge domain (for instance e-retail). The main contributions of this paper are work-integrated learning and customer learning support whatever the place, the time, the organizational and technological contexts of the individual or collective learning and working processes. Moreover, we propose an adaptive and context-aware model of scenario based on an interdisciplinary approach (education, computer science, social sciences, and business) for a pervasive learning system supporting working and learning situations. This model enables us to choose how to achieve activities according to the current situation.*

Keywords: *Pervasive learning, context-aware, adaptation, scenario model, task/method paradigm.*

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1. Introduction

Nowadays, technology-enhanced learning (TEL) systems must have the ability to reuse learning resources from large repositories, to take into account the context and to allow dynamic adaptation to different learners based on substantial advances in pedagogical theories and knowledge models [2].

For TEL systems, several terms are used: pervasive, ubiquitous, mobile, ambient and nomadic learning systems. We consider that these expressions are synonymous. They are used for highlighting a specific property in learning systems ([17]; [37]). Generally, such type of learning systems used to have all properties of mobile, pervasive and ubiquitous computing. The main idea is to embed learning activities into everyday life or work by means of lightweight devices and network communications. Nevertheless, mobile, pervasive or ubiquitous learning is not just about learning using lightweight devices, but learning across context and are best viewed as mediating tools in the learning process [36]. Many definitions about these types of learning systems are given in literature [17, 37,4, 23]. We can cite the following one: "Pervasive learning environment is a context (or state) for mediating learning in a physical environment enriched with additional site-specific and situation dependent elements – be it plain data, graphics, information, knowledge, and learning objects, or, ultimately, audio-visually enhanced virtual layers [17]. In pervasive learning, some issues are as follows: combination of formal (at school) and informal (outdoor, at home, at workplace etc.) learning, integration of mobile devices in broader educational scenarios, combination of collaborative, mobile learning and inquiring learning, context-as-construct and seamless learning across different contexts ([2]; [36]).

In this paper, we are interested in TEL systems integrating context-aware corporate learning and working activities in a particular framework: e-retail (retail through shops and hypermarkets). The main contribution of this paper are: work-integrated learning and customer learning support, continuous professional training at workplace, professional learning whatever the place, the time, the organizational and technological contexts of the individual or collective learning and working processes context-as-construct and seamless learning.

The design and engineering of pervasive learning systems must be considered as an interdisciplinary problem requiring the integration of different scientific approaches from computer science, education, commerce, social sciences, etc. While learning focuses mainly on how to support individual's and group's learning process through the pedagogical guidance and how to enhance the learner's knowledge. The workplace identifies the problems and requirements about quality and efficiency of information and services to increase market share. Moreover, working activities are about solving tasks and particularly in knowledge-intensive organizations which implies continuous learning. Inexperienced persons learn from their experienced colleagues and they acquire the knowledge necessary to solve their work tasks. However, learning is a process that takes place mainly unconsciously.

Solving the particular working tasks is prior (i.e, learning is just a means). In such a framework, several innovative scenarios have been setting up according to two main learning and/or working situations for the seller and the potential customers as learners: i) seller or customer, outside the shop counters: seller in the back office or storage areas, client at home or other place; ii) seller in his department, alone or with a customer having resources from the Smart spaces surrounding them (large LCD screen, printers,…etc). Scenario analysis reveals that current learning and working situations could be modeled by an explicit task model partly because working and learning activities are well structured and stable. Activities, represented by tasks, cannot be achieved in the same way according to different situations. It is necessary to have a context-aware and adaptive mechanism to decide how to achieve an activity according to a given situation.

The main contribution of this paper is an adaptive and context-aware model of scenario based on an interdisciplinary approach (education, computer science, social sciences, and business) for a pervasive learning system supporting working and learning situations. This model enables us to choose how to achieve activities according to the current situation.

The scenario model is based on a hierarchical task model having the task/method paradigm. We defined a context model to deal with dynamic contexts. The context-aware and adaptive process can be viewed as the selection of the relevant methods for a given task according to the current working and/or learning situation.

The remainder of this paper is organized as follows. Section 2 collects recent researches focusing on technology and pedagogy supported mobile learning examples in facilitating mobile learning process. Section 3 analyses and explains the context model and its organization. Section 4 defines pervasive learning situations in workplace. Section 5 presents the scenario model and its relationships with the context model. Section 6 presents the key architectural concepts of our platform, and provides implementation details of typical use case. Finally, the conclusion highlights the main results of this study and some perspectives.

2. Literature Review

Recently, the concept of context-aware ubiquitous learning has been further proposed to allow students learning with variety of mobile devices and facilitate a seamless ubiquitous learning environment [35, 34], which learning situation focuses on emphasis the characteristics of learning at the right time and right place with right resources in the right ways and conducts real-world learning activities with adaptive supports from the learning system [19, 30, and 42].

In order to achieve context-aware and seamlessly learning environments, some ubiquitous computing technologies and devices were usually utilized to detect or sense users' context information, such as RFID, GPS, specific sensors, contact-less smart cards, wearable computers, and wireless communications. [11, 18]. The acquired context information was not merely used to identify learners' situations but also utilized to support personalized learning guidance.

Through physical integration, students can learn physical materials in the real world and conduct authentic activities based on learner-centered and situated learning pedagogies [11, 18]. For example, Chen, Kao, and Sheu [6] developed a mobile butterfly watching learning system which supports independent learning and outdoor learning based on a wireless network, data mining technologies and using PDAs. Yang [42] constructed three systems and utilized the effective and efficient advantage of ubiquitous learning to design the strategy of peer-to-peer learning model to the learners. El-Bishouty, Ogata, and Yano [11] proposed the Knowledge Awareness Map which provides personalized learning condition to the students according to their current need and location and recommends the best matched materials according to learner's current task and current location. Tan, Liu and Chang [38] developed an Environment of Ubiquitous Learning with Educational Resources (EULER), which allow students observing real learning objects and sharing learning experiences to each other. Chen and Hsu [5] proposed a personalized intelligent mobile learning system which utilized the fuzzy Item Response Theory presenting the appropriately English news articles and suitable vocabularies to the learners. Hwang et al. [19] developed a context-aware u-learning environment to assist inexperienced researchers in learning single-crystal X-ray diffraction operations, and used the knowledge-based systems developed for instructing the learners based on the contexts sensed in the real learning environment. Peng et al. [30] proposed a Ubiquitous Performance-Support System which combines digital and physical resources and the manner of data-driven decision making to assist with administrators and educators for understanding the perceptions of experts and students.

In addition to the integration of suitable software, how to combine appropriate pedagogical strategy for enhanced learning application was another critical important issue in mobile learning environment. Some of the studies proposed the navigation mechanism and intelligent tutoring system supporting suitable tutorial strategies for students increasing learning opportunities [12, 28, 33, and 40]. Moreover, the high interaction strategy was proposed to use for promoting social interaction and enhancing user experience in several studies [14, 41]. Collaborative and cooperative learning are generally the first method chosen in mobile learning environment. Collaborative and cooperative learning is based on the constructivist theory which prompts students to learn by doing and construct knowledge for themselves, and that pedagogical strategies have been widely applied in mobile learning activities([8, 11, 15, 16, 29, and 42]. Besides described above, Peng et al. [30] proposed the approach of data-driven decision making as a mind tool which should facilitate critical thinking and higher-order learning by adapting to the learners. Zurita and Nussbaum [43] developed a constructivist learning environment by providing each child with a share of the necessary information to accomplish the educative activity goal.

3. Context Modeling

There have been several attempts to define the notion of context in different fields. We only focus on definitions giving the relationships between the physical world and users' activity. We claim that activities embedded in a particular physical world (or environment) are key issues to give us intention and meaning according to different situations and finally to determine the relevant features describing the different situations. These definitions are as follows: 'learning context is used to describe the current situation of a person related to a learning activity; in addition to attributes relying on the physical world model' [9]; 'information and content in use to support a specific activity (being individual or collaborative) in a particular physical environment' [24].

In pervasive learning systems, a context model must consider a crucial context features: dynamic and/or context-as-construct. According to Dourish [10], context can be viewed as an interactional problem: contextuality is a relational property that holds between objects or activities:

- The context is not defined in advance. On the contrary, the scope of contextual features is defined dynamically,
- Context is an occasioned property, relevant to particular settings, and particular instances of activities,
- Context arises from the activity.

Context cannot be separated from activities. It is actively produced, maintained and enacted in the course of activity. In mobile learning, Sharples [36] defines a context as follows: 'context should be reconceived as a construct that is continually created by the interaction of learners, teachers, physical settings, and social environments', and Balacheff [2] states that: 'learning not only occurs in the context, it also creates context through continual interaction'.

Our context model has to consider the context-as-construct property, the combination of formal (at school for professional) and informal (outdoor, at home and at workplace) learning, the integration of mobile devices in broader educational scenarios, and the seamless learning across different contexts. Furthermore, our context model is composed of: i) a set of dimensions defining a set of relevant features and their structure; ii) a set of views consisting of a subset of features which are relevant to a given content category (e.g, activity, resource, web service) for adaptation. Thus, an adaptation process does not manage the same features for different categories of content. For a given content category, its features and those of the corresponding view can be matched in the adaptation process; and iii) a set of situations that are organized in historical dependencies. A situation is a partial instantiation of the context model consisting of the relevant features describing the current learning situation and its physical environment. A user activity can be influenced by his previous work and learning activities. As soon as a new situation is occurring, the next activity or the activity continuation can be chosen according to the historical dependencies, for instance to ensure seamless learning.

4. Pervasive Learning Situations in Workplace

A learning situation in workplace is composed of the physical environment, learning and commercial setting of the user's current work situation. Several context dimensions are combined together to describe different pervasive learning situations. In a company, a learner used to work and sometimes learning and working are interweaved in a pervasive environment. A substantial part of learning does not happen during the training but during working activity performance. Learning and professional activity support must be integrated. The learning system must overcome three main obstacles: time pressure, inadequate learning support in the working context and cognitive and structural disconnection between work, knowledge, and learning. In retail shops, a seller equipped with a PTA (Personal Training Assistant) close to shelves (without a customer) can revise his knowledge about products or can continue his previous learning activity to improve his/her knowledge or he/she can verify the product's labeling or access to product information.

During the selling process or the selection/decision phase, the seller can use his/her mobile device for both revising his/her knowledge about products and selling characteristics or as a coach to help him/her, etc. According to the current and past user activities, the learning system has to select the relevant way to achieve the current activity, the resources and the web services according to context changes. Moreover, the current status of activities, suspended or unfinished in the past, need be restored to ensure the seamless learning and working. The relevant activities and resources can be provided to the user according to the current user's work situation. Our context model is represented by ontology. A situation and its historical dependencies are used to select and/or to continue an activity by means of a scenario model.

5. Scenario model

The main role of a scenario model is to integrate mobile devices in broader learning and working scenarios, formal and informal learning and to enable us to manage seamless learning across contexts. As a scenario describes all users' activities (with or without mobile devices, formal or informal learning activities), an author can manage a global activity consistency to deal with the previously mentioned issues.

Several research studies in artificial intelligence focus on the hierarchical task model using the task/method paradigm [3, 7, and 27]. In learning environment, hierarchical task models were also used for designing, for instance, authoring tools [1, 13, 21, 22, and 31], learning systems [20, 25, 26, and 39]. The mechanism of hierarchical and recursive decomposition of a problem into sub-problems is one of the basic characteristics of the hierarchical task model [3, 7, 27].

5.1. Task/Method Concept

Within the framework of the Task/Method paradigm, tasks represent activities and sub-activities managed by a knowledge-based system. A method describes how a particular task can be achieved. There are two types of tasks: abstract task and atomic task. An atomic task is not composed of sub-tasks. It can be achieved by a simple procedure defined inside a method. An abstract task represents a high level activity composed of sub-activities. A method defines how an abstract task is composed of sub-tasks which can either be abstract or atomic tasks. For a given task (abstract or atomic), several methods can be used to accomplish it. Methods are described by contextual features for adaptation and selection. It is composed of a property set according to the corresponding context view. A method, associated to an abstract task, defines a control structure which allows the recursive decomposition of tasks into sub-tasks and the sub-task order at runtime - by means of operators. At present, three different operators are used: sequence, alternative and parallel. A Method, associated to an atomic task, can have:

- a resource specification for resource retrieval,
- a service specification for web service retrieval,
- a procedure/function specification for a simple procedure or function.

5.2. Context-Aware Learning Scenario for Workplace

Pervasive learning scenarios in the workplace are modeled by a hierarchical structure of tasks/methods representing learning and working activities. For a complete presentation and execution of the scenario, another category is needed: mixed activities. Thus, working and learning activities are represented by working, learning and mixed tasks.

Specifically in Figure 1, the contextual features and the control structure of some methods related to e-retail example are represented for different categories of tasks.

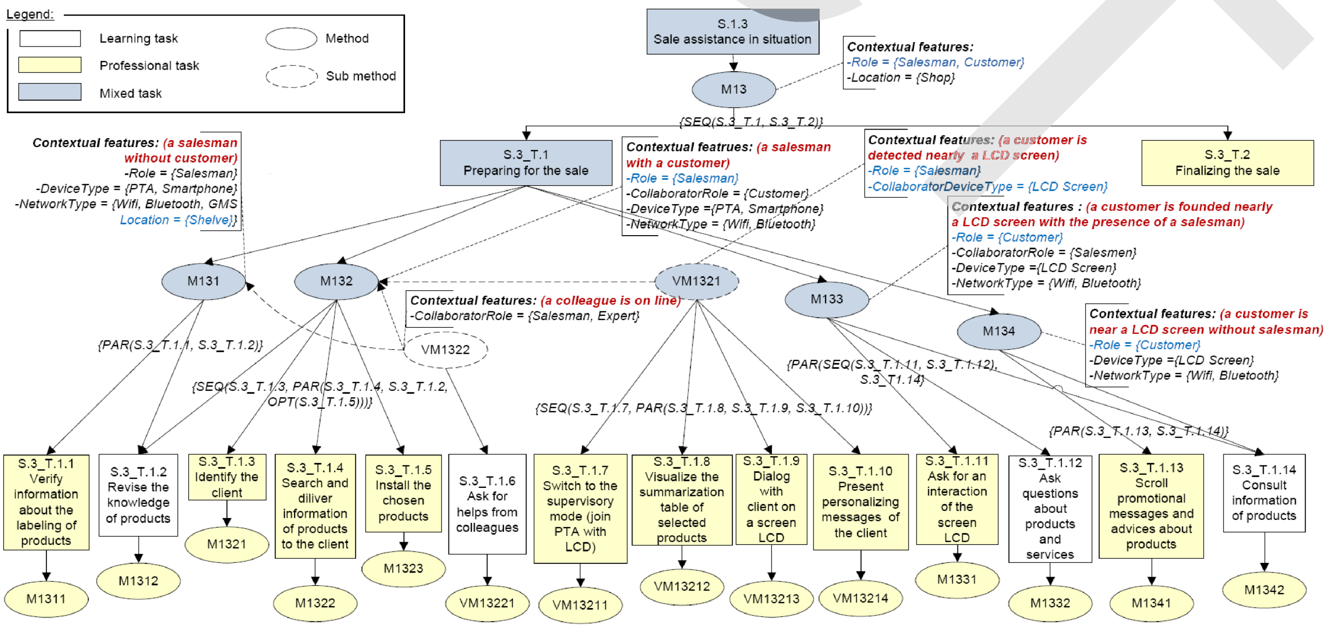

Figure 1. A small portion of the e-retail scenario [32].

6. Design and Implementation

This section aims to present our system implementation details and results. Three fundamental parts of this system were designed as semantic, logical and physical parts. Thus, our prototype is based on four java projects that are presented in the following:

- Pervasive_Learning_Utilities: provide all classes for common functions;
- Pervasive_Learning_Server: gives all classes to manage network connections and services;
- Pervasive_Learning_Composition: performs all features of semantic and logical levels;
- Pervasive_Learning_Presentation: performs all features of physical level.

6.1. Inference Engine, Ontologies and Adaptation in Semantic Level

In literature review, we have collected a variety of inference engines. The main feature of these engines is reasoning. On the other hand, the ontology representation can be in logic description (DAML-OIL or OWL) or in frame logic (F-logic). Furthermore, the F-logic frame is characterized by:

- the transformation of F-logic to Horn logic standard is straightforward;
- the reasoning engine based on F-logic is strong and provide significant capacity of expression by adding new logic rules.

6.1.1. Main Tools

Ontobroker is an ontology inference engine that supports Oracle (version 9i) and Microsoft SQL Server 2000, to store rules and facts. Ontobroker engine is composed of three elements, including query interfaces, inference engine, and webcrawler (Ontocrawler). Each element is accompanied with formalization language. Specifically, the query language is used to create queries, the representation language to represent ontologies and the annotation language for annotating web documents with ontology.

- Query language: The query language is oriented towards presentation of ontology based on logic frame that defines key concepts such as class, attribute and value. The generic scheme is: O :C [A-»V] where O is mechanism, C is class, A is attribute class and V is attribute value. This scheme means that the object O is an instance of the class C which has the attribute A with the value V.
- Ontology representation language: The Ontobroker engine designs ontologies in F-logic language. In addition, the relationships between ontologies are presented in the following:
  1. Subclass: C1 is subclass of C2 is noted C1::C2
  2. Instance: O is an instance of the class C is noted O:C
  3. Attributes declaration: Instances of class C1 have the attribute A which is instance of the class C2 is noted [A-»C2]
  4. Attribute value of: Instance O have the attribute A which have the value V is noted O[A–>V]

6.1.2. System Ontologies

Our pervasive learning system is based on several models such as user model and domain model. Furthermore, the system uses various ontologies including ontology of user, ontology of scenario computing model, ontology of context, ontology of adaptation, ontology of metadata, ontology of adapted predicates and rules. All these ontologies are represented as F-Logic. The most complex ontologies provided by our system are user model and scenario computing model.

- Ontology of the user model: As depicted in Figure 2, this ontology allows to describe all information about the tutor and learner.
- Ontology of scenario computing model: As shown in Figure 3, this ontology designs all types of tasks and their relationships.
- Context ontology: As shown in Figure 4, this ontology designs the overall information and environment of e-retail application.
- Adaptation ontology: Figure 5 shows class diagram of adaptation model ontology. This ontology provides the most important class named classification, which allows to implement dynamic adaptation rules. Moreover, the semantic level (base level) provide two types of adaptation related to resources and learning method (adaptation) allowing learner to select “good” methods according to their profiles (knowledge, skills, preferences, context of use).

6.1.3. Adaptation Process

The adaptation process is specified for a content type (methods and services) and an adaptation category. The input content of the adaptation process can be achieved in different ways depending on the content type: input methods are specified directly by the current task while input services are selected by a search process based on a query which “compares” the service requirement of the selected task/method coupled with the service description. The three stages of the adaptation process are presented as follows:

Evaluation/Classification: input content is classified according to the current situation in several equivalence classes: two classes {“Good”, “Bad”} for each transitory feature and up to five equivalence classes {“VeryBad”, “Bad”, “ToConsider”, “Good”,

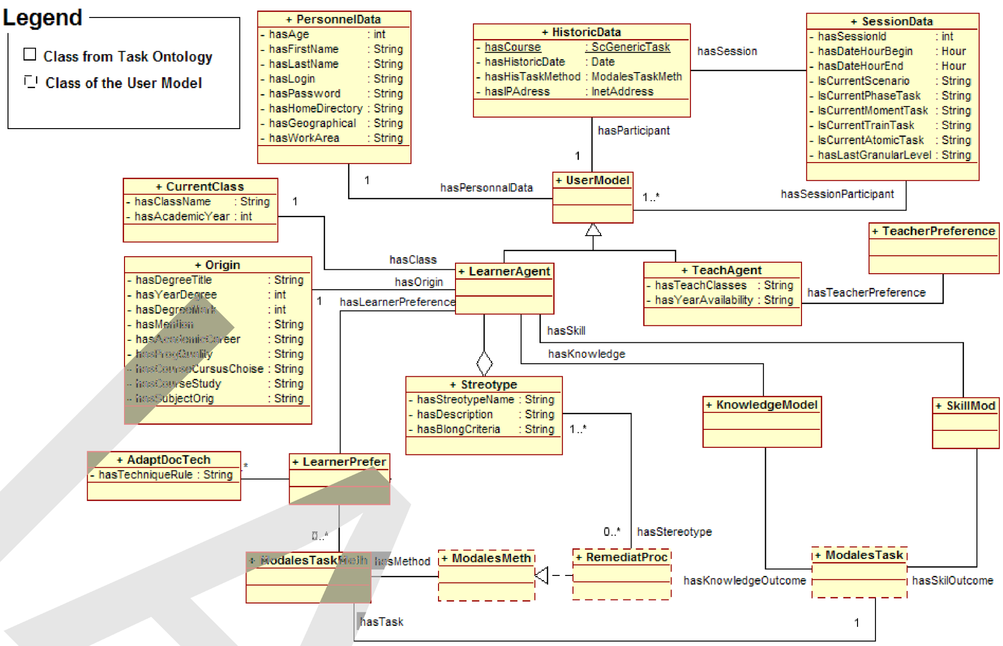

Figure 2. Class diagram of the user model ontology.

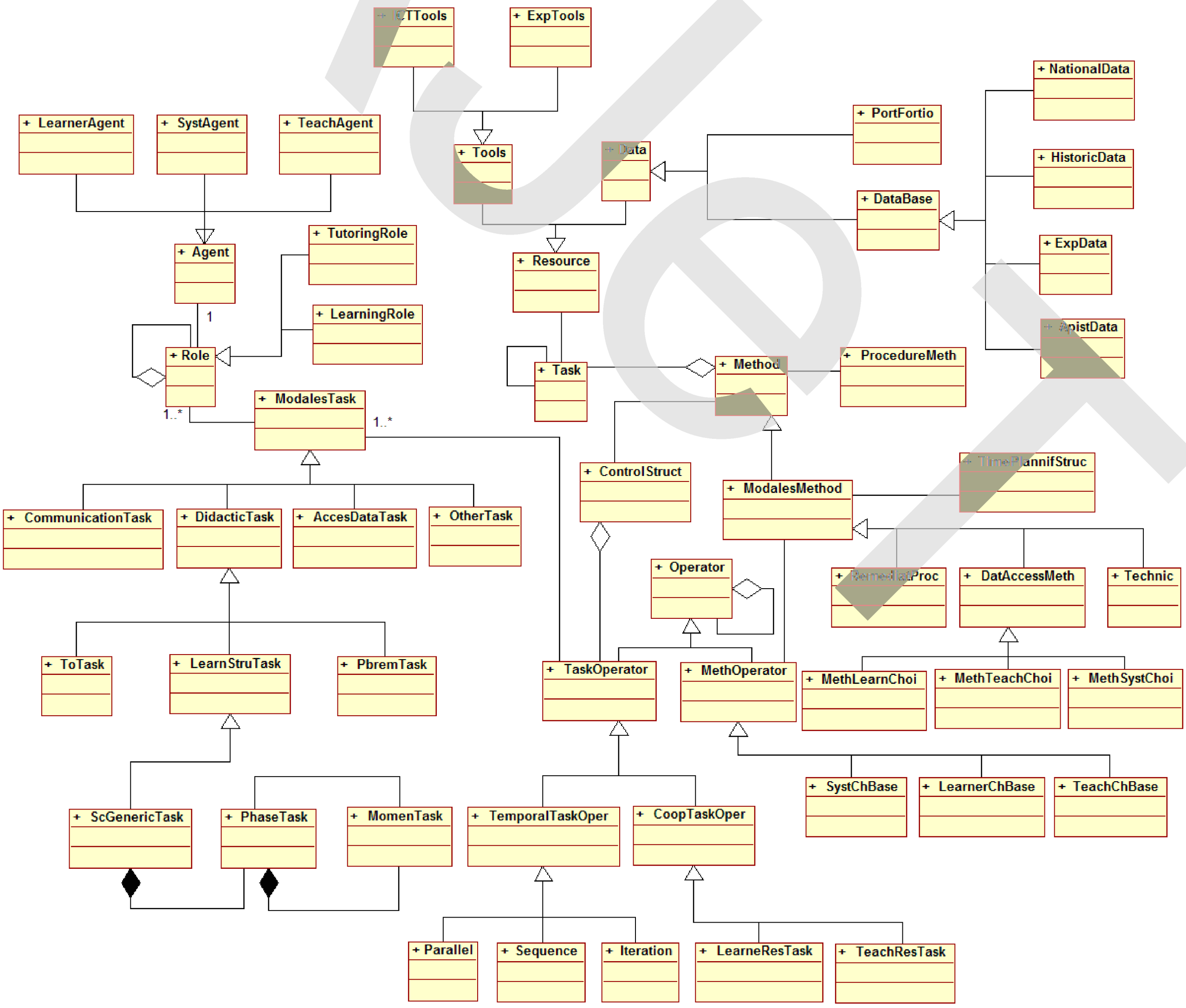

Figure 3. Class diagram of scenario computing model ontology.

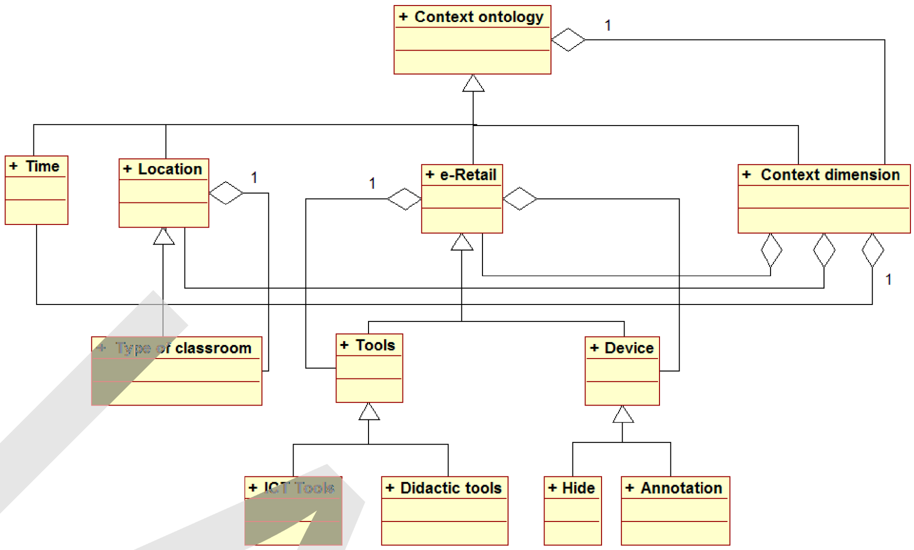

Figure 4. Class diagram of the context ontology,

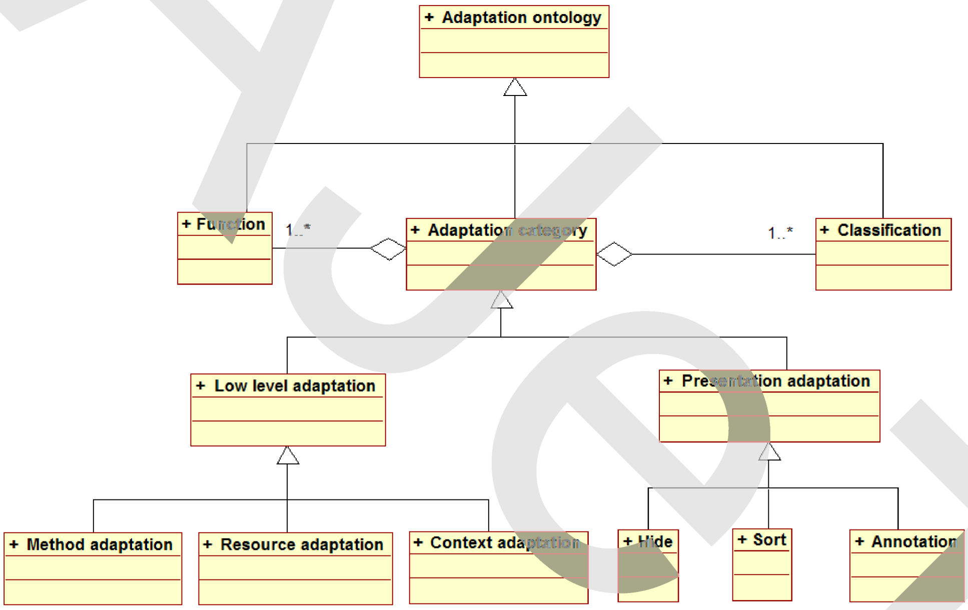

Figure 5. Class diagram of adaptation model ontology.

"VeryGood"} for all permanent situation features, together. The content belongs to an equivalent class if it satisfies its membership rules;

- Filtering: all content belonging to "Bad" classes according to a transitory feature are filtered out. In other words, these content are discarded. For example, with the network dimension, the class "Good" is considered as relevant while the class "Bad" is not. This means that the system hence will eliminate all content that belongs to the class "Bad";
- Adaptive navigation: permanent situation features are used to evaluate and classify the remaining content. An adaptive technique can be chosen by the system or by the user according to an author decision. All content belonging to the same equivalence class are treated in the same way. Annotation and sorting are processed according to the total order of equivalence classes. For hiding, only contents belonging to the class "Good" and "VeryGood" are maintained.

6.2. Templates and Adaptation in Presentation Level

The presentation level provides all users (tutor and learner) interfaces corresponding to possible tasks through XML templates. In this case, we distinguish two types of users (tutor and learner), seven atomic tasks, three abstract tasks (scenario, method and task composition) and two types of devices (PC and PDA). Therefore we should construct 2*(7+3)*2 = 40 different templates.

6.3. Designing Web Pages Related to User Profiles

In this level we will rebuild the HTML pages from XML pages that are carried out from logic level thanks to XSLT language. Therefore, we should implement fourteen files related to logic level templates.

6.4. Experimental Results

In this section, we present some results obtained with real learning features. Therefore, experimentation is performed for different tasks such as sign-in (as shown in figure 6-a) and for learners (as shown in figure 6-b), tutors (as shown in figure 6-c).

(a)Sign in (b) Learner profile (c) Tutor profile

Figure 6. Pervasive learning screenshot.

Moreover, the JavaScript language is used to automatically detect the device types (PC or PDA).

7. Conclusion

In this paper, we have proposed an adaptive and context-aware model of scenario based on a hierarchical task model having the task/method paradigm for a pervasive learning system supporting working and learning situations. This model enables us to choose how to achieve activities according to the current situation. In other words, the relevant methods are selected dynamically according to the current situation. Integration of mobile devices in broader learning and working scenarios, formal and informal learning and management of seamless learning across contexts has been achieved by means of the scenario model and the adaptation process in using the context model.

Our context model and adaptation process is able to mange to deal with dynamic contexts (i.e., context-as-construct and seamless learning) and working across contexts. These issues are managed in a limited way. Thus, our current scenarios are not sufficiently detailed to enable us to define accurate strategies to deal with seamless learning and working. Our context and scenario models have necessary properties to managed seamless learning (situation and its historical dependencies). In future work, we need investigate in depth our scenarios to establish rules able to manage seamless learning. As our scenarios are limited, we also have to study in depth our adaptation policies to manage dynamic context. Another perspective is to outline the semantic description of web services to enable the selection, composition and execution of web services to achieve objectives specified by learning and working activities. This model enables the selection of the relevant methods or services to realize activities according to the current situation.

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