Ontology-based Architecture for Reusing and Learning Through Context-aware Annotations Memory

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***Abstract*— This paper describes a conceptual model and an ontology-based framework for reusing and learning through context-aware annotations memory. This memory manages annotations and adapts actors (learner, tutor, teacher, and co-author) behaviours with the various contexts of their activities. It offers a great reutilisability to share and have a better quality of learning. The annotation model that we propose is composed of three facets: cognitive, semantic and contextual. The architecture of our annotations memory contains many modules based on Web Services. This facilitates its integration with the other tools used by the actors of a computer environment for human learning like, for example, the e-Learning platforms and annotations tools.**

***Keywords* -** *CEHL; context-aware; annotation; adaptation; learning.*

I. INTRODUCTION

Teachers, tutors or co-authors, during their activities of teaching, as well as learner, during its training, in a Computer Environment for Human Learning (CEHL), manage a significant number of learning objects to support their activities. These objects are most of the time in numerical format. In order to memorize the learning objects elements,, these actors create, on the objects, different type of annotations, in order to re-use them like a working memory. Each actor thus, constitutes an external memory for his learning and teaching activities.

The external memory created, is composed of all learning objects and their annotations. It allows the teacher, for example, to memorize an idea to find it, thereafter, in a fast way, or to create an annotation in a context and to re-use it in another context. This external memory is useful and exploitable for all the actors of a computer environment for human learning; it must be well structured according to the semantics of the used annotations and to adapt them to the current context of the actor's activity. Thus, it will make it possible, for each actor of a CEHL to exploit in a fluid way its annotations.

In this work, we propose a new general architecture of the adaptive annotations memory with a detailed description of the functionalities offered by each module of the architecture of ontology-based framework for reusing and learning through context-aware annotations memory (OARLCAM). This architecture is based on a context meta-model and an annotation meta-model. The first one represents the learning context of the various actors of the annotations memory. The annotation meta-model describes the semantics of the annotation to be able to re-use them, share them and learning from knowledge included in these annotations according to a pedagogic objective.

This paper is organized as follows. The first section presents our research field. The second section exposes our research problematic by explaining the need for an adaptive memory of annotations for the different actors of a CEHL and by pointing out the basic concepts used. In the third section, we present the state of the art of the related approaches to our research by showing their advantages and their limits. In the fourth section, we propose and describe the architecture OARLCAM conceived to solve the whole of the released limits.

II. BASIC CONCEPTS AND PROBLEMATIC

The various actors of a CEHL find difficulties to create and consult the annotations associated to learning objects, during their learning activities. Generally, they use manual annotations which are very difficult to manage, to exploit, capitalize and share. These actors annotate in a different ways the learning objects according to their training activities and their learning goals. For this purpose, the existence of an annotations memory is necessary for these various actors. Indeed, it allows the automatic management of all these annotations making possible their capitalization and sharing. It is a learning based on annotations affixed by the various actors according to a particular learning context and a special learning objective. The numerical annotations constitute an added value for the learning objects. They add knowledge to the original contents of these objects.

By re-using the annotations stored in the memory annotations, a teacher for example, can re-use these annotations and those of the co-authors with the knowledge witch contains to improve his process of teaching and to be able to teach in a best way a given learning object.

He can also profit from all the critical, explanatory and prescriptive annotations posted by the tutors to improve the contents of the learning object and thus the quality of the training. He can even recover the learner's annotations and take them into account to add explanations to the learning object. A learning object can be annotated several times, in different contexts, in different places and moments and by heterogeneous tools. Then, it quickly becomes illegible at the time of its consultation. On another side, the actor of a

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CEHL creates an annotation, in a given context, to re-use it in another context.

As a result, of these two remarks, we think that an annotation meta-model is essential to unify the various annotations produced by the actors. Moreover, it must be able to adapt itself to the context which surrounds the activity of annotation. Before presenting our architecture, we briefly expose the basic concepts, around our research.

A. Annotation

The state of the art relieves several definitions of the Annotation concept. The most adapted to our work was given by Mille [13], who considers an annotation as being "a trace of the activity of the reader, perceptible on a document as a mark, placed with a specific aim, and in a specific place of which it cannot be dissociated". In fact, the annotation object belongs to the document. An annotation has an objective that is well defined, because the annotator does not annotate for nothing, but for an essential goal.

According to this definition an annotation is regarded at the same time as an object and an activity [1]. An activity of creation of the annotation object aims to realise a user objective in the learning object.

B. Context and Context-awareness

According to the dictionary free on-line dictionary,Howe [8], the context is all that surrounds and gives a meaning to another thing. In this case, a definition of the context cannot be given in an isolated way without taking into account the element concerned with the context. This definition shows that the context must be external to the element concerned with this context.

A formal definition for the context is given by Azouaou and Desmoulins [1] as follows:

The context of an element X is the whole of properties P of any element of Y such as:
Y is around X.
Y gives meaning to X.
P is relevant for X.

In the literature, we find several definitions of context-awareness (conscience of the context). Schilit and Theimer [15] define the conscience of the context as being all the applications adapted to the context. Another definition given by Dey [5] specified that a system is considered as context-awareness, if it uses the context to give relevant information or a service to a user, knowing that the relevance depends on the activity of the user.

In addition, Context-awareness emerged in the fields of mobile and pervasive computing like a technique to design applications with a conscience of the environment, to ensure high level autonomy and flexibility. The context-awareness or the conscience of the context is known under other synonyms like *adaptive* or *reactivate* [4].

C. Personalization and of Adaptation of the CEHL

In order to be able to start the reflexion on the adaptation and personalization, we start by defining these two concepts.

The personalization of information consists in providing to one learner a relevant information equivalent to its preferences and its needs [3].

The adaptation is a transformation of an organization (or a genetic material…) in order to give it more adequacy with a new environment (a natural environment, a new political situation, a technology…) stimulating this adaptation. More particularly, in the context of adaptation of one system to the user, this generic term includes two specificities: adaptability and adaptivity.

In this way, Moisuc [14] explains, "*the adaptability is the capacity of the system to adapt to the personalizations explicitly requested by learner for example, while adaptivity indicates its capacity to meet the needs for learner without his explicit intervention*".

From this definition, we understand that the adaptation, whatever static (adaptability) or dynamic (adaptivity), requires a recognition of the learning context in order to be able to adapt the training according to the context and the learning objective.

The following section presents researches related to our problematic.

III. APPROACHES RELATED TO OUR RESEARCH TASKS

During last years, several researches were carried out to delimit the needs of CEHL actors and to recense the main elements helping to develop e-learning systems better adapted to their trainings and their needs.

Although they are diversified, those researches do not take into account the capitalization of the learning experiments which can be exploited later by other actors. In fact, we think that the major stake of e-learning is to integrate an approach to re-use the learning annotations within a CEHL

A. Adaptation Approaches and personalized e-Learning systems

In the last decades, the scientific researches were oriented to the adaptation and the personalization of the HMI, in particular in the CEHL field. Indeed, several researches support the personalization in this field to guarantee a better satisfaction of learning.

One approach consists to allow teachers to make scenarios for all the learner's uses possible of the system. A teaching scenario describes goals and learning situations while defining how the learning objects will be implemented in a precise context of training [10]. However, the teaching scenarios help the teachers to integrate the CEHL into their work practices, but do not allow creating sequences of activities adapted to each learner's competences.

A second approach of Duclosson, Daubias, and Riot [6] and Leroux [12] devotes a part of the e-learning system to be personalized by the teacher. Thus, teachers can parameterize the generation of the activities or select the activities which are appropriate for their learner. This personalization is done manually by the teacher, without bond with possible learner profiles, and can't be considered as based on a generic or unified model. In fact, each teacher can use several e-learning systems and must control several environments of personalization to succeed in defining in each case his teaching choices. Moreover, teacher himself needs to profit from its experiments and those of the other teachers, in addition to the tutor ones. We notice that this second approach is interested just in the training of learners and is not based on models.

A third approach consists in personalizing the e-learning systems automatically so that their contents are adapted to knowledge of each learner. This personalization can progressively be made throw the learners' answers (as a result to their behaviours) and uses the stereotypes associated to the learners [7] or using the learner model according to the e-learning systems. This automatic personalization is adapted to the system's knowledge about learner but is not always adapted to the teacher's learning goals.

Each one of these approaches answers part of the problem, but does not provide a solution to the whole: the adaptation of CEHL to the activities of the teachers and the adaptation of their contents to each one of their learners [11].

We present, in the following, some examples of projects working on the adaptation and the personalization in the e-learning systems.

B. *Approaches of annotations memories in e-learning*

The recent work on the annotations memories, Ouadah, Azouaou and Desmoulins [9] propose an annotation tool context-aware for an external annotations memory for the teacher. "*We are based on two architectures to propose the general architecture of our adaptive annotations tool. This tool must be able to identify the current context of teacher's activity in order to adapt to his behaviour and the changes of its situations of activity*".

This approach supports the teacher at his annotation activity to re-use it in another context. However, it is not an annotations memory for a general learning. Indeed, it can be integrated into an annotation tool and not into a computer environment for human learning. In addition, it is dedicated to only one actor who is the teacher.

In this way, we deduce the lack, in the literature, of an adaptable approach for the training of all CEHL actors based on annotations according to a given context.

IV. Generic Architecture Based on Web Services

In our work, we propose an approach to mitigate the limits illustrated above by introducing a personalized learning architecture based on annotations (experience feedback). This ontology-based architecture OARLCAM makes possible to capitalize and re-use a collective annotations memory for training. Its main goal is to provide all actors with a best training relative to their learning objectives and the current context extracted from the annotations memory, the learning objects warehouse or both. Such a system can be used as an assistance for the original authors, co-authors, tutors and learners.

Our contributions can be presented as follows: i) modelling the semantic of various annotations used in CEHL by a top level ontology, ii) modelling the various contexts of training by a context top level ontology and iii) proposing the approach OARLCAM to automatically exploit this knowledge to generate the learning objects with an added value of annotations adapted and personalized.

The following figure presents our modular architecture.

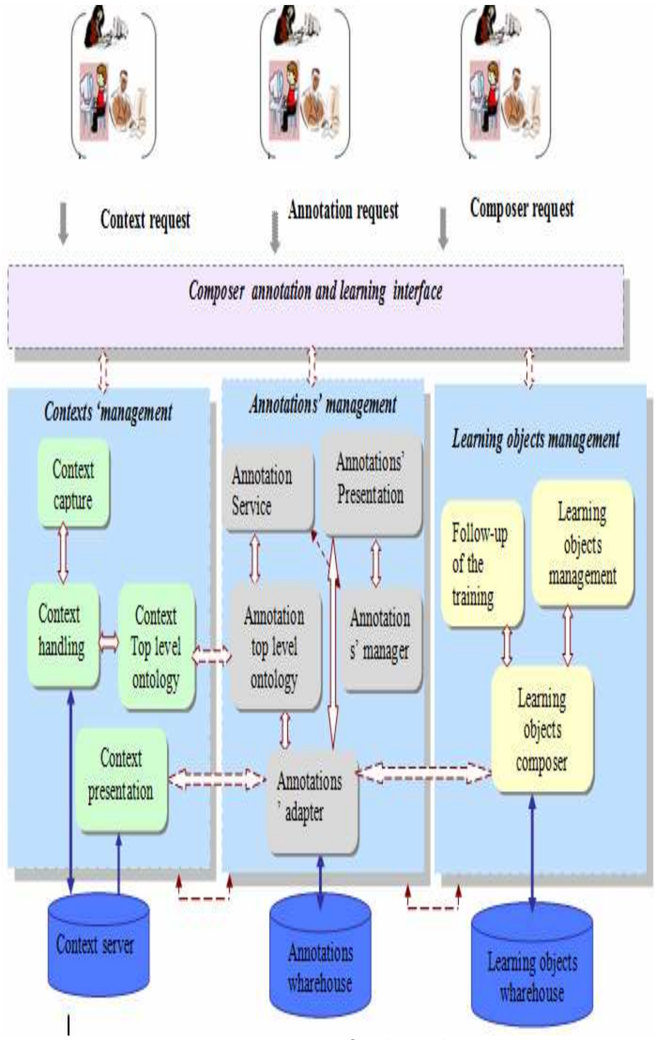

Figure 1. Our approach OARLCAM

This modular architecture is based on a context-aware approach coupled to some ontological engineering techniques in order to build a learning annotations memory, unified by an annotation top level ontology and a context top level ontology for an appropriate learning for all actors. It allows associating the adequate annotations with the appropriate learning object according to learning objective in a given context in order to improve the educational content and to activate the training process.

This architecture OARLCAM assures the reuse, the adaptability and the interoperability between our framework and the various tools used by the various actors, whom can use it as an external memory.

Our architecture includes three subsystems : i) the subsystem of contextualisation, containing the modules of context capture, context handling, context server, context

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presentation and a context top level ontology of training ii) and the learning subsystem, containing the modules of learning objects management, learning objects composer and follow-up of the training; and iii) the annotation subsystem, containing the annotation module, the annotations' manager, the annotations' adapter, the annotation top level ontology, the annotations' presentation module and the annotations warehouse, for later re-uses. The following sections describe the modules of the architecture.

A. Subsystem of contextualisation

1) The context capture module: The capture of the context is carried out using a whole of services which interact with sources of context (operating system, learning objects manager, organizer, etc…). This interaction can be made in a direct way if context information is accessible, or in an indirect way thanks to an export operation of context from the context source and an import of these data on the level of this module.

2) The context handling module: Context informations, provided by the context capture module, are treated according to our context top level ontology in order to be stored in the context server. This treatment consists in making a mapping between data types of the context source and our context model.

3) The context server module: The context informations are stored in XML format in order to facilitate their sharing and their use by the adaptive application and to keep the contexts history.

4) *The context presentation module*: context information is presented using the Web services standards (the details of this presentation are not in this paper). Each Web service can be consumed by other applications to be adapted to their context. This module is a service which gives information about the current context to the annotations' adapter module, knowing that those informations are extracted from the context server.

5) *The context top level ontology module.* It is a generic and exhaustive context ontology which provides the proprieties of context related to learning provided by our annotations memory.

The context top level ontology is conceived to solve the limits and the insufficiencies of the existing context models. For a given learning objective and a given context, we must extract the adequate annotations from the annotations memory. We use then a mapping method for determining the similarities between a learning context (context top level ontology), annotation semantics (annotation top level ontology). The annotation top level ontology contains three facets: cognitive, semantic and contextual. On another side, the context top level ontology contains six facets. Four of these facets (user, activity, environnement, collaboration) where defined by [9]. We add two more facets composition and objective to have an exhaustif context model which take to account the context of reuse of learning and learning objective.

6) Algorithm of similarities between different contexts: This algorithm aims to determinate similarities between different contexts of reuse of learning annotations; we take into account both semantic and structured similiraties between the concepts of ontology concepts. For example, the concepts of context ontologies of learning : context 1 ontology and context 2 ontology of learning. The algorithm below describes the process to find similarities between contexts :

Algorithm: Similarities
INPUT :
1) *CO1* and *CO2*: Context Ontology 1 and Context Ontology 2
2) V_{SS}: Semantic vector of similarities
3) V_{SSt} : structural vector of similarities
4) Sim_{St} : Weight of structural similarities
5) Sim_S : Weight of semantic similarities
OUTPUT : V_{SG} : global (Semantic and structural) vector of similarities
Begin
/* go to each concept of context ontology 1 */
For each *(CCO1 ε CO1)* **do**
/* go to each concept of context ontology 2 */
For each *(CCO2 ε CO2)* **do**
If *CCO1*.type==*CCO2*..type **then**
/*Extract semantic similarities between *CCO1* and CCO2 of V_{SS}*/
Sim_S=EXTRACTSIM (V_{SS}, *CCO1, CCO2*)
/*Extract structural simiraties de *CCO1*et *CCO2* of V_{SSt}*/
Sim_{St}=EXTRActSIM (V_{SSt}, *CCO1, CCO2*)
/*calculate global similarity*/
$Sim_G = Sim_S + Sim_{St}$
/* Add CCO1, CCO2 and Sim_G in V_{SG}*/
Add ((*CCO1, CCO2*, Sim_G), *VSG*)
Return (V_{SG})
END

The proposed algorithm of similarities has as input the two ontologies of context 1 and context 2, the two vectors of semantic and structural the similarities (VSS, and VSST), as well as the weights related to the semantic and structural similarities (SimS and SimSt). It produces in result a vector of global similarity, VSG. The function EXTRACTSIM extracts the value of the similarity corresponding to the two concepts (CCO1 and CCO2) from the vector of similarity (VSS or VSST). For each couple of concepts, CCO1 and CCO2, having the same category of two context ontologies , CO1 and CO2, the global similarity is calculated as follows:

SimG (CCO1; CCO2) = SimS (CCO1; CCO2) + SimSt (CCO1; CCO22)

B. Subsystem of the learning objects management

1) The learning objects management module: This module is used to create, to add, to remove, and to modify learning objects.

2) The learning objects composer module: This module serves to compose the learning objects with existing annotations for a given learning objective and a given context.

3) The follow-up of the training module: This module serves to save the learning activities history of our architecture's actors

C. Subsystem of annotation

1) The annotation module: This module allows actors to add an annotation according to our annotation top level ontology.

2) The annotations' manager module: This module manages the annotations affixed according to our annotation tool, for example, to add, to modify or to remove an annotation.

3) *The adapter annotations' module:* This module adapts the annotations stored in the annotations warehouse according to the context of training (objective) provided by the service of context presentation. This service has also as a role to provide the result of the adaptation for the services of learning objects composer to combine them with these objects (annotations source) or to provide them directly to the annotations' presentation module (the result of the request). For example, one learner during his revision wants to extract from a learning object all the explanatory annotations related to this object (in an explanatory context). He also wants that this annotation will be posted only during its next envisaged revision in a given day and a given hour. In this case, the service of annotation checks the properties of the context provided by the context services and posts the annotation only if the context is verified.

4) *The annotation top level ontology module:* It is a generic and exhaustive annotations ontology which provides the semantics of different learning annotations. We develop this ontology to mitigate the various insufficiencies in the state of the art.

5) *The annotations' presentation module:* This module presents, for the architecture various actors, the annotations adapted to the learning context. These annotations are treated to be adequate to the actors' requests and their learning objectives.

D. Communication between the various modules with XML

The use of the Web services to publish the context data facilitates the interoperability of our framework with any application sensitive to the context. On another side, XML is currently the standard language used for the data exchange on the Web. For this reasons we adopt it for the exchange of the data between all the modules composing our architecture. In the same way, the communication between the various services is done using the SOAP protocol which is based on XML.

E. Illustrative scenario

This section gives an illustrative example of our architecture's use. One learner at the time of its revision for an examination of the first session, for example, wants to recover all the explanatory and analytical annotations relating to a given learning object. He then makes training from our system by specifying its learning objective and its learning activity (examination). This learning is located in a C1 context (learning objective=revision, pedagogic activity=examination, date=d1, hour=h1, place=p1, learning domain= data bases) and this learning can be re-used by the same learner or another actor in a C2 context. For example, a preparation context of a part of learning object by one teacher (learning objective= course conception, pedagogic activity=course preparation, date=d2, hour=h2, place=p2, learning domain=data bases).

Thus, the training provided to this learner through our framework must be adapted according to his context and his learning objective.

Then we note that, the same learner can re-use the same context C1 another time for its next planned revision. For example, if the properties values of the learning contextual facet are (date=15/11/2010, learning objective =revision, pedagogic activity =examination), learner specifies also the context of re-use of these annotations, for example, for the final examination, by choosing directly the next context C2 (date=15/01/2011, learning objective =revision, pedagogic activity =examination). Automatically, the 15/01/2010, during the nearest examination, the annotation is posted for learner, to remind him his second revision.

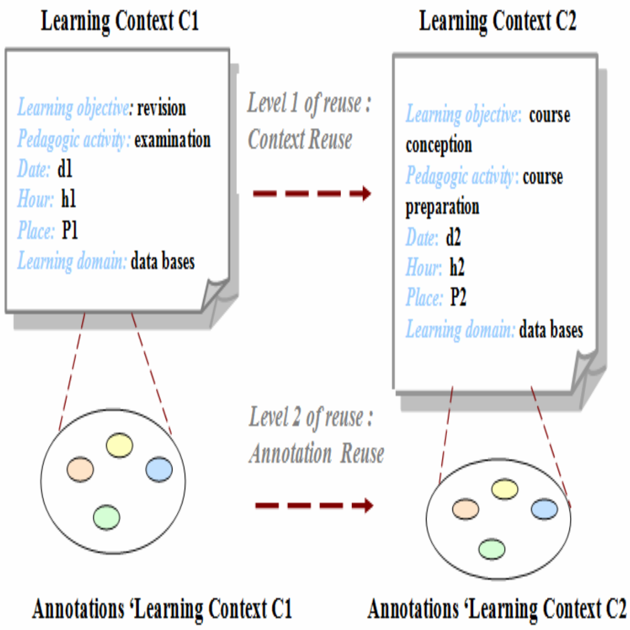

Figure 2. Reuse of context

In fact, our framework is able to provide a re-use on two levels. The first re-use (and sharing) is of annotations as well as the knowledge which is included there. The second re-use concerns the context. It means that a given context is reused in another context covering the same contextual properties and stored in the context server for a several re-uses later by the same actor or others.

Moreover, the annotations can be presented with or without their learning objects. In the first case they can be used to obtain an added value for the learning objects (learning objects composed with annotations). In the second case, they constitute an important knowledge to be capitalized.

V. CONCLUSION AND FUTURE WORKS

This paper represents a preliminary study to realize an adaptive annotation memory for context-aware training for the various actors in a CEHL. This memory can satisfy the need for training according to a given objective and a given context of all the actors in terms of utility, re-use, sharing and adaptability.

The running mechanism of our framework articulates around a whole of modules. Each module allows a functional need well defined and is composed of Web services. This framework aims to facilitate its integration, its interoperability with other e-learning systems. Moreover, it is based on three independent but communicating subsystems. The first is a subsystem for the training context capture, its treatment, its storage and its sharing by context sensitive applications. The second subsystem is devoted to the management and the adaptation a given annotation, from annotations memory, to the captured context. The third subsystem is planned for the management and the composition of the learning objects with the annotations extracted by the second subsystem.

Several perspectives are possible for this work. In particular, we aim to use the techniques of data warehousing (wrapper, monitor, etc.) to extract annotations from the annotations data bases and warehouses relative to other e-learning tools. Thesis extracted annotations will be total forwarded to our annotations memory according to our annotation top level ontology.

Also, we think that adding an ontology for the automatic deduction of the context annotation reuse, deduced for each actor, would be an important enrichment to our architecture and its functionalities.

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