Using and modeling context with ontology in e-learning: the case of teacher's personal annotation

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Abstract. This article aims at defining a context ontology of teacher's personal annotation, in order to use it in a context-aware annotation tool "MemoNote". Starting from a general definition of the context and its application to teacher's annotation, we define the uses of active and passive contexts in MemoNote (annotation ontologies selection, annotation memorization, pattern definition and selection). We then develop completely teacher's annotation context annotation ontology using the classical method specified for Protégé. Finally the current state of the tool development is sketched, in terms of context-aware functionalities.

1 Introduction

As in traditional education, documents are one of the main resources handled in e-learning. Since these pedagogical documents are digital in this case, textual and graphical annotations taken by teachers directly on documents need also to be digital. Moreover, these digital annotations can be capitalized into a digital and personal memory in order to be retrieved later. The MemoNote tool [2] aims at providing such a digital and personal memory based on annotations made on pedagogical document. It enables teachers and learners to annotate digital documents with their own comments and point of view as on paper. Relying on ontologies [6], the annotations created in the tool have an explicit semantics for both the annotator and the digital memory. In this paper we focus on annotations made by teachers during various teaching activities (preparing a lesson, teaching it, marking an exam …).

Taking into account the personal and semantic aspects of annotation [2] is the core of MemoNote tool, but it needs also to take into account the fact that people annotate differently according to the current context [15]. Consequently MemoNote needs also to adapt its services and functionalities in accordance with the teacher's annotation context. This adaptation would enable MemoNote to personalize and contextualized teacher interaction. It is then necessary for MemoNote to incorporate a context model, to represent all the relevant context data. From the various possible models to represent the context, a solution is to choose an ontological representation, which respects Buccholz assertion [4] "*A representation of the context information should be*

applicable throughout the whole process of gathering, transferring, storing, and interpreting of context information".

Our objective in this paper is to model a context ontology to be used by a specific e-learning application, MemoNote.

The article is organized as follows. In the first section, we study the context in order to define it and to explore the ways it has been used in e-learning. In section two, we describe MemoNote annotation tool, the way it uses context and we define what is teacher's annotation context. This leads us to develop in section three, following a classical method of ontology design, the teacher annotation context ontology. Finally we describe how this context ontology is implemented into MemoNote functionalities.

2   Context in e-learning

2.1   Definition of context

According to the Free on-line dictionary of computing [12] the context is "*that which surrounds, and gives meaning to, something else*". The basis of this definition is that the context cannot be defined solely, without considering the object it concerns, the context of *something*. This definition expresses also that the context of *something* is **external** to this *something*, **outside** of it. Finally, this definition states that from the various objects, events, person that surrounds something, the context is restricted to the meaningful elements as regards to this *something*.

We can then reformulate more formally this definition by "the context of an element X is the set of elements Y such as:
  – *Y is around X*
  – *Y gives meaning to X"*

We need to accurate this definition in the case of software applications to specify which properties are considered to describe the context elements.

This lead to the following definition: "*The context is meaningful properties about that which surrounds, and gives meaning to, something else*". It means that not all the properties of the context elements are considered, but only the meaningful ones regarding what the context is about. Formally, the new definition is then

"*The context of an element X is the properties P of any element Y such as:*
  – *Y is around X*
  – *Y gives meaning to X*
  – *P is meaningful for X.*

2.2   Context uses in e-learning.

According to [5] *there are essentially two ways to use context: automatically adapt the behaviours according to discovered context (using active context), present the context to the user on the fly, or store the context for the user to retrieve later (using*

passive context). Chalmers elaborates by identifying six uses of contextual information that we incorporate in the Chen's two ways of using context:

- Using active context.
  - o To reconfigure
    - ▪ Available services. *Context aware configuration e.g., to cause printing to be on the nearest printer, or cause selection of nearby proxies when needed.*
    - ▪ Services or data presentation. *Context aware presentation refers to the adaptation of the user interface or the presentation of data, e.g. adjusting interaction widgets according to the display device.*
  - o To adapt behaviour. *Contextual mediation is the use of context to modify services provided or the data requested to best meet the needs and limits arising from the context of the interaction.*
  - o To trigger actions. *Context triggered actions such as loading map data for the predicted next location.*
- Using passive context.
  - o To inform users. *Context display where sensed context is presented to the user, e.g. display of the current location.*
  - o To memorise contextual data. *Contextual augmentation annotates data with the context of its generation, e.g. meeting notes can be associated with people attendees and the meeting location.*

Context in e-learning is not currently broadly used and related literature is recent.

Dichev and Dicheva [9] use context for information seeking in a knowledge base where concepts are linked through relationships. It is a kind of passive use of context intending to inform users, where the objective is to provide the learner with the situation of the concept in the knowledge base. The context of a concept t in this case is the set of contexts c such as c and t are arguments of the same relation (*weak context*) or the set of relations r where t is an argument of r (*strong context*).

Derntl and Hummel [7] use context to control the learner's activity in two ways:

- Choosing the next activity depending on the current context.
- Altering the way the next activity is conducted (minor variations).

They are both active uses of context intending to reconfigure the e-learning service. In this case, context is mainly the physical entities in the room (laboratory equipment, books, and people).

Muhlenbrock [17] is using the context to help teachers to form groups of learners. It integrates to learner profile, context data such as sensor-derived activity and availability. The system is based on a probabilistic approach automatically learning individual characteristics and indicating relevant situations. It is a kind of passive use of context intending to inform users (teachers) on the learners needs regarding joining a group.

Schmidt and Winterhalter [22] are using context to retrieve relevant learning object for a given user. The matching service *computes a similarity measure between the current user context abstraction and the ontological metadata of each learning object and then can present a ranked list of relevant learning objects*. It is a kind of active use of context intending to reconfigure available services (learning objects).

3 Teacher's annotation context

Semantic annotation in e-learning concerns two types of activities. The most common is the semantic annotation of resources in order to describe their content and help retrieving them [3]. The second one aims at memorising the reader's viewpoint. The MemoNote tool we are developing is concerned with this kind of semantic and personal annotation-based memory.

MemoNote is the generic name for a set of tools providing memory facilities to the various e-learning actors, mainly learners and teachers. Two versions have been currently implemented, a Tablet-PC version for mobile use and a Web-based version. The focus in this paper is on the MemoNote version that is dedicated to teachers.

To represent the semantic and personal viewpoint of a given annotator, MemoNote represents teacher's annotation with three facets [1].

- The **semantic facet** represents why the annotation was created by the teacher, its content, its addressee and its value for the teacher (confidence and importance).
- The **physical facet** represents the document side of the annotation that is its visible form and its anchor on the document.
- The **episodic facet** represents the context in which the annotation was created, described by the pedagogical situation and the annotation author.

Most of these facets attributes are represented with ontologies, depending on the current e-learning context. The set of these ontologies is called "annotation ontologies".

The two main functionalities of MemoNote are to memorize annotations during the document use and to remind annotations created in the past. To create these annotations, MemoNote provides the annotator with two functionalities, manual annotation and semi-automatic annotation using annotation patterns. Each annotation pattern formalizes an annotation habit. It enables then MemoNote to deduce the annotation's semantics from the annotation form chosen by the teacher. For example if the teacher annotates a text using a question mark, MemoNote deduces that the teacher has annotated to memorize that he has not understood this passage.

The manual annotation functionality is a kind of both passive and active use of context. The passive use consists in memorizing the current context in the annotation object (episodic facet). The active use consists in changing the set of annotation ontologies, for example, the semantic annotation facet refers to different ontologies if the context is "Chemistry lab" or "Mathematics lecture".

The semi-automatic annotation using patterns functionality is a kind of active use of context. The tool is able to automatically select and display annotation patterns that are suitable to the current context.

Finally, the pattern creation functionality is a kind of passive use of context. The tool automatically records the current context into the pattern at its creation.

The *context of teacher's annotation activity* can be defined following the generic definition provided in section 2.1 as follows:

The properties P of any element Y such as:
- Y is around the teacher's annotation activity
- Y gives meaning to the teacher's annotation activity
- P is meaningful to the teacher's annotation activity.

4   Annotation context ontology

There is no one "correct" way or methodology for developing ontologies and several methods are proposed aiming at ontology design and development. To design the annotation context ontology we follow the iterative approach for ontology development proposed in [18].

4.1 Ontology domain and scope

We start the ontology development by defining its domain and scope and this by answering the following questions:

What is the domain that the ontology will cover? The domain of our ontology is the context of the teacher's annotation activity. Therefore it is unlikely that the ontology will include concepts about learner's annotation, or teacher's annotation concerning his/her lectures out of his/her teaching activities. It does not include either semantic web annotations, which are not aimed directly to human use, but which are aimed to be machine interpretable.

For what are we going to use the ontology? We need to use this ontology to incorporate both passive and active context-awareness functionalities in MemoNote.

These uses, described in section 3, are presented following the Chalmers categorization as follows:

- Using active context to reconfigure services or data presentation.
  - ➢ *Contextual patterns selection*
  - ➢ *Contextual configuration of annotation ontologies*
  - ➢ *Contextual assistance at the pattern management*
- Using passive context to memorize contextual data
  - ➢ *Passive context memorization of annotation*

We have to keep in mind these contextual functionalities during the design process by eliminating the annotation context related terms which are not relevant to these functionalities.

Who will use the ontology? This ontology is not aimed at human use, but it is aimed at machine processing, enabling MemoNote to provide context-aware functionalities.

4.2 Reuse of related work

The aim of this step is to reuse existing ontologies, even if they are aimed at other uses. This avoids us to develop the ontology from scratch. Anyway, these ontologies have to be adapted and refined.

Several context ontologies are defined in the literature, most of them (generic ontologies) concern mobile and pervasive computing [23], [19], [20], [5], [13] ,[11] and some concern e-learning [10], [14], [21] [8].

These ontologies claim that important aspects of the context of a given user's activity include the following elements:
1. *Computing profile.* Available processors, accessible devices for user input and display, network capacity, connectivity, and costs of computing.
2. *User profile*. Location, collection of nearby people, and social situation.
3. *Physical profile.* Lighting and noise level.
4. *The time.* Such as time of a day, week, month, and season of the year.

Both generic and e-learning ontologies share the same upper part of the ontology which corresponds to the context categories described above and that the annotation context ontology should reuse. In addition to these elements, the e-learning ontologies provide specific e-learning concepts as: organizational role [21], e-learning services [8], pedagogical resource, institution, domain, learner's activity, teacher's activity, place… [10].

4.3 Concepts identification and hierarchy

To identify the ontology concepts, we apply the definition of the annotation activity in e-learning (see section 3). It means to identify elements/concepts which are around the annotation activity and which are meaningful for it. These concepts are relevant regarding the context uses in MemoNote.

We apply the definition for each one of the following steps:

1. **Using concepts gathered from generic ontologies**
- For passive context use, we keep the user profile (user=teacher) as MemoNote is a personal memory, and the time.
- For active context use, we keep both the computing (software and hardware) and the user profile (user=teacher) as MemoNote adapts its behavior depending on them.
- The physical profile (like temperature and humidity) is not meaningful as MemoNote only deals with annotation on documents where physical elements have little impact.

2. **Using concepts gathered from e-learning ontologies**
- For passive context use, we keep learner activity, teacher activity, learning domain and learning degree and place that are relevant for annotations retrieval.
- For active context use, we keep learner activity, teacher activity, learning domain and learning degree as MemoNote adapts its behavior depending on them. For example, the pattern contextual selection depends on the learning domain.

3. **Complete the ontology by meaningful concepts**

- We need to add two relevant concepts for active context use. MemoNote needs to know which *annotation tool* (PC version, web version…) is used by the teacher and in which *host system* (Windows, Linux, LMS…) the teacher is using the annotating tool. MemoNote uses this data to adapt patterns selection.

We structure these concepts in a hierarchy following a top-down approach leading to the following ontology concepts:

- *Context*
- *Computing*
  - o *Computing Software*
    - ▪ *Annotation tool*
    - ▪ *Host system*
  - o *Computing Hardware*
- *Teacher*
- *Learning Activity*
  - o *Learning Domain*
  - o *Learning Degree*
- *Teacher Activity*
- *Place*
- *Time*.

4.4 Classes properties

As the classes alone do not provide sufficient information to represent the context of annotation activity, we must then describe the inner structure of each concept.

We have already identified concepts (classes), which are meaningful for annotation activity in e-learning. For each concept we identify meaningful properties as specified in the definition of the annotation context (see section 3).

As result we obtain the following properties:

Table 1. Concepts properties

Ontology concept	Property	Type
Context	*contextID*	*String*
	usedTool	*Instance of AnnotationTool*
	currentHost	*Instance of HostSystem*
	usedDevice	*Instance of Hardware*
	annotator	*Instance of Teacher*
	currentTeachingActivity	*Sub-concept of TeachingActivitie*
	learnerActivity	*Instance of LearnerActivitie*
	currentPlace	*Instance of Place*
	currentDate	*Date*
AnnotationTool	*Name*	*String*
HostSystem	*Name*	*String*

Hardware	*name*	*String*
Teacher	*Name*	*String*
Teaching activity	*name*	*String*
Learning activity	*Name*	*String*
	learningDomain	*Sub-concept of Domain*
	learningDegree	*Sub-Concept of Degree*
Learner domain	*Name*	*String*
Learner degree	*Name*	*String*
Place	*Name*	*String*
Time	*Date*	*Date*

The following table provides the is-a hierarchy of each concept of this ontology.

Table 2. Concepts hierarchy

- Software
  - MemoNote-PC
  - MemoNote-Web

- Host system
  - Operating system
  - Mac OS
    - Mac OS X
    - Mac OS Tiger
  - Windows
    - Windows XP
  - Linux
    - Linux Mandrake
    - Linux Red-Hat
  - Other
  - Browser
  - LMS

- Hardware
  - Personal assistant
  - Personal computer
  - Tablet pc

- Teacher

- Place
  - School place
    - Library
    - Labs room
    - Meeting room
  - Home
  - Public transportation

- Learning activity
  - Course
  - Exercise
  - Labs
  - Simulation

- Teaching activity
  - Assessment
  - Design
  - Doing
  - Preparation

- Learning domain
  - Chemistry
    - Organic
    - Mineral
  - Mathematics
    - Algebra
    - Geometry

- Learning level
  - Bachelor
    - Bachelor 1
    - Bachelor 2
    - Bachelor 3
  - Master
    - Master 1
    - Master 2

4.5 Instances

The last step is creating individual instances of classes in the hierarchy. We provide such two instances in the following table, demonstrating the coherence of the ontology.

Table 3. Two instance samples

Property	Sample value 1	Sample value 2
contextID	C152	C123
usedTool	MemoNote-PC	MemoNote-Web
currentHost	Windows XP	Browser
usedDevice	HP-TC 1100	PowerBook G4
annotator	Cathy	David
currentTeachingActivity	Preparing	Reviewing
learnerActivity	LA12	LA27
	Chemistry	Algebra
	Master 1	Bachelor 2
currentPlace	Lab45	Public Library
currentDate	12/10/2006, 10h45	22/02/2006, 15h40

5 Current state of implementation

MemoNote's architecture is context-centric, it is based on autonomous components with precise responsibilities. Indeed, a dedicated context capture component gathers the required context data and sends it to the context manager. This latter builds an instance of the context ontology. According to this instance values, MemoNote adapts its behaviour and functionalities. The current state of implementation of context-awareness in MemoNote is different depending on the platform in which it is implemented.

5.1 Tablet-PC version

MemoNote was first developed on Tablet-PC computers on WindowsXP for mobile uses. This version is based on Mobipocket Reader [16], a multiplatform e-book reader, working with document in OEB (an XML-based format). This requires converting document (.doc, .html) to this format prior to read and annotate them.

In this version, annotation ontologies and annotations are represented with XML whereas pattern and context are represented in RDF.

It provides the following context-aware functionalities:
- ➢ *Contextual patterns selection*
- ➢ *Contextual assistance at the pattern management*
- ➢ *Passive context memorization of annotation*

Contextual configuration of annotation ontologies is no yet implemented and the teacher needs to change manually the configuration of these ontologies.

The context is currently gathered at each session change, by asking the teacher to himself/herself provide context information.

5.2 Web-based version

MemoNote's last version is a Web-based one. It is developed using JavaScript on the client side and a ZOPE annotation server. Annotations can be made on HTML documents.

In this version, annotation ontologies are represented in OWL, and annotations in RDF. It does not include semi-automatic annotation with patterns for the moment and then it provides only context-awareness for memorizing contextual annotation data. As for Tablet-PC version, the context is gathered at each session change, by asking the teacher to himself/herself provide context information.

6 Conclusion and future work.

Starting from MemoNote core functionalities enabling teacher to memorize semantic and personal annotations, our objective was to extend them with context-aware capabilities thanks to a context ontology.

We defined precisely what is the context of a teacher's annotation activity, that is "meaningful properties about that which surrounds, and gives meaning to teacher's annotation". We categorized MemoNote context uses in terms of active and passive context.

From this definition and these uses, we have been able to develop a context ontology for teacher's annotation activity that includes generic properties (computing – software and hardware, place, time, user) and specific e-learning properties (teacher activity, learner activity, learning domain and degree).

This ontology has been integrated into MemoNote TabletPC version, particularly for context-aware pattern functionality.

A short-term perspective is to integrate the whole set of context-aware functionalities in the Web version of MemoNote, taking advantage of the Semantic Web standards for ontology (OWL) and annotation (RDF) (like reasoning about context and context constraints). This Web version could also easily be integrated into a Learning Content Management System (LMCS) and automatically picks up context information from it.

We could also study how to augment MemoNote context-awareness by developing lacking uses regarding the uses categorization we provided. Triggering actions on context change means in our case to automatically trigger annotation behavior previously attached to annotation, we call pro-active annotation (for example a reminder depending on the date and student activity). Available services depending on context could mean in our case to restrict the annotation retrieval to the annotations matching with the current context.

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