Semantic Annotations and Context Reasoning to Enhance Knowledge Reuse in e-Learning

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Abstract. We address in this paper the need of improving knowledge reusability within online Communities of Practice of E-learning (CoPEs). Our approach is based on contextual semantic annotations. An ontological-based contextual semantic annotation model is presented. The model serves as the basis for implementing a context aware annotation system called "CoPEAnnot". Ontological and rule-based context reasoning contribute to improving knowledge reuse by adapting CoPEAnnot's search results, navigation and recommendation. The proposal has been experimented within a community of learners.

Keywords: community of practice of e-learning, e-learning, knowledge reuse, semantic annotation, context, reasoning.

1 Introduction

With the large amount of pedagogical knowledge which is constantly growing among Communities of Practice of e-learning (CoPEs), the issue of knowledge reuse remains a serious problem [1]. Through the participation to the CoPE, e-learning actors create both, tacit and explicit knowledge. The main concern, however, lies in reusing tacit knowledge. Some research studies explore the use of semantic approaches for knowledge modeling and reuse. The works carried out in [2] [3] [4] rely on using ontological approaches to indexing resources. These approaches are useful to index and manage explicit knowledge, but are not suitable for eliciting tacit knowledge which requires externalization mechanisms. According to [5], semantic annotation approaches are more useful to modeling both tacit and explicit knowledge. These approaches have been shown their effectiveness in knowledge modeling disregarding how to reuse and reap benefit from that knowledge. In this regard, we consider that the preservation of knowledge context can be very useful at their reuse. The context of knowledge refers to parameters describing the situation in which this knowledge is modeled or reused. Few works have introduced the notion of context [5] [6], but without taking into consideration important aspects such as context reasoning.

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The object of this paper is to use both semantic annotations and context for modeling knowledge within CoPEs. The resulted model is used to improve knowledge reuse and sharing by benefiting from context reasoning.

The paper is organized as follows: In section 2, we describe the proposed context-based semantic annotation model. In section 3, context reasoning mechanisms are described. In section 4, the context-aware architecture of the proposed annotation system is presented. Section 5 discusses the implementation and experimentation of our proposal. Finally, section 6 contains concluding remarks and future work.

2 Context-Based Semantic Annotation Model

We propose in this section, a contextual annotation model of four dimensions (Fig. 1): Resource, Annotation, Controlled vocabulary and Context. Accordingly, the model represents the important aspects of annotation, which includes the description of the annotated resource, the representation of various elements of annotation and their links to the controlled vocabularies, as well as the description of members' context during the process of creation, evaluation or reuse of annotations. The model is implemented using ontology.

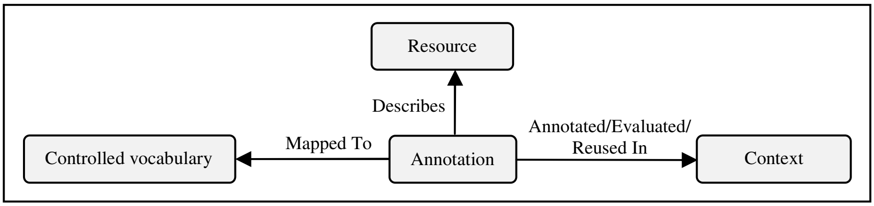

Fig. 1. General annotation model

2.1 Resource

This dimension represents the resource or the part of the annotated resource. Resources are heterogeneous and varied on their nature, form, size, etc. This dimension includes the following attributes (see Fig. 2): URL, title, authors, description, and type (e.g. course, exercise, presentation, etc.).

2.2 Annotation

This dimension represents the externalized knowledge which reflects personal knowledge and experiences of the annotator, and also those of recipients of annotation; those who reuse the annotation may express their judgments and feedback about the annotation via another annotation. This dimension is formalized based on the annotation models in [5] [7]. The conceptual model of annotation is presented in Fig. 2, two categories of annotation are distinguished: personal and shared.

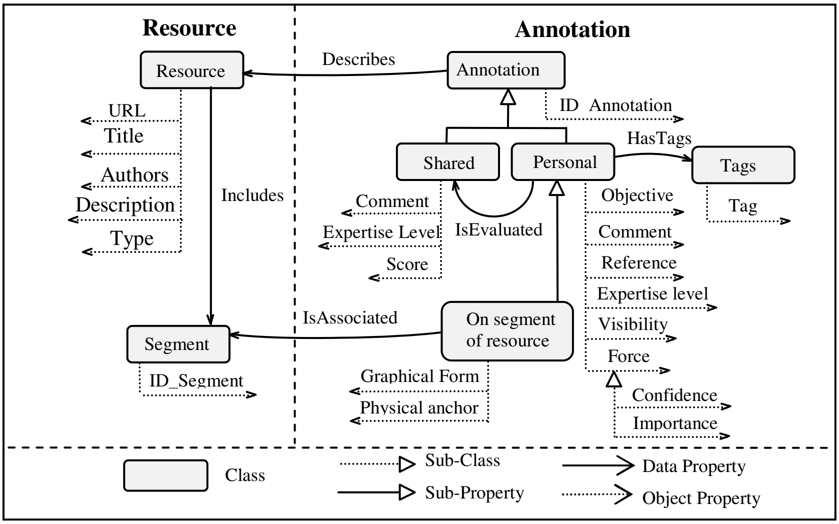

Fig. 2. Conceptual model of Resource and Annotation

"Personal" annotation. It is associated to the author of the annotation. In the case of annotation on the whole resource, the annotation has the following attributes:

- Tags: this is one or more keywords associated to the resource. It can better organize the resources, as well as it provides a simple and effective browsing technique.
- Objective: it represents the reason why the annotation is created. It serves to reuse the annotation, and it is associated with a controlled vocabulary.
- Comment: it contains free text, allowing the annotator to freely express his points of views, opinions and expertise about the annotated resource.
- Reference: it represents a link to another resource (e.g. reference book, citation, URL, etc.). It allows the annotator to argue or enrich his annotation.
- Expertise level: this attribute is important and people tend to trust an expert over a novice.
- Visibility: it refers to the access rights to annotation, we distinguish three types: *Private*, *Public*, and *Group*.
- Force: is the value that represents the annotation for the annotator, including "Importance" which describes the significance character of annotation relative to its creator and "Confidence" which means the assertion about the annotation.

In the case of annotation on a segment of the resource, the annotation includes also the following attributes:

- Graphical form: it represents the graphical aspect of annotation (highlighting, underlining, etc.). That is used to change the appearance of information to make it more visible [7].
- Physical anchor describing the annotated segment in the resource.

"Shared" annotation. This dimension of annotation doesn't exist in the previous models of annotation in [5]. It allows members to evaluate and enhance the annotation. It includes the following attributes:

- Comment: a free text provided by the recipient, which allows him to express his points of view, interpretations, judgments about the annotation.
- Expertise level: of the member who evaluates the annotation.
- Score: appreciation of the value (i.e. a relevance measure) given to the annotation.

2.3 Context

The conceptual model of context is represented in figure 3. This model is inspired from [5] and [6]. Two levels of context are distinguished. The first level represents the generic concepts of context, it describes the context of annotation in general and it can be applied to numerous fields.

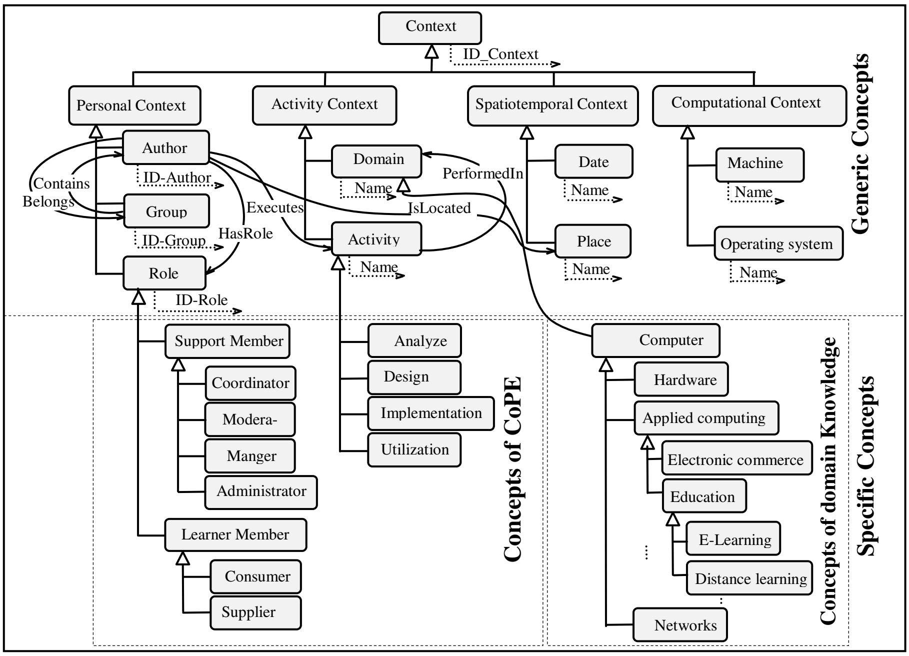

Fig. 3. Conceptual model of Context

The model of context is composed of four components:

- Personal Context: it includes the "Author" representing the member, the "Role" of member in the CoPE, and the "Group" to which the member belongs to.
- Activity Context: it includes the "Domain" which represents the knowledge domain (e.g. mathematics, physics, computer science, etc.), and the member's "Activity" in the CoPE.

- Spatiotemporal Context: it describes the "Date" and the "Place" in which the member creates, evaluates or reuses the annotation.
- Computing Context: it includes the "Operating system" installed on the host and the "Machine" on which turns the annotation tool.

The second level represents ontologies describing specific concepts of context. The ontology of CoPE [8] describes concepts related to CoPE. ACM Computer Classification System [9] is used to describe computer science domain.

2.4 Controlled Vocabulary

It represents ontologies associated to different elements of annotation like tags and attributes (e.g. graphical form, objective of annotation, etc.). We opt for the ontology proposed in [9] that including a rather comprehensive list of annotation graphical forms. As far as vocabulary associated to the objective of annotation, we reuse the ontology proposed in [10], describing learners' annotation objectives. Thereafter, other controlled vocabularies can be developed.

3 Context Reasoning

Formal approaches for context modeling such as ontology, offer many advantages, the foremost advantage is the reasoning capabilities. Context Reasoning aims to check consistency of the model as well as to infer new information about context and to derive high level of context. Indeed, the contextual information provided by the system, user, sensors, etc. leads to elementary data about context, whereas some contextual information are useful only if they are combined with other elementary or composite contexts. Context reasoning is used to support the knowledge reuse by providing annotations that best fit member's context. The reasoning tasks are grouped into two categories: ontological reasoning and rule based reasoning.

3.1 Ontological Reasoning

The OWL-DL language provides efficient reasoning, which makes it the ideal to represent the context ontology. The standard reasoning rules supported by this language includes: subClasseOf, subPropertyOf, TransitiveProperty, disjointWith, inverseOf, etc. They are used to infer the implicit context from the explicit context.

Fig. 4 shows some examples illustrating the use of ontological reasoning rules in our context ontology. For instance, "ActivityContext" is subclass of "Context" and "Activity" is subclass of "ActivityContext". Thus, "Activity" can be defined as subclass of "Context" using "subClassOf" rule. Furthermore, the concepts "Analyze" and "Design" are disjoint. The rule "disjointWith" can be used to infer a contradiction when the instance "ScenarioConception" is defined as instance of both classes at the same time. Also, "Belongs" is an inverse property of "Contains", the explicit context shows that "Author1" "Belongs" to "Group1", through the rule "inverseOf", a new context that "Group1" "Contains" "Author1" can be implicitly deduced.

Explicit context

```
<owl:Class rdf:ID="ActivityContext">
   <rdfs:subClassOf>
      <owl:Class rdf:ID="Context"/>
   </rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:ID="Activity">
   <rdfs:subClassOf>
      <owl:Class
rdf:ID="ActivityContext"/>
   </rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:ID="Analyze">
   <owl:disjointWith>
      <owl:Class rdf:ID="Conception"/>
   </owl:disjointWith>
</owl:Class>
<owl:ObjectProperty rdf:ID="Belongs">
   <owl:inverseOf>
      <owl:ObjectProperty
rdf:ID="Contains"/>
   </owl:inverseOf>
   <rdfs:range rdf:resource="#Group"/>
   <rdfs:domain
rdf:resource="#Author"/>
</owl:ObjectProperty>
<Author rdf:ID="Author1">
   <Belongs rdf:resource="#Group1"/>
</Author>
```

Implicit context

```
<owl:Class rdf:ID="Activity">
   <rdfs:subClassOf>
      <owl:Class rdf:ID="Context"/>
   </rdfs:subClassOf>
</owl:Class>
<Conception
rdf:ID="ScenarioConception">
<Analyze rdf:ID="ScenarioConception">
--- Error
<Group rdf:ID="Group1">
   <Contains
rdf:resource="#Author1"/>
 </Group>
```

Fig. 4. Ontological reasoning

3.2 Rule-Based Reasoning

Some contextual information cannot be easily inferred using ontological reasoning. Accordingly, we propose the use of predefined rules, considered as a flexible mechanism to infer other contextual information. Inference rules are described with Generic Rule Language specified by Jena API and based on first order logic.

Table 1. Context tuples

ID-Context	ID-Author	ID-Group	Role-Name	Activity-Name	Domain-Name
C1	Author1	Group1	Manager	Conception	E-learning
C2	Author2	Group2	Coordinator	Conception	E-learning
C3	Author3	Group1	Moderator	Conception	Distance Learning

The tuples in table 1 correspond to individuals of Context. The first tuple “C1” represents the current context of annotation. Context reasoning basis on the rule “R” (Fig. 5) infers a new context that the tuple of context “C1” has the same group and the same activity as the tuple “C3”. More precisely, the rule R defines the relationship “SameGAc” between two instances of “context”, when their authors belong to the same group and execute the same activity. This rule is based on relationships defined in the other inference rules (“Sameidc”, “InC”, “SamePerson”, “SameGroup” and “SameActivity”).

```
[R:(?c1 rdf:type prefix:Context)(?c2 rdf:type prefix:Context)
noValue(?c1 prefix:Sameidc ?c2)(?a1 rdf:type prefix:Author)
(?a2 rdf:type prefix:Author)(?a1 prefix:InC ?c1)(?a2 prefix:InC ?c2)
noValue(?a1 prefix:SamePerson ?a2)(?g1 rdf:type prefix:Group)
(?g2 rdf:type prefix:Group)(?a1 prefix:Belongs ?g1)(?a2 prefix:Belongs ?g2)
(?g1 prefix:SameGroup ?g2)(?ac1 rdf:type prefix:Activity)
(?ac2 rdf:type prefix:Activity)(?a1 prefix:Executes ?ac1)(?a2 prefix:Executes
?ac2)(?ac1 prefix:SameActivity ?ac2) -> (?c1 prefix:SameGAc ?c2)]
```

Fig. 5. Reasoning rule

4 Context-Aware Architecture

We propose, in this section, the context-aware architecture for our annotation system called CoPEAnnot. Many researchers have proposed several context-aware architectures and most of them are proposed in pervasive and mobile computing domain. The works in [6] [11] proposed architectures for context-aware annotation systems. The proposed architecture (Fig. 6) differs from the above architectures by the reasoning support it provides. It consists of two main components: context and annotation management, as proposed in [12]. The authors suggest that the body of application must be designed in isolation from contextual data.

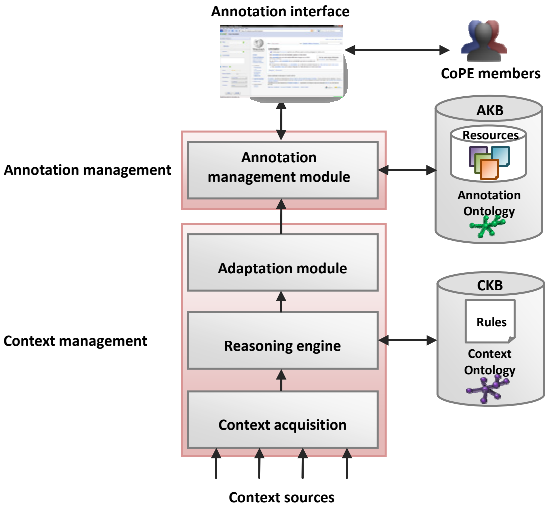

Fig. 6. CoPEAnnot Architecture

1. Context Management: it includes the following major steps:

- Context acquisition: is responsible for collecting contextual information from different sources (operating system, user model, physical sensors, etc.), for interpreting contextual information (transform them into more useful and meaningful information) and for their storage in accordance to the context ontology.
- Reasoning engine: is in charge of reasoning about contextual information acquired by the acquisition module. Based on ontological and rule-based reasoning,

the reasoning engine infers information about annotations' context which is semantically closest to the current context.

- Adaptation module: this module adapts the functionalities of context-aware system according to the contextual information provided by the reasoning engine.

2. Annotation management: it includes the following major steps:

   - Annotation management module: is in charge to insert, store and update, research, navigation and recommendation of annotations. These last three features are adapted according to the current context of the annotation.
   - Annotation interface: it represents the graphical interface that allows the exchange and interaction between the CoPE members and the annotation tool.

The context knowledge base (CKB) contains the context ontology and the inference rules. The annotation knowledge base (AKB) includes the resources and the ontology which defines the annotation model and their controlled vocabularies.

5 Implementation and Experimentation

We have developed a prototype system CoPEAnnot, based on the above architecture and annotation model. The ontologies are developed using Protégé editor. The system is implemented in client-server architecture. The client has as browser Mozilla Firefox, in which the annotation tool is an extension. Graphical interface was built using XUL, DOM, JS and CSS. AJAX is used to insure the communication between the client and the server. On the server side, we used Tomcat as a Servlet container. Servlet are java programs that used to handle http requests/responses. Jena frame work is also used to support rule-based reasoning.

Fig. 7. Screenshots of CoPEAnnot tool

The annotation extension provides the following main features: CoPEAnnot (Home), resource, annotation, navigate, search and help. Home sidebar shows the tag cloud and the recommended annotations adapted to the current context of the member (part B Fig. 7). Members can annotate any type of resources. Graphical forms can be used to annotate on a part of html resources (part A Fig. 7). Thereafter, members can also edit, share, and evaluate an annotation. In addition to the standard features of navigation, the tag cloud enables faster discovering of knowledge. The tool provides also contextual semantic search based on controlled vocabularies (part C Fig. 7).

In order to validate CoPEAnnot, we consider the following experimental process:

1. Identify the key dimensions of evaluation: a questionnaire has been established based on the evaluation dimensions proposed in [13]: "utility", "usability" and "acceptability". Further, we evaluated the adaptation quality of the tool.

   - The utility represents the accordance between the features offered by the system and those expected by the user. We evaluate members' satisfaction about each feature of CoPEAnnot.
   - The usability indicates the ability to learn and use the system. We evaluate user-friendliness and simplicity of CoPEAnnot. Thus, we check if the members are become more familiar with annotations, tags and taxonomies.
   - The acceptability represents user's mental attitude towards the system. We measure members' satisfaction on using the tool and we see how often they want to use it.
   - The adaptation quality measurement, by assessing the appropriateness of tag cloud, recommended annotations, navigation and search results according to the current context of members.

2. Test Organization: this step involves gathering information from members of a community of learners in academic discipline in computer science. The questionnaire and the CoPEAnnot tool have been made available for the members.
3. Results Analysis: this step includes a statistical analyses of experimental data. Twenty four students (10 man and 13 women) were interviewed using the questionnaire. The average age of the respondents is 25 years. The results of this investigation were satisfactory and the learners have expressed a high level of satisfaction. The figure below presents the satisfaction rates of each dimension in the questionnaire.

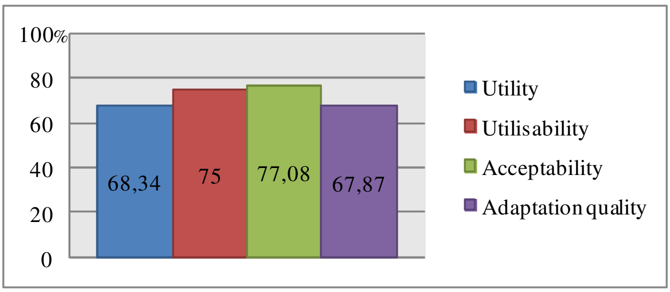

Fig. 8. Experimental results of CoPEAnnot

6 Conclusion

This paper recognizes the knowledge reuse problem within CoPEs and proposes a framework based on semantic annotation and context reasoning. A contextual semantic annotation model has been proposed to model the shared knowledge. Ontological and rule-based context reasoning mechanisms are used to adapt annotation system features according to the current members' context. The experimentation results of CoPEAnnot were very promising. Our future work will focus on improving the tool by extending reasoning capabilities on other elements of context like member's profile and developing controlled vocabularies. Semi-automatic annotation mechanisms can be further integrated to facilitate the annotation activity.

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