Yang, S. J. H., Chen, I. Y. L., & Shao, N. W. Y. (2004). Ontology Enabled Annotation and Knowledge Management for Collaborative Learning in Virtual Learning Community. *Educational Technology & Society*, 7 (4), 70-81.

Ontology Enabled Annotation and Knowledge Management for Collaborative Learning in Virtual Learning Community

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Abstract

The nature of collaborative learning involves intensive interactions among collaborators, such as articulating knowledge into written, verbal or symbolic forms, authoring articles or posting messages to this community's discussion forum, responding or adding comments to messages or articles posted by others, etc. Knowledge collaborators' capabilities to provide knowledge and the motivation to collaborate in the learning process influence the quantity and quality of the knowledge to flow into the virtual learning community. In this paper, we have developed an ontology enabled annotation and knowledge management to provide semantic web services from three perspectives, personalized annotation, real-time discussion, and semantic content retrieval. Personalized annotation is used to equip the collaborators with Web based authoring tools for commenting, knowledge articulation and exertion by extracting metadata from both the annotated content and the annotation itself, and establishing ontological relation between them. The real-time discussion is used as a bridge to link collaborators and knowledge and motivate collaborators for knowledge sharing by building profiles for collaborators and knowledge (in the forms of content and annotation) during every discussion session, and establishing ontological relation between the collaborators and knowledge for the use of semantic content retrieval. The semantic content retrieval then utilizes the ontological relations constructed from the personalized annotation and real-time discussion for finding more relevant collaborators and knowledge.

Keywords

Ontology, semantic web services, metadata, annotation, collaborative learning

Introduction

Virtual learning communities (VLCs) are information technology based cyberspaces in which individual and groups of geographically dispersed learners and providers of knowledge to accomplish their goals of learning implement collaborative learning. They are designed information spaces which enable multi-authoring, using information in educational interactions, indicating information source, maintaining information, structuring information and adding meta-information, and sharing information among participants. VLCs have become growing initiatives during the past years for business organizations, educational institutions, and governments to pursue and mobilize knowledge via the Internet. The explosion in Web based technology leads to increasing volume and complexity of knowledge, which stimulates the proliferation of VLCs.

The literature of VLC demonstrates no agreement on what constitutes a virtual learning community. However, it has gained widespread acceptance that VLCs are knowledge based social entities where knowledge is the key to their success. An important activity in a VLC is the collaborative learning. Many VLCs strive to attract new members or encourage members to learn and to contribute knowledge. However, the knowledge per se does not assure the success of VLCs. It is the collaborative efforts made by the learners and collaborators to manage the knowledge, to enrich the knowledge reservoir, and to help each other accumulate their knowledge in their domain that is central to the continuous growth of the VLCs. As Leonard (1995) indicates, valuable knowledge collects in individuals' head and is embodied in machines, software, and routine processes. The participants need to understand precisely what knowledge will fulfill their needs, and to keep this knowledge on the cutting edge, deploy it, leverage it in performing their tasks, and spread it across the community. 'People' is thus herein considered as the second key element in VLCs.

The nature of the collaborative learning involves intensive interactions and exertion of knowledge effect. It cannot be achieved without the capabilities of the participants to manage their knowledge. These capabilities include articulating knowledge into written, verbal or symbolic forms, authoring articles or posting messages to this community's discussion forum, responding or adding comments to messages or articles posted by others, etc. Knowledge collaborators' capabilities to provide knowledge and the motivation to collaborate in the learning process influence the quantity and quality of the knowledge to flow into the knowledge reservoirs, while knowledge learners' capabilities to locate the knowledge collaborators and requested knowledge impact the learning outcome. Lacking the capabilities will impede the interaction among the participants and may finally fails the collaborative learning. The process of learning in VLCs mostly requires collaboration. However, if some piece of knowledge is ignored by most learners, there is no way that this knowledge can be acquired by simply collaboration. The facility to link the two key elements –knowledge, people- together is critical to the success of collaborative learning. Web based technology tools in this sense become the third key element of VLCs by linking the related knowledge and the individuals who possess valuable knowledge together.

In this paper, we have developed an ontology enabled annotation and knowledge management to provide semantic web services from three perspectives, personalized annotation, real-time discussion, and semantic content retrieval. Personalized annotation is used to equip the collaborators with Web based authoring tools for commenting, knowledge articulation and exertion. Our system has enhanced conventional annotation system by extracting metadata from both the annotated content and the annotation itself, and establishing ontological relation between them; in addition, we utilize such ontological relation to find more related content from either the annotation or the annotated content. The real-time discussion is used as a bridge to link collaborators and knowledge and motivate collaborators for knowledge sharing. Our system has enhanced conventional discussion board by building profiles for collaborators and knowledge (in the forms of content and annotation) during every discussion session, and establishing ontological relation between the collaborators and knowledge for the use of semantic content retrieval. The semantic content retrieval then can utilize the ontological relations constructed from the personalized annotation and real-time discussion for finding more relevant collaborators and knowledge.

Knowledge Management in Collaborative Learning

Despite the respective importance of knowledge, people, and technology in facilitating collaborative learning in VLCs, none of them determines its success alone. Collaborative learning involves a series of knowledge based activities, and thereby requires effective management of knowledge of the shared reservoir. Arthur Andersen and APQC's (1996) report states that knowledge can be accumulated by using technology to integrate people and information, and sharing the information among individuals to spread it across the organization. Davenport and Prusak (1998) indicate: "technology alone won't make a person with expertise share it with others." McDermott's study (1999) concludes that information technology could inspire but could not deliver knowledge management. Coleman (1988) also points out "if you are looking at collaboration and knowledge sharing, try to deal with the people/culture issues, the hard stuff, first."

The information processing view of knowledge management has been prevalent in information systems (IS) practice and research over the last few decades (Malhotra, 2000). However, a VLC is not merely an information processing machine, but an entity that creates and defines problems, and then further develop new knowledge through action and interaction. Researchers and academics have taken different perspectives on knowledge management, ranging from technological solutions to the communities of practices, and the use of the best practices (Bhatt, 2001). Knowledge management shapes the interaction pattern between people and technology. It helps to organize and implement a VLC's learning process. While the dynamics of a VLC are numerous and complex, understanding the concept of knowledge management will be conducive to the construction of the collaborative learning environment.

There have been several efforts at developing frameworks of knowledge management (Holsapple and Joshi, 1999). Some celebrated models include Wigg's (1993) framework of knowledge management pillars, Choo's (1996) framework of the knowing organization, and van der Spek and Spijkervet's (1997) framework of knowledge management stages, Leonard's (1995) framework of core capabilities and knowledge building, and Arthur Andersen and APQC'smodel of organizational knowledge management. Each of them addresses certain KM elements; however, none of them appears to subsume all of the others (Holsapple and Joshi, 1999). Given that a VLC is a learning environment supported by information technology, and the effective knowledge management cannot be achieved without a supporting learning platform and learners' capabilities to execute the course of actions (e.g., share, create, apply) required to manage knowledge, this study integrates the frameworks proposed by Leonard and Arthur Andersen and APQC, which both accentuate the roles of people, knowledge, and technology in manipulating the KM process.

Leonard introduces a KM framework comprising four core capabilities and four knowledge-building activities. The four core capabilities identified in this framework are physical systems, employee skills and knowledge, managerial system, and values and norms. She classifies the skills and knowledge by how much they are codified and their transferability. Also, she contends that technological competence accumulates not only in the heads of people but also accumulates in the physical systems. Physical systems are the software, hardware, equipment, and accepted procedures that reservoir the structured and codified knowledge. Such systems may enhance individuals' temporary or long-lived advantage, depending on learners' adapting and absorbing capabilities. The four knowledge-building activities that surround the core capabilities are shared and creative problem solving, implementing and integrating new methodologies and tools, experimenting and prototyping, and importing and absorbing knowledge. Capabilities grow through the activities undertaken by individuals. As Leonard stresses: "a core technological capability is a system partly comprising technical competencies in the form of: people's skills and the knowledge embedded in physical system".

Arthur Andersen and APQC propose a model of knowledge management which comprises two parts: KM processes and the enablers that facilitate the workings of the KM processes: The seven KM processes includes create, identify, collect, adapt, organize, apply, and share, while the four interrelated enablers are technology, measure, leadership, and culture. Technology and performance measure propel the operation of the seven processes to accelerate the knowledge collection, properly adapt and apply the knowledge, and allow people to retrieve the knowledge in a cost-effective way. Leadership and culture, however, deal with people issues. These two enablers facilitate not only the understanding of the task/job definition, the required knowledge in each stage of the work routines, and the methodology to apply the right knowledge in the right stage, but also the motivation for contributing, learning and continuous change for improvement. Each of the seven KM processes relates to each other and is influenced by the four enablers. The synergy of the four enablers and the seven processes will be the effective knowledge management, which in turn lead to value creation of the whole team.

Annotation in Knowledge Management

W3C defined annotation as comments, notes, explanations, or other types of external remarks, which attached to a Web document or a selected part of the document in Amaya project (2003). According to Euzenat (2002) mentioned, an annotation is the content represented in a formal language and attached to the document. Campbell (2002) addressed that annotation provides commentary on information objects at other times and usually by others people. It facilitates the access and use of information on World Wide Web. Aiken, Thomas and Schennum (1976) pointed out material that was in a learner's notes were twice as likely to be recalled as material that was not in the learner's notes. Shimmerlick and Nolan (1976) mentioned the group who took reorganized notes recalled more of the passage on an immediate test than the sequential notes group as well as on a delayed test given one week later. In addition, the result shows that the effects of reorganizing note taking were particularly strong for students who were not above average in verbal ability. Based on mentioned studied, annotation is an important learning reference, which supplement and enhance the acknowledgment of course content. IIes, Glaser, Kam, and Canny (2003) proposed a shared whiteboard system running on wireless handheld device. Anselm (2002) proposed a visual interface to index and allows people using their handwriting note or text notes to retrieve and share specific media component. Annotation can benefit learning in the following categories:

1. Attention: help students to focus on annotated concept or specified sentence.
2. Discussion: help students to discuss assignment based on each one's aspect in an efficient manner.

3. Organization: help student construct his own knowledge based on annotations, remind him the important concepts.
4. Indexing: using bookmark to indicate the annotated objects, using anchor to bind the annotation to annotated object, facilitating the personalized knowledge discovery in view of information retrieval.

For a specific content, people may have a variety of comment. Experienced people, likes experts, senior engineers, or managers, write down their opinions, which are valuable to improve overall performance. It is very important to respect, preserve and share other people's viewpoints. In this paper, we called these viewpoints as "personalized annotation". How to efficiently and effectively manage personalized annotation is a challenging and must need problems.

Euzenat (2002) pointed out annotation need to be close relation with it use. In his study, ontology, background knowledge and annotation enable the reconstruction of content. It provides a methodology of annotating with formal content. The behaviors of sharing annotation are discussed in Sannomiya's (2001) study, such as writing annotation, browsing annotation and feedback. In past decade, several metadata schemas have been proposed to describe learning content, such as Dublin Core (DCMI, 2004), Learning Object Metadata (LOM, 2004), and Shareable Content Object Reference Model (SCORM, 2004). These metadata schemas are designed to provide semantic information adhered to E-document. User can use this information to retrieve related learning resource. In 2001, W3C has proposed web-based shared annotation system based on a general-purpose open RDF infrastructure, called Annotea (Kahan, 2001). User can use Amaya to browse content and make annotation through Annotea. This annotation can be stored either in annotation severs or in local end. To associate annotation with content, Annotea use XPointer technology to insert annotation position within XML document. It implies initial state of content modified, after adding annotation. Due to the maintenance of linking relations, XPointer is suitable for static documents, but not for frequently changed document. A "pencil-icon" appeared to indicate an annotation existed. To sharing others annotation, Annotea provides discussing-board like mechanism to let people review others opinion. A specific querying request service is not supported. Microsoft has published OneNote (2001), which is a personalized annotation system. User can choose pen, keyboard or voice to input his annotation. The note or annotation is shared only by e-mail. This limits the usage of annotation.

One purpose of the semantic Web services is to improve content retrieval by automating computers to read and understand digital content resources such as MS word, PowerPoint, Adobe PDF, HTML, XHTML, SMIL, which are all referred to e-document in this paper. To facilitate the use of computing process, personal annotation should be established in a machine readable format and closely related to the annotated object (could be sentence, paragraph or picture). There are three major issues on annotation management; the first issue is the annotation anchoring which address how to increase the precision of annotation's spatial position with respect to the annotated objects. The second issue is the personalized annotation which addresses how to distinguish annotation's belonging and retrieval the right annotation when multiple collaborators are making annotations in a same e-document. The third issue is the semantic annotation retrieval which addresses how to find more related annotated objects, annotations, and collaborators. Take an annotation "OWL-S" for example, we can find more annotations and their annotated objects related to this "OWL-S" and the collaborators who made the annotations, as well as the e-document and the authors encompass the annotated objects.

Personalized Annotation Management

We have developed a personalized annotation management (PAM), which consists of four functional modules, and three repositories as shown in Figure 1. The functional modules include Annotation Creation, Anchoring, Annotation Review, and Real-time Discussion Board. The e-documents, annotations, and semantic metadata are stored in e-document, annotation, and knowledge repositories, respectively. Users can retrieve e-document from e-document repository and write his annotation into Annotation Repository. Before e-document and Annotation stored into repositories, all the information will be parsed and classified into clusters based on extracted semantic in Knowledge Repository. When users request for an annotation through the "Annotation Review" module, system will computes the similarity of the requested annotation based on the semantic metadata stored in the knowledge repository and reply matched or partial matched results to users. Anchor mechanism provides the binding service to associate annotation with corresponding annotated objects. Through the Real-time Discussion Board, users can interchange their opinions by making and reviewing annotations online. The related discussion log is saved for further Web mining and user behavior analysis.

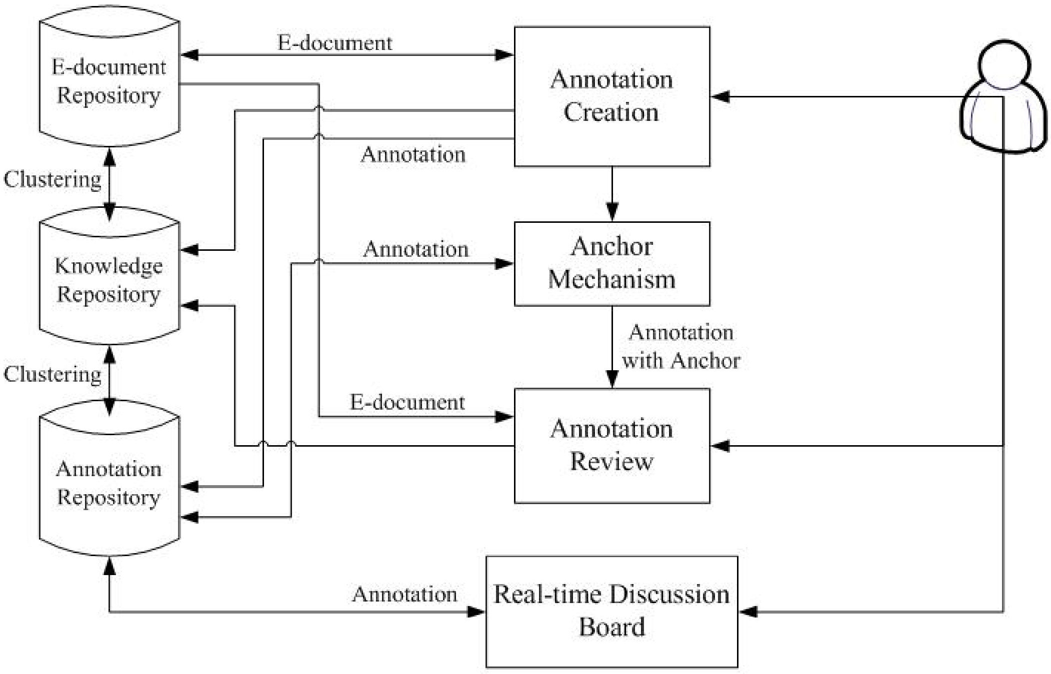

*Figure 1***.** Architecture of Personalized Annotation Management

We have developed two models to describe the two core objects in PAM, the content model for the annotated objects, and annotation model for the annotation.

Content Model

A content model is defined by a content profile and a content process model. A content profile consists of three metadata to describe e-documents in html format. The three metadata are core metadata, structural metadata, and behavioral metadata. The relationship of the three metadata is depicted in Figure 2.

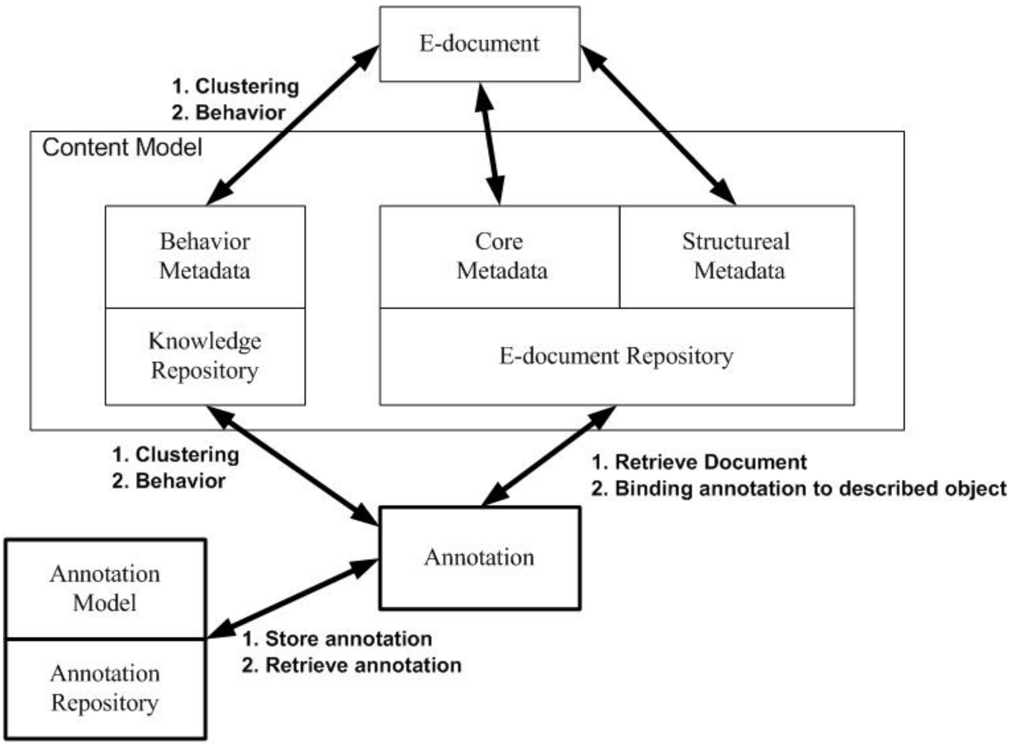

Figure 2. Using content model to describe resources of e-document

Core metadata contains 13 attributes to describe primitive attributes of an e-document. The 13 attributes are described as follows:

Attributes	**Description**
Document_Title	e-document's title
Document_Description	topic of the e-document
Document_Creator	entity for making the content of the resource
Document_Identifier	account of the content of the resource
Document_Publisher	entity responsible for making the resource available
Document_Date	date of an event in the lifecycle of the resource
Document_Content_URI	reference to a resource from which the present resource derived
Document_Type	nature or genre of the content of the resource
Document_Structure	reference with decomposed objects of present resource
Document_Format	physical or digital manifestation of the resource
Document_Language	language of the intellectual content of the resource
Document_Relation	reference to a related resource
Document_Annotation_ID	reference with related annotation of present resource

Structural metadata contains five attributes to describe the structural properties of the objects encompassed in an e-document. The five attributes are described as follows:

Attributes	**Description**
Object_ID	identifier of each object
Object_Type	type of object, likes text, image, audio
PreObject	object in front of the annotated object
SucObject	object successive to the annotated object
Document_Identifier	identifier of corresponding e-document

Behavioral metadata contains three attributes to describe the behavioral relationship such as inter-document relationship, inter-annotations relationship, and inter-document-and-annotation relationship.

Attributes	**Description**
Inter_Document_relation	describe the similar semantic cluster derived from document in ontology-based aspect
Inter_Annotation_relation	describe the similar semantic cluster derived from annotated document in personal aspect
Inter_Document_annotation_relation	describe implied relations from annotation cluster to document cluster or vice versa

All kinds of e-documents, such as HTML, WORD, PowerPoint, etc, can be represented in markup languages by content model. In this paper, we emphasize personalized annotation management and exploit the relation with E-document.

Content process model defines processes for serving the Web content described by the content profile. In this model, service process can be classified as atomic process and composite process. An atomic process is the most primitive building block for providing content service. Composite process is a combination of several atomic processes.

Annotation Model

Annotation management must provide annotation retrieval besides annotation creation and browsing. Therefore, in addition to using content model to describe the annotated e-documents, we also need an annotation model to describe the annotation itself.

Annotation Model ($AM_{u,i}$, where *u* represents annotator and *i* indicates Annotation_ID) contains eight attributes to describe the primitive properties of the annotations encompassed in an e-document. The eight attributes are described as follows:

Attributes	Description
Annotation_ID	unique identifier of an annotation
Annotation_Name	name of the annotation
Annotation_Type	indicates types of annotations such as commentary, question, explanation, bookmark, sketch, drawing, and link
Annotation_Format	indicates formats of annotation such as text, graph, and voice
Annotation_INK	reference to annotator's handwriting
Annotation_Description	describes the context of the annotation
Annotator	indicates the author of the annotation
Anchor_Position	contains the anchoring position of the annotation in the e-document

Ontological Relation between Content and Annotation

There are two important ontological relations between annotation and the annotated e-document as shown in Figure 3, which we can derive from annotation creation and annotation anchoring. One is an association relation to associate an annotation to its annotated object. The other is a spatial relation to place an annotation to its annotated object's position in an e-document. Based on the association and spatial relations, we have developed an anchoring process as follows:

1. Retrieve structural metadata (SM_I) of the annotated e-document (Document_Content_URI in CM_I)
2. Specify the desired annotated object (Object_ID in SM_I)
3. Compute anchor position which consists of a start and a stop position of the anchor (Anchor_Position of $AM_{u,i}$) based on specified object (Object_ID).
4. Write down the note (Annotation_INK) via Annotation pad.
5. Recognize handwriting note (Annotation_INK) as digitalized text format (Annotation_Description)
6. Store handwriting and recognize text information with anchor position, i.e. established Annotation Model established ($AM_{u,i}$)

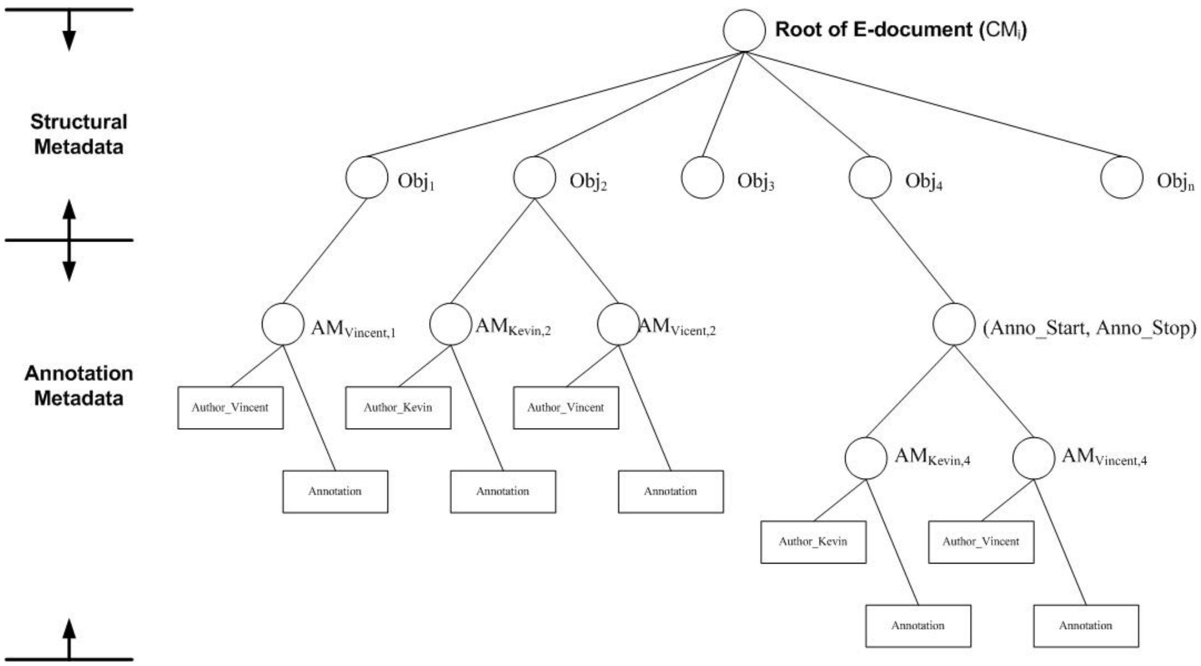

Figure 3. Ontological tree denoting relation between annotation and e-document

This anchor's position is added to XSL file, which support the styling function. With XSL technology, annotation can be invoked and incorporated into e-document during browsing without modified to the original copy. In this way, the separated annotation and e-document can be merged as user requests. In addition, we apply content adaptation techniques to this XSL-based anchoring mechanism and make anchors and the annotated annotation displayed adaptively depends in which types of devices are used for annotation browsing.

Annotation Creation and Storage

Annotation as shown in Figure 4 can be created by either a single user or multiple users to annotate specified objects in an e-document.

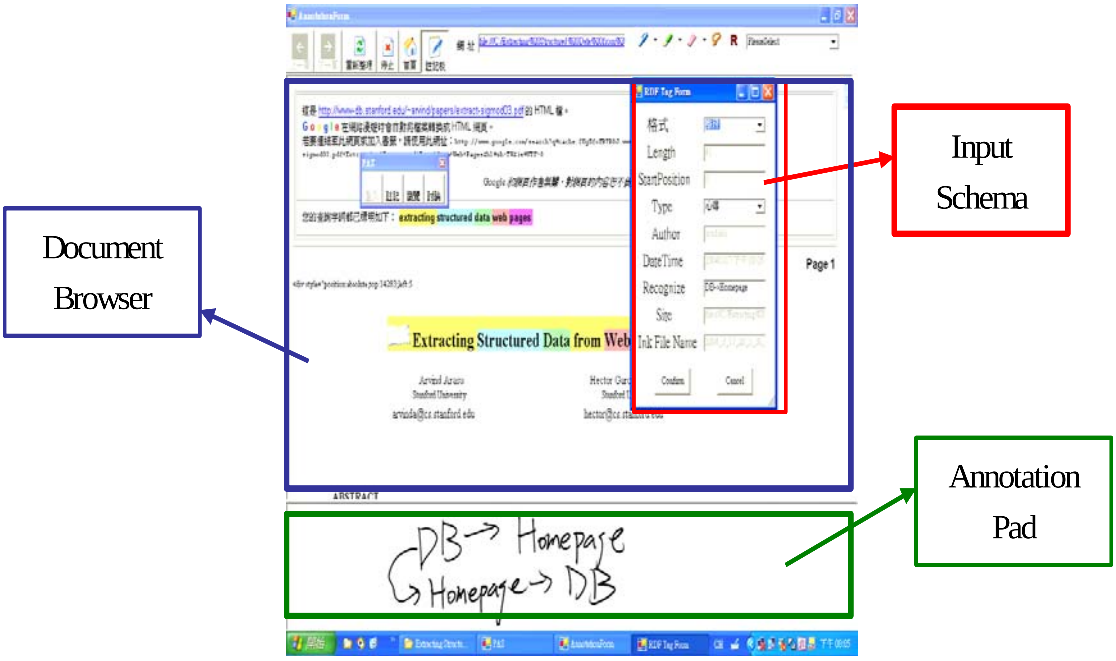

Figure 4. Annotation Editor

For the case of a single user annotates a specified object, likes subtitle, paragraph or image. Let an e-document has been interpreted by content model, denoted as CM_i. A user annotated a specified object in this e-document via annotation model $AM_{u,i}$. This annotation could be bound to a specified object in the e-document by means of object and e-document identifier. For example, in Figure 3, the ontological relation between $AM_{Vincent,1}$ with Obj_1 depicts this case. For the case of multiple users annotate on a same object. Let user A and B annotated on a same specified object in an e-document denoted as CM_i via two annotation model $AM_{a,i}$ and $AM_{b,i,}$ respectively. This annotation could be bound to the specified annotated object in this e-document by means of object, e-document identifier, and annotator. For example, in Figure 3, the ontological relations between $AM_{Kevin,2}$ and $AM_{Vincent,2}$ with Obj_2 depict this case. For the case of semantic clustering of annotations, we have developed a clustering mechanism and based on the attribute Annotation_Description of $AM_{u,I}$ to compute annotation's similarity in terms of semantic meaning and categorize them into related clusters. The result of annotation clustering is that we can establish inter-relation between annotations, which can be saved as behavior metadata in content model. Similarly, we can cluster e-document and establish the inter-relation among e-documents. These relations of inter-annotation and inter-E-document can be represented in a term-document matrix format as shown in Table 1. From Table 1, we found that annotation $AM_{x,070}$ is related to $AM_{y,090}$ through term "mobile learning". When users review the annotations associated to an e-document CM_{090}, they can further search for additional annotation related to "mobile device", and through this, they can find more related e-document about "mobile device".

Table 1. Term–Document Matrix

Cluster $_i$	$AM_{Bormida,070}$	$AM_{Sharples,070}$	$AM_{jones,070}$	$AM_{Bijorn,090}$	$AM_{Sutinen,090}$	…	$AM_{Smordal,100}$
personalized metadata	1	1	1				
adaptive mobile learning	1	1	1	1	1		
mobile learning	1	1	1	1	1		
multi-sensory learning				1	1		
pervasive learning				1	1		
mobile devices	1		1	1	1		
handhold devices				1	1		1
…							

Figure 5 shows the relations among annotations and e-documents. The annotations described by annotation model (*AM*) are stored in annotation repository, the e-documents described by content model (*CM*) are stored in e-document repository, and the relation among *AM* and *CM* are stored in knowledge repository. Although user can trace e-document by means of corresponding annotations and vice versa, there are some other useful information need to be exploited. In author's perspective, the relations among annotations and the corresponding annotated e-documents imply personalized knowledge which is associated with semantic knowledge. Therefore, during information retrieving process, the searching scope could be extended or restricted by reasoning the knowledge repository to improve the search performance.

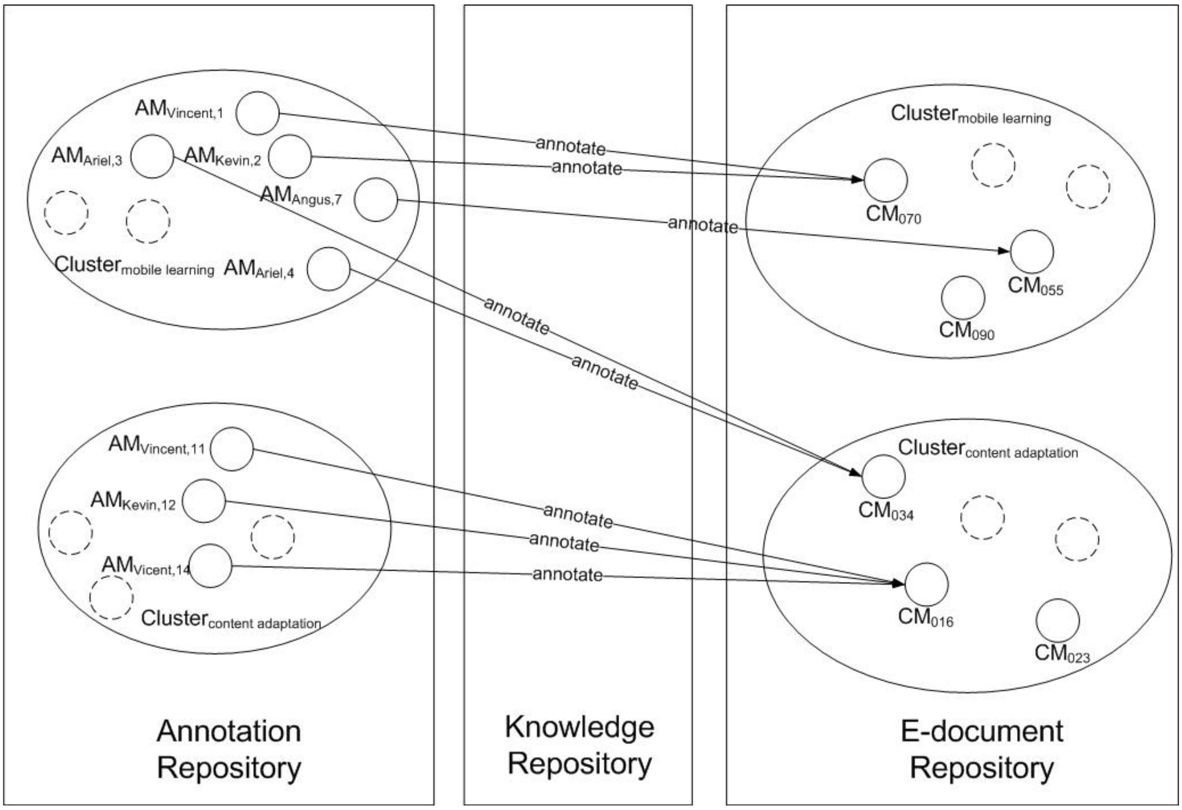

Figure 5. an example of relations among annotations ($AM_{i,j}$) and e-document (CM_k)

Real-Time Group Discussion

Let various collaborators are gathering and making their annotations regarding a specific subject via a real-time discussion board as shown in Figure 6, if we put all the annotations made by various collaborators in the same content model, the individual aspect of each collaborator might be ignored or simply lost. Besides, sharing individual's annotation to the public is a violation of privacy. Therefore, our approach is to gather all collaborators' annotations to establish a group annotation representing the group's aspect regarding the discussion subject.

For the case of group discussion, let members of a discussion group can review all the annotations made by the others denoted by $AM_{u,i}$, where $u = 1,..m$, and let the annotated e-document denoted as CM_i. Based on our anchoring mechanism, these annotations made by the same group can be aggregated, organized and displayed as a group annotation denoted by $AM_{m+1,\, i+1}$, and associated with the annotated e-document, CM_i.

Semantic Content Retrieval

We classify all annotation models and content models into clusters based on concepts which can be inference to be semantically similar. For example, OWL and OWL-S are classified in the same cluster with concept "semantic Web" since they are both ontology for describing semantic web services. Based on the clustering and ontological relation between annotation model and content model, we can extend a conventional search to a semantic search as follows:

1. User input query, system will identify the query (q_i)
2. Computing the similarity between query and concept of clusters, and determine possible cluster,
3. Confine search domain to possible clusters in annotation repository,
   (1) Compute the similarity between each query (q_i) with each annotation model ($AM_{u,j}$)
   (2) Assign a repository weight (w_{anno}, for example 0.6) to corresponding result ($AM_{u,j}$),
   (3) Rank all candidates based on weighted similarity ($w_{anno} \times AM_{u,j}$).
4. Confine search domain to possible clusters in e-document repository,
   (1) Compute the similarity between each query (q_i) with each e-document, content model (CM_j)
   (2) Assign a repository weight (w_{docu}, for example 0.4) to corresponding result (CM_j),
   (3) Rank all candidates based on weighted similarity ($w_{docu} \times CM_j$).
5. Rate the matched results from annotation and e-document repository. When weighted a similarity ($w_{anno} \times AM_{u,j}$ and $w_{docu} \times CM_j$) is great than a predefined threshold (TH_{basic}), then
   (1) Case 1: If the weighted similarity ($w_{anno} \times AM_{u,j}$ and $w_{docu} \times CM_j$) directs to same e-document, then assigned extra weight to this weighted similarity ($1.5 \times w_{anno} \times AM_{u,j}$ or $1.5 \times w_{docu} \times CM_j$).
   (2) Case 2: If the weighted similarity ($w_{anno} \times AM_{u,j}$ and $w_{docu} \times CM_j$) directs to different e-document, then no extra weight will be assigned.
   (3) re-arrange the sequence of e-document base on the result of weighted similarity, and then reply to user for selection
6. If there is no qualified candidates to reply to user, system will ask user refine input query.

For example, according to clustering theorem, all e-documents in same cluster are similar in semantic level. Same case applied to annotation. From Figure 5, tracing annotations in $Cluster_{mobile\_learning}$, it can be found that $Cluster_{mobile\_learning}$ and $Cluster_{content\_adaption}$ in e-document repository are related.

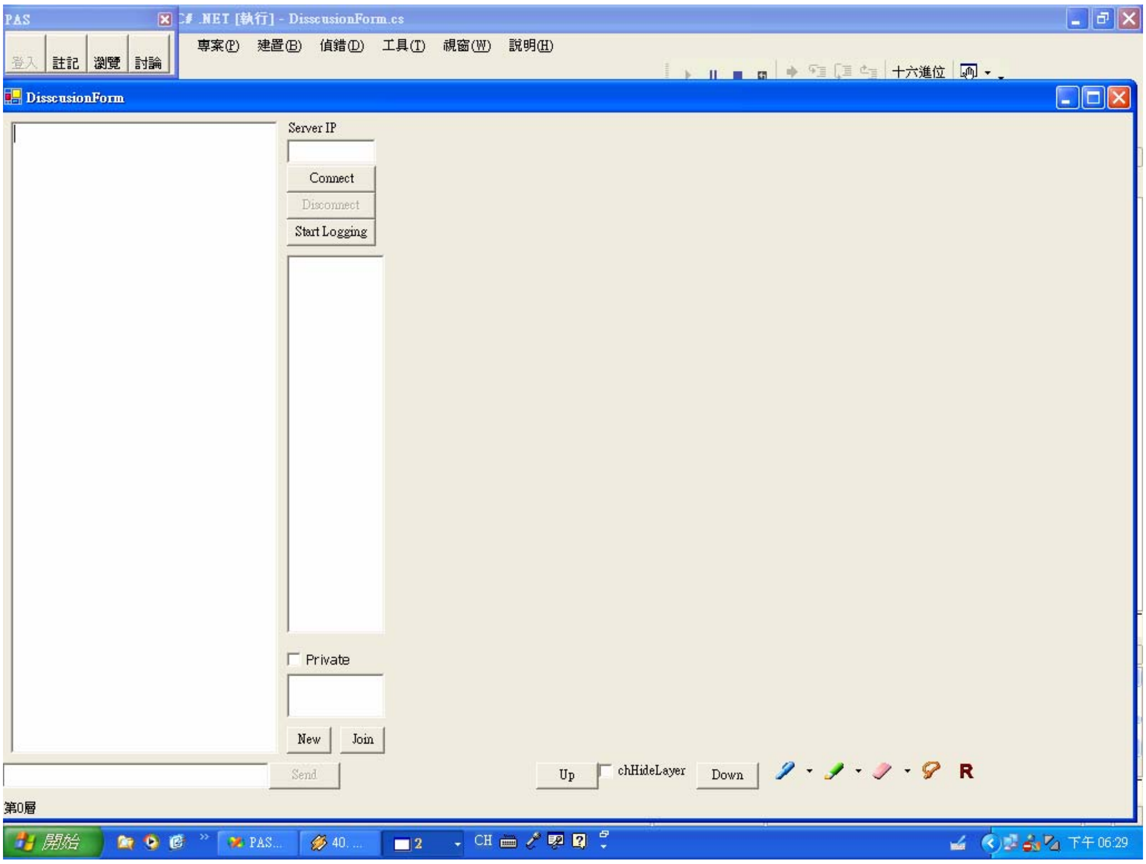

Figure 6. A Real-time group discussion board

Conclusion and future Research

In this paper, we have proposed two metadata models, content model and annotation model to formally describe content and annotation, respectively. In addition to utilizing the two models to formally describe content and annotation, we also derived ontological relation between the two models to lift the two models from syntax to semantic level. We have built an ontology enabled annotation and knowledge management system to demonstrate our ideas. The system not only provides annotation creation and clustering for annotation and knowledge management, but also provides real-time discussion for collaborative learning, and a query-by-annotation for semantic search. In our future research, we will enhance the current system to be universal access that is to make the annotation creation and browsing through various devices, to make the real-time discussion mobilized, and make the semantic search more context awareness to meet the collaborator's need by extending the knowledge repository with additional user profiles, device profile, and service profiles.

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