Supporting Personal Semantic Annotations in P2P Semantic Wikis

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Abstract. In this paper, we propose to extend Peer-to-Peer Semantic Wikis with personal semantic annotations. Semantic Wikis are one of the most successful Semantic Web applications. In semantic wikis, wikis pages are annotated with semantic data to facilitate the navigation, information retrieving and ontology emerging. Semantic data represents the shared knowledge base which describes the common understanding of the community. However, in a collaborative knowledge building process the knowledge is basically created by individuals who are involved in a social process. Therefore, it is fundamental to support personal knowledge building in a differentiated way. Currently there are no available semantic wikis that support both personal and shared understandings. In order to overcome this problem, we propose a P2P collaborative knowledge building process and extend semantic wikis with personal annotations facilities to express personal understanding. In this paper, we detail the personal semantic annotation model and show its implementation in P2P semantic wikis. We also detail an evaluation study which shows that personal annotations demand less cognitive efforts than semantic data and are very useful to enrich the shared knowledge base.

1   Introduction

Semantic Wikis [1,2,3,4] are one of the most successful Semantic Web applications. They are widely used for collaborative knowledge building. In semantic wikis [1,3], wikis pages are annotated with semantic data to facilitate the navigation, the information retrieving and ontology emerging. Semantic data represents the shared knowledge base which describes the common understanding of the community. The knowledge base is built collaboratively through an iterative and social process.

However, collaborative knowledge building is basically a spiraled process where knowledge first emerges at individual context and then is socialized [5,6]. This process [7,6] involves *externalization*, *publication*, *internalization* and *reaction*. Most of semantic wikis only support the knowledge socialization, but it is

fundamental to support personal knowledge building too [8]. Personal Semantic Wikis [8,9] provide an easy way to manage personal knowledge often without collaborative functionality. However, to carry out a collaborative knowledge building activity, user needs to manage and combine both shared and personal knowledge.

Existing collaborative knowledge building systems support partially or completely this process. For instance, [10,11,12] are collaborative knowledge building systems, however, they are more oriented towards collaborative ontology development rather than ontology emerging. Other systems like semantic wikis [1,2,3,4,8] are more appropriate to support collaborative knowledge emerging, however, they do not provide functionalities to manage combined personal and shared understandings. For example, Semantic MediaWiki (SMW) only enables shared knowledge building. On the other hand, SemperWiki [9] only supports personal knowledge building. Currently, there are no semantic wikis that help people to combine and manage in a usable way both kind of knowledge.

The goal of this work is to propose an innovative semantic wiki approach that supports both personal and shared knowledge building. In this approach, the shared knowledge is unique and accessible to everyone, while the personal knowledge is only accessible by its owner and represents the user private view (perspective) of the shared one. Personal knowledge can differ from the shared one, but it can also have overlapped parts.

For the emerging of shared knowledge, we follow the same approach as SMW where *shared semantic annotations* are embedded in the wiki text by using a suitable syntax. For the personal knowledge, we propose *Personal Semantic Annotations* to externalize personal understanding. *Personal semantic annotations* are associated to the wiki page and they are only accessed by the owner user. For the end-user, the *personal semantic annotations* look like *tags*, however they are semantically richer: they support categories and individuals.

We believe that the addition of *Personal Semantic Annotations* to semantic wikis enables:

− To support the individual understanding in the collaborative knowledge building process [6]
− To provide personalized knowledge retrieving, structuring and navigation.
− To enable a combined personal and shared knowledge retrieving.
− To enrich the shared semantic annotations and to augment, therefore, the shared knowledge base.

Moreover, adding personal semantic annotations and shared ones involve complementary activities. Whereas adding a shared semantic annotation seems to be suitable during editing activity, adding a personal one seems to be more suitable during browsing activity. In order to validate these hypothesis, we have conducted an evaluation study.

In this paper, we introduce a peer to peer semantic wiki called *P-Swooki* that supports both personal and shared knowledge building. *P-Swooki* extends a peer-to-peer semantic wiki Swooki [3] by adding personal knowledge building.

We choose to validate our approach in a peer to peer semantic wiki because in a P2P architecture information dissemination is easily controlled *i.e.* shared annotations are broadcasted and integrated by all peers while personal semantic annotations remain local.

The paper is organized as follows. The next section 2 gives a brief background about collaborative knowledge building process. Section 3 introduces a P2P collaborative knowledge building process and discusses the personal annotations problematic. Sections 4 and 5 present the implementation and architecture of *P-Swooki*. Section 6 details a usage study which shows that personal annotations demand less cognitive efforts than the shared one and they are very useful to enrich the shared knowledge base. The last section concludes the paper and points further works.

2   Background: Collaborative Knowledge Building

The majority of works on knowledge management focus on *organizational knowledge management* [13,14]. Many of them follow the traditional KM approach [5] to creates large centralized knowledge repositories, in which corporate knowledge is collected, represented and organized, according to a single - shared - conceptual schema [15]. In [16], the authors noted that *"This centralized approach -and its underling objectivist epistemology- is one of the reasons why so many KM systems are deserted by users"*. In [13,16], the authors propose a P2P organizational knowledge management in order to make organizational memory more flexible. However, this approach is more suitable to *knowledge discovery and propagation* rather than collaborative and personal knowledge building.

Collaborative knowledge building focuses on understanding as a learning process where personal understanding can not be built internally without social interaction. People need to participate in a social process and create new knowledge collaboratively. Gerry Stahl in [6] proposes a conceptual collaborative knowledge building model which shows the *"mutual constitution of the individual and the social knowledge building as a learning process"*, as depicted in the figure 1. This process should be adapted to the P2P semantic wikis context.

Stahl's process starts with the description of the *personal understanding* by specifying personal beliefs, which are tacit. Then, they can be articulated in a *"language"* and enters into a social process of interaction with other people and their shared understanding. Later, this shared knowledge enters again in the personal understanding and provokes a change in personal beliefs, motivations and concerns. When this happens, these modifications become a new tacit understanding and will be the new starting point for future understanding and further learning. In [7], the authors reinterpreted this process and proposed a four steps spiral process for centralized knowledge sharing.

− knowledge *externalization* where knowledge goes from tacit to explicit. This is an individual activity.

− Knowledge *publication* where the knowledge goes from individual context to share context. This produces a new shared knowledge contribution.

– Knowledge *internalization* where knowledge goes from explicit to tacit and from the shared to the individual context.

– *Reaction* is the act of opening a discussion and argumentation linked to previous shared contribution to achieve a consensus. A reaction always involves a externalizations and an eventual publication.

In this work, we will adapt the simplified version of Stahl's process to the context of P2P semantic wikis.
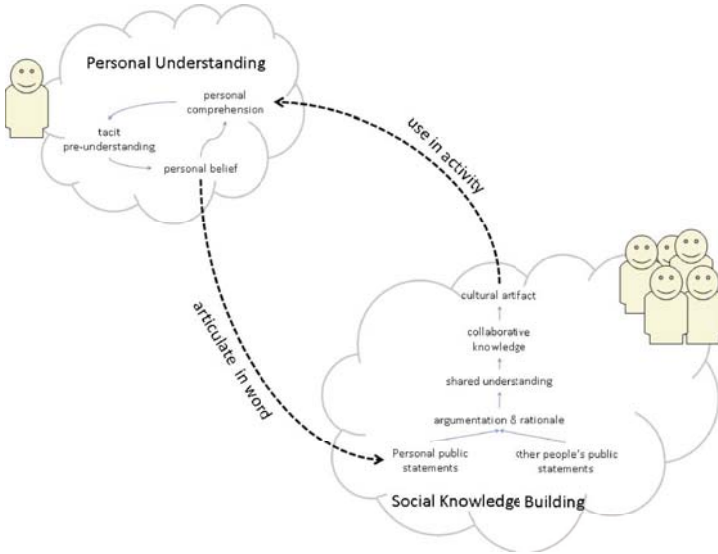

Fig. 1. Stahl's Collaborative Knowledge Building Process

3   P2P Collaborative Knowledge Building Approach

In this work, we extend P2P semantic wikis by supporting personal understanding building. In addition to shared semantic annotations embedded in the wiki text, users can also associate *personal semantic annotations* to semantic wiki pages. These private annotations express personal understanding of the users. For example, if a user was navigating to the semantic wiki page "Semantic Wiki" as it is shown in the figure 2, eventually, she would like to annotate this page as "Collaborative Tool", "Web" and "Semantic Wiki". If these annotations only express personal understanding, they should be private. Other annotations as "Semantic Web" or "Wiki" are shared, they could be defined by the same user or by other users. We can notice that users manage simultaneously both shared and personal semantic annotations.

We adapt the collaborative knowledge building process to P2P settings as it is detailed in the next section.
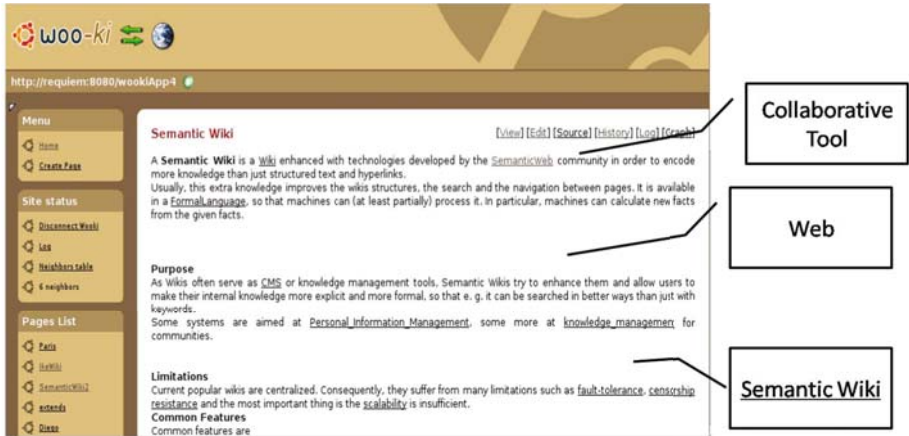
Fig. 2. Adding Personal Semantic Annotation in Semantic Wiki

3.1   P2P Collaborative Knowledge Building Process

A P2P collaborative knowledge building process is a continuous spiraled process which involves *externalization*, *publication*, *internalization* and *reaction*, where externalization and publications steps had to be redefined to support P2P settings. Internalization and Reactions are not modified.

Besides, users manage in a well-differentiated way both, personal and shared understandings. Every user needs to manage in separated spaces the personal and shared annotations. We define two repositories: the *personal understanding repository* and the *shared understanding repository* respectively. In a P2P setting, we consider that every user works in one peer and has both repositories. The *shared understanding repositories* will be eventually identical for all users due to the synchronization algorithms [17].

Our P2P collaborative knowledge building process redefines the externalization and publications steps as:

– *Externalization* where personal knowledge goes from tacit to explicit. Users use personal semantic annotations to externalize their own knowledge. This is an individual activity, this knowledge remains private in the context of the personal understanding space.

– *Publication* where the knowledge goes from the individual context to the shared one. As a result, a personal semantic annotation becomes a shared one. In other words, this involves to move a personal semantic annotation from a given user's personal understanding repository to the shared one. This step involves to replicate the annotation to every user as a shared annotation.

For example, in the figure 3 the "user1" externalizes "Collaborative Tool" personal annotation on her personal repository. Then, when she performs a publication this personal annotation should be disseminated to every user, even

to herself. After the publication, the semantic annotation "Collaborative Tool" should appear in every shared understanding repository as a shared annotation.

Consequently, personal understanding building is achieved by supporting the separation of both knowledge repositories (personal and shared) and the externalization step.
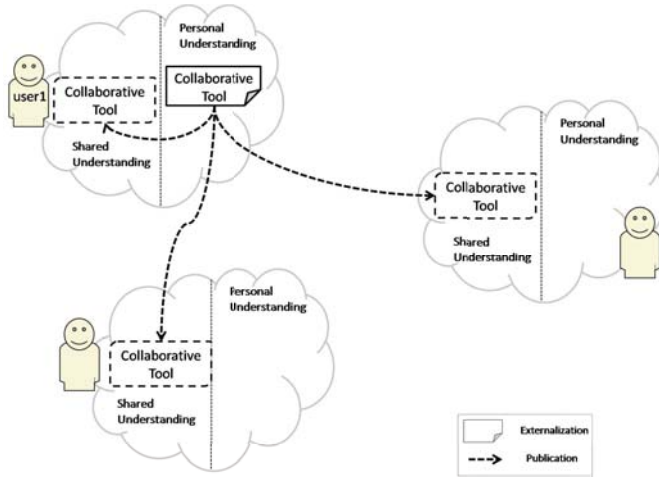

Fig. 3. P2P Collaborative Knowledge Building Process

This P2P collaborative knowledge building approach has several advantages:

− *Personal navigation*: the system allows the users to have simultaneously personal and shared navigation on the the same content. Shared navigation is the traditional navigation supported by any semantic wiki. Personal navigation is a new kind of navigation, it is personal and it is the consequence of the personal semantic annotations. The user has an instant gratification after adding personal semantic annotations.

− *Enrichment of shared knowledge*: the user can make public her personal semantic annotations. Consequently, the shared knowledge is enriched.

− *Improve system usability*: adding shared semantic annotations and personal semantic ones involves complementary activities. Whereas adding shared semantic annotations seems to be suitable during the editing activity, adding personal annotations seems to be more suitable during reading activity.

3.2   Personal Semantic Annotations: Individuals and Categories

Every semantic wiki page could be tagged with several personal semantic annotations as it was shown above. A personal semantic annotation can be a *category* or an *individual*.

Categories define a family of elements. For example, in the previous example (figure 2), the annotation "Semantic Wiki" was underlined in order to indicate that this wiki page is a *Semantic Wiki category definition*.

Individuals denote elements that fall at least in one category. *Semantic Mediawiki* is an individual that fall in the category Semantic Wiki. An Individual can belong to many categories.

A semantic wiki page can be annotated with many annotations. For example, a user personally would like to annotate the wiki page "Swooki" as a "Semantic Wiki" and as "P2P application".

Currently, the annotation model is simple, it only considers categories and individuals. In the near future, we will enrich it in order to support relationships and attributes.

4 P-Swooki: P2P Collaborative Knowledge Building System

We have developed *P-Swooki*, a P2P collaborative knowledge building system that extends the P2P semantic wiki *Swooki* with personal semantic annotations.

Shared semantic annotations are already supported by *Swooki* as detailed in the section 4.1. Therefore, we had only to add personal annotations functionalities to Swooki. In sections 4.2, 4.3 and 4.5, we detail the personal annotations management, the data model and its associated operations.

4.1 Shared Semantic Annotation Management

In Swooki every peer hosts a copy of all wiki pages and the *shared understanding repository*. When a peer updates its local copy of data, it generates a corresponding operation. This operation is processed in four steps:

1. It is executed immediately against the local replica of the peer,
2. it is broadcasted through the P2P network to all other peers,
3. It is received by the other peers,
4. it is integrated to their local replica. If needed, the integration process merges this modification with concurrent ones, generated either locally or received from a remote server.

To synchronize data, Swooki [18] implements a modified version of the P2P synchronization algorithm detailed in [17]. Swooki synchronization algorithm ensures the convergence on the wiki text and the *shared understanding repository* i.e. when the system is idle, all copies are identical.

4.2 Personal Semantic Annotations Management

In *P-Swooki*, personal semantic annotations are hosted locally. When a user updates her personal semantic annotations, she generates a corresponding operation. The operation is executed locally against the user *personal understanding repository*. This operation is *not* broadcasted to other peers.

The process to annotate a wiki page is simple as it was explained above. The system enables users to annotate a wiki page as a new *category* or as an *individual* of an existing category.

In order to handle personal semantic annotations, we extended Swooki's data model and defined new editing operations.

4.3 P-Swooki Data Model

The data model is an extension of Swooki [18,19] data model. Therefore, each semantic wiki peer has assigned a global unique identifier named $NodeID$.

As in any wiki system, the basic element is a wiki page, therefore every wiki page has assigned a unique identifier $PageID$, which is the name of the page. The name is set the page is created. If several servers create concurrently pages under the same name, their content will be directly merged by the synchronization algorithm. Notice that a URI can be used to unambiguously identify the concept described in the page. The URI must be global and location independent in order to ensure load balancing. For the sake of simplicity, in this paper, we use a string as page identifier.

The figure 4 describes the personal semantic annotations data model. This data model is described by the Ontology Definition Meta-model (ODM) [20].
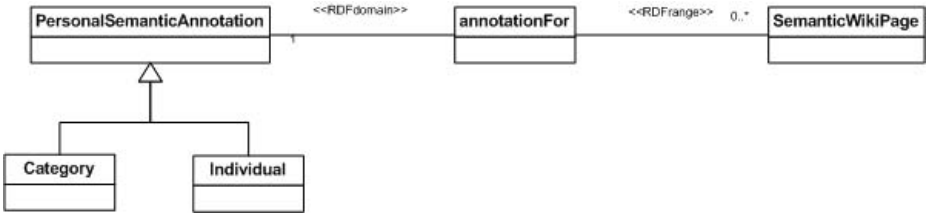

Fig. 4. Personal Semantic Annotation Data Model

4.4 Personal Semantic Annotation Storage Model

RDF is the standard data model for encoding semantic data. In P-Swooki, every peer has two local RDF repositories : *Personal Statements* and *Shared Statements*. They implement the *personal understanding repository* and the *shared understanding repository* respectively.

– The *Shared Statements* contains a set of RDF statements which were extracted from the wikis pages. A statement is defined as a triple (Subject, Predicate, Object) where the subject is the name of the page, the predicates (or properties) and the objects are related to the concept involved in the page.

– The *Personal Statements* contains personal semantic annotations which are represented as personal RDF statements. A personal RDF statement is defined as a triple (Subject, Predicate, Object) where the subject is the wiki page and

the predicate annotates the page as a personal semantic annotation type as described in the next section.

We define two operations on the RDF repositories:

– insertRDF(R,t): adds a statement t to the *Personal Statements* or *Shared Statements* repository R.
– deleteRDF(R,t): deletes a statement t from the *Personal Statements* or *Shared Statements* repository R.

These operations are not manipulated directly by the end-user, they are called implicitly by the editing operations as it is shown in the following section.

4.5   Editing Operations

There are four editing operations for editing personal semantic annotations: *addIndividual*, *addCategory*, *delIndividual* and *delCategory*. An update is considered as a delete of old value followed by an insert of a new value.

1. *addCategory(PageID, CategoryName)*: where $PageID$ is the identifier of the semantic wiki page. $CategoryName$ is the name of the new category.
This operation sets the wiki page $PageId$ as a category in the user personal repository. This operation calls the *insertRDF(Personal Statements,(PageId, RDF.Type, CategoryName))* function to add a new triplet into the personal RDF repository.

2. *addIndividual(PageID, CategoryName)*: sets the wiki page $PageID$ as a member of the category $CategoryName$. If $CategoryName$ does not exist, it is added automatically to the *Personal Statements* repository by calling the operation *addCategory* and then the operation automatically annotates the $PageId$ as member of the $CategoryName$.
During this operation an RDF statement is added to the personal repository by calling *insertRDF(Personal Statements, (PageId, belongsTo, CategoryName))* where *belongsTo* is a predicate to associate an individual to a category.

3. *delIndividual(PageID, CategoryName*: eliminates the $PageID$ as member of the category $CategoryName$ from the personal RDF repository by calling *DeleteRDF(Personal Statements, (PageId, RDF.Type, CategoryName))*.

4. *delCategory(PageID,CategoryName*: first, calls the *delIndividual* operation for each member of the category $CategoryName$, and then deletes the category $CategoryName$ from the personal RDF repository by calling the *DeleteRDF* operation.

5   *P-Swooki* Architecture

P-Swooki is implemented as an extension of Swooki. Swooki is a P2P semantic wiki which is implemented in Java as servlets in a Tomcat Server and uses Sesame 2.0 as RDF repository.

P-Swooki is developed over a Swooki architecture using one peer per user. A P-Swooki peer is compound by the following components (see figure 5). The
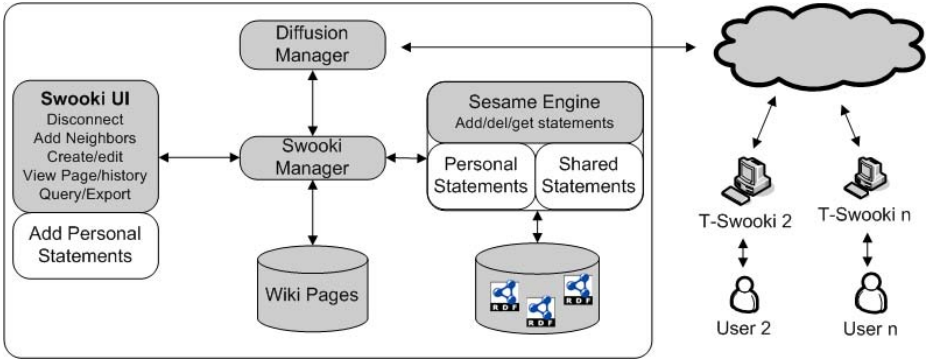
Fig. 5. P-Swooki Architecture

Fig. 6. P-Swooki Interface

grey boxes are Swooki components whereas the white ones are the P-Swooki components.

User Interface. The P-Swooki UI component is composed by the Swooki wiki editor and it incorporates the functionalities to make personal annotations. This basically divides the wiki page into two areas: the shared and private annotation spaces. The shared space is defined by a regular wiki editor supported by Swooki functionality. The private annotation one includes a box to add personal semantic annotations and to visualize them (see figure 6).

Swooki Manager. The Swooki manager implements the synchronizing algorithm.

Sesame Engine. We use a multi-set [18] extension of Sesame 2.0 [21] as RDF repository. Sesame is controlled by the Swooki manager for storing and retrieving

RDF statements. P-Swooki stores the private annotations using a different name space. This allows to reuse the storing and retrieving facilities already implemented by Swooki.

Diffusion Manager. The diffusion manager is in charge of maintaining the membership of the unstructured network and to implement a reliable broadcast for the shared repositories.

6   Evaluation

In this section, we present the evaluation of our approach. We have conducted two separate experiments, one in France and another one in Argentina. The total number of participants were 15 people. The participants ranged in age from 25 to 45. All participants were involved in computer science, all were familiar with wikis and 5 of them were familiar with semantic wikis and have some experience in ontology building. The participants were in different rooms and they were not allowed to communicate to each other during the experience.

We started the first experience in France by a short explanation about semantic wikis, shared knowledge and personal knowledge. We asked participants to develop a semantic wiki by using both kinds of annotations. They started with a non empty wiki. In fact, there were created in advance 2 semantic wikis pages; one about *Semantic Wiki* and another one about *Semantic Web*. We also suggested participants to use a special syntax in order to control vocabulary explosion as it occurs in folksonomies [22].

In order to consolidate the first experience, we have repeated the same experience in Argentina which confirmed the results previously obtained in France. These experiences show a preliminary evidence of the contribution of our approach regarding the usability of personal semantic annotations and their complementarity with the shared knowledge. In the following we show the results of these experiences. As both experiences showed the same outcome, we will only present the results from France.

The tables 1 and 2 show the type (individual or category) and the amount of personal semantic annotations that each each participant has added to the *Semantic Wiki* and *Semantic Web* wiki pages respectively.

The *Semantic Wiki* page was annotated by all the participants. They annotated this page as individual 17 times and as category 15 times. The most active participant added 11 personal semantic annotations to this page. The average number of annotations per participant was 4.5. The average without the most active participant was 3.5.

The *Semantic Web* page was annotated by all the participants. They annotated this page as individual 8 times and as category 9 times. The most active participant added 11 personal semantic annotations to this page. The average number of annotations per participant was 2.5. The average without the most active participant was nearly 1.

Table 1. Personal Semantic Annotation for *Semantic Wiki* Page

User	Individual	Category	Total
1	1	1	2
2	1	0	1
3	2	5	7
4	6	5	11
5	2	1	3
6	4	3	7
7	1	0	1

Table 2. Personal Semantic Annotation for *Semantic Web* Page

User	Individual	Category	Total
1	0	1	1
2	1	0	1
3	0	2	2
4	6	5	11
5	1	1	2
6	1	0	1
7	1	0	1

The results above confirm our initial hypothesis about the usefulness of the personal semantic annotations because all the participants have added personal annotations.

The table 3 shows the shared and personal semantic annotations used by the participants for the *Semantic Wiki* page.

Table 3. Personal and Shared Semantic Annotation for Semantic Wiki Page

Shared annotations	Individual	Category
Category: PersonalInformationManagement	ResearchTopic	SemanticWiki (4)
Category: KnowledgeManagement	SemanticWeb (4)	Wiki(2)
Category: SemanticWeb	CollaborativeTool(2)	SemanticWeb
Category:FormalLanguage	Web	Web (2)
KindOf: Wiki	NoDelete	CollaborativeTool
has: FactBox	Semantics	WebOfData
limitation : fault-tolerance	KnowledgeWeb	NoUndoTag
limitation : scalability	Something	WWW
limitation : censorship	Wiki (3)	CSCW
	Web	Semantic

The column *Shared annotations* regroups the shared semantic annotations. At the beginning of the experience, it was empty. This page could be annotate as a category such as *Category: PersonalInformationManagement* or as an object property such as *limitation : scalability*.

The second and third columns regroup all the personal semantic annotations. Notice that in some cases many users used the same semantic annotation. For instance, four users used *SemanticWeb* annotations and two users used *Wiki* annotations.

We can observe that the total number of semantic annotations is increased. Therefore, personal semantic annotations could be useful to augment the shared knowledge.

With this evaluation we learn the following lessons:

– Every participant used both personal and shared semantic annotations;
– Most participants said that it is easy to use personal semantic annotations, because it is not necessary to embed them into the text.
– Some participants had difficulties to distinguish between a category and an individual.
– All participants have manifested the importance to have a good user-interface to facilitate personal navigation.
– For some participants personal annotations were useful to structure their own navigational map according to their personal taxonomy.
– Personal annotations were easier for people not familiar with semantic wikis whereas someone familiar with semantic wikis did not see exactly the added value of personal semantic annotations.
– One participant did not understand the difference between personal and shared semantic annotations.
– For most participants, it was easier to add personal annotations when they were browsing and to add shared annotations when they were editing the wiki pages.
– Most participants found that combining both kind of annotations could help them to make better knowledge retrieving.

Although, it is premature, the average of personal annotations shows a tendency: people feel comfortable using personal annotations and adding personal annotations is a complementary activity in semantic wiki.

These first results encourage us to continue in this direction, however, we need to conduct large scale experiences to consolidate these results.

7   Conclusion and Further Work

In this paper, we have introduced an approach to manage personal and shared knowledge in P2P semantic wikis. Shared knowledge is managed as in any semantic wiki. On the other hand, personal knowledge is defined as personal semantic annotations.

We have designed a P2P collaborative knowledge building process by basically supporting personal understanding. Personal annotations is the mechanism we have proposed to support personal understanding. Personal semantic annotations are private and appear in the context of the wiki page. This approach involves personal, shared or personal and shared navigation and retrieving. In

this research, we have adopted a P2P approach because it is the more suitable to control personal knowledge. We have implemented *P-Swooki* as an extension of the P2P semantic wiki, Swooki. As our approach is general, it could by applied to any semantic wiki, such as Semantic MediaWiki.

The evaluation of *P-Swooki* has confirmed our hypothesis that the usability of semantic wiki system can be improved by adding personal knowledge management. Most of the participants have used personal annotations. To consolidate these results, we plan to conduct more experimentations.

For instant, the personal annotation model is simple, it only considers categories and individuals. In the near future, we will enrich it in order to support relationships and attributes. Shared knowledge could be also enriched by publishing personal annotations. Therefore, it is needed to extend the current approach with a mechanism to "easily integrate" personal annotations in the shared repository and also in the wiki text.

From the experience, we also noticed that many users have defined the same personal semantic annotations. Although, these knowledge means a common understanding, they were not in the shared knowledge base. In the future, we plan to use discovering knowledge techniques to enrich the shared knowledge base.

Acknowledgments

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