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Abstract:

Semantic wikis are very promising tools for producing structured and unstructured data. However, they suffer from a lack of user provided semantic annotations, resulting in a loss of efficiency, despite of their high potential. This paper focuses on an original way to encourage users to annotate semantically pages. We propose a system that suggests automatically computed annotations to users. Users thus only have to validate, complete, modify, refuse or ignore these suggested annotations. We assume that as the annotation task becomes easier, more users will provide annotations.

The system we propose is based on collaborative filtering recommender systems, it does not exploit the content of the pages but the usage made on these pages by the users: annotations are deduced from the usage of the pages and the annotations previously provided. The resulting semantic wikis contain several kinds of annotations that are differentiated by their status: human provided annotations, computer provided annotations (suggested by the system), human-computed interactions (suggested by the system and validated by the users) and refused annotations (suggested by the system and refused by the user). Navigation and (semantic) search will thus be facilitated and more efficient.

Key-words: Semantic Wikis, Recomander System, Annotations

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Coopération homme-machine pour l'amélioration des annotations dans les wikis sémantiques

Résumé : Dans ce papier, nous proposons une coopration homme-machine pour augmenter le number des annotations sémantiques dans les wikis sémantiques.

Mots-clés : Wikis sémantiques, recommandation, annotations

Contents

1 Introduction

Web 2.0 provides anybody with an easy way to produce new content and to make it broadly available on Internet. Users collaborate all together to increase quantity and quality of available contents, by using for example tools such as wikis. At the same time, this large production increases the difficulty to access the right information at the right moment. The question is no more to determine if a specific content exists but to find where it is available and how to access it. It is thus mandatory to develop tools to help users finding the pertinent information on the web. Semantic wikis are one of the most promising approach to overcome this problem. Compared to classical wikis, they allow users to add *semantic annotations* in the wiki pages. In semantic wikis, users not only collaborate for writing the content of the wiki pages but also for writing semantic annotations that will allow a better and easier usage of wiki pages. For example, it will be possible to answer queries by exploiting information from different wiki pages, based on the semantic annotations. However, adding semantic annotations is neither an easy task nor a valuable action for users as it is time consuming and not directly visible. The consequence is that only few users annotate pages semantically. As it is not easy to motivate users to provide annotations, many existing semantic wikis contain only few annotations, that decreases their potential added value. A crucial problem is thus to develop new ways to obtain additional annotations. One possible solution is to propose an automatic system that suggests pertinent annotations to users, to encourage them to annotate wiki pages, thus coping with the lack of human provided annotations.

In this paper, we propose a new vision of semantic wikis relying on a strong collaboration between users and machine in order to produce pertinent, useful and reliable semantic annotations. We investigate how to suggest new annotations to users by mining the automatically collected observations about the real usages of wiki pages. These "computer recommended" annotations are suggested to users that can either validate (and/or complete), modify, refuse or ignore them. Specific mechanisms are thus added to usual semantic wikis to validate or discard computer recommended annotations. Based on these suggested annotations, the task of the users is made easier as the users do not have to completely create the annotation from the scratches (they do not always know which annotations add, how many, etc?), they can exploit the annotations suggested by the system. This results in a Human Computer Collaboration.

This paper is organized as follows: section 2 will give a brief overview of the system we propose. The following section summarizes the required background in terms of semantic wikis. Section 4 describes recommender systems and the way we suggest to use them to automatically determine possible additional semantic annotations. Section 5 presents how we propose that users and machines collaborate to provide reliable semantic annotations. Section 7 presents the architecture proposed for our system. The last section ends the paper with the perspectives of this work in progress.

2 Overview of the system

Wikis have demonstrated how it is possible to convert a community of strangers into a community of collaborators producing all together valuable contents. Semantic wikis [22, 20, 17, 4] by introducing semantic annotations within wiki pages, have opened an interesting way to mix Web 2.0 advantages with the Semantic Web approach [6].

Semantic wikis are a new generation of collaborative editing tools, thye allow users to add semantic annotations in the wiki pages. These semantic annotations can then be used to find pertinent answers to complex queries. Semantic wikis can be viewed as an efficient way to better structure wikis by providing a means to navigate and answer questions or reason, based on annotations.

The efficiency of semantic wikis relies among others on the quantity and the quality of the available semantic annotations. Similarly to content production, a promising way to obtain these annotations is to encourage collaboration between users. Users therefore collaborate not only for writing the wiki pages but also for writing semantic annotations. An essential problem still remains: how can we encourage and support users to provide semantic annotations?

In this paper, we address this question by introducing the machine as a partner of the collaborative process of annotation. The community of users becomes a community gathering humans and computers working together to produce semantic annotations. Humans and computers do not have equivalent roles within the community: computers can only suggest new semantic annotations but they do not have any influence on the final decision to keep, modify or discard them. In contrast, humans can not only add new semantic annotations but also participate to the final decision of inetgrating or not a given annotation provided by computers to contents. In this way, the system we design can be viewed as a semi-automatic annotation tool.

We have first to design a specific recommender able to suggest possible annotations to humans. These annotations will be referred to as *Computer Annotations* (CA). The generated CA will be suggested to humans, and every humacan decide to ignore, accept (and/or complete) or refuse them. If agreed, the status of the annotation will change to become a *Human Computer Annotation* (HCA). If refused, the CA will be discarded but memorized by the system as *Refused Annotations* (RA) to avoid to suggest it anymore. The HCA annotations will be added to the usual annotations resulting from humans collaboration, called *Human Annotations* (HA).

So every annotation can have four different status :

- Human Annotation (HA) : this annotation results only from humans collaboration;
- Computer Annotation (CA) : this annotation is suggested by the recommender but nothing has been decided about it by the humans;
- Human Computer Annotation (HCA) : this is a computer annotation that has is agreed (and/or completed) by the users;
- Refused Annotation (RA) : this is a computer annotation that had been discarded by the humans.

Both HA and HCA annotations will be used to support navigation and answer semantic queries in the wiki pages. CA can be used to only support navigation when no other annotations are available.

In this work, we choose to investigate collaborative recommendation based on usage mining. We decide to design a recommender relying on the exploitation of the usages of the wiki pages by the humans. We use the observations of the actions made on wiki pages by users and the navigational sequences among wiki pages to determine pertinent suggestions of annotations. In that sense, the recommender exploits implicit collaboration between users: we consider that users that share usages collaborate implicitly. The originality of this approach is that the content of the wiki pages is not taken into account to perform recommendations, only the usage of these pages is considered.

So we can say that our system is based on three levels of collaborations:

- Level 1: Explicit humans collaboration when users write annotations, HA.
- Level 2: Implicit humans collaboration when the system suggests CA.
- Level 3: Human-computer collaboration when users validate and complete CA that become HCA.

We integrate our proposal in semantic wikis. The following section presents backgrounds on semantic wikis.

3 Semantic Wikis

Wikis are the most popular tools of Web 2.0, they provide an easy way to share and contribute to global knowledge. The encyclopedia Wikipedia is a famous example of a wiki system. In spite of their fast success, wiki systems have some drawbacks. They suffer from search and navigation [10], and it is not easy to find information in wikis [5].

Semantic wikis are an extension of wiki systems that preserve the same principles of wikis such as simplicity in creating and editing of wikis pages. Semantic wikis embed semantic annotations in the wiki content by using Semantic Web technologies such as RDF and SPARQL. These annotations allow to better organise and structure the wiki contents. In semantic wikis, users collaborate not only for writing the wiki pages but also for writing semantic annotations. They provide a solution for creating and managing pages and allowing knowledge representation. Traditionally, authoring semantics and creation ontologies has mainly been in the hand of "ontologies" and knowledge management experts. Semantic wikis allow mass collaboration for creating and emerging ontologies. In other words, semantic wikis guid the users from informal knowledge contained in texts to more formal structures.

Many semantic wikis are being developed such Semantic MediaWiki [10], IkeWiki [20], SweetWiki [5] and Swooki [18]. Existing semantic wikis follow two approaches:

- Some semantic wikis require the load of an existing ontology. For instance, IkeWiki [20] aims to create an instance of existing ontologies. Semantic annotations about wiki pages are outside the content of the page. They appear near the page in a special GUI. The aim is to build controlled vocabularies but it can be too rigid for emergent domains where ontologies are not clearly defined.

```
France is located in [Europe]
The capital of France is [Paris]
```

Figure 1: Content of wiki page "France"

```
France is located in [locatedIn::Europe]
The capital of France is [hasCapital::
Paris]
```

Figure 2: Content of semantic wiki page "France"

- Others semantic wikis such as Semantic MediaWiki (SMW) [10], let users choose their own vocabularies. In SMW, semantic annotations are integrated directly in the wiki text, therefore, they appear in their context. Every SMW wiki page is considered as a concept. Pages and concepts are therefore related with each other. Users add semantic annotations to wiki page text to represent relations and properties on this page. The main advantage of this approach is to allow the emergence of an ontology.

3.1 Semantic Annotations in Semantic Wikis

In this section, we represent how a user can add semantic annotations in a semantic wiki. We focus on the approach developed by SMW. In SMW, links between wiki pages are typed. For instance, a link between the wiki pages "France" and "Paris" may be annotated by a user as "capital". Figures 1 and 2 show the example of a wiki page and the corresponding semantic wiki page.

These annotations express semantic relationships between wikis pages. Semantic annotations are usually written in a formal syntax so they are processed automatically by machines and they are exploited by semantic queries. For the end-user, a semantic wiki page will appear as a normal wiki page.

In semantic wikis, semantic annotations are added by users so they are *Human Annotations* (HA). Human Annotations in semantic wikis are the *Level 1* of collaboration as presented in section 2

3.2 Peer-to-Peer Semantic Wikis

Semantic wikis, as classical wikis, suffer from scalability, availability and performance problems [23, 13] and they do not support offline works and atomic changes [7]. To overcome these limitations, in previous works, we proposed a peer to peer extension for semantic wiki called SWooki. SWooki [17] is a peer to peer (P2P) semantic wiki that follows the same annotation principles as SWM. A P2P semantic wiki is a P2P network of autonomous semantic wiki servers (called also peers or nodes) that can dynamically join and leave the network. Every peer hosts a copy of all semantic wiki pages and an RDF store for the semantic data. Every peer can autonomously offer all the services of a semantic wiki server.

When a peer updates its local copy of data, it generates the corresponding operation. This operation is processed in four steps:

- It is executed immediately against the local replica of the peer,
- it is broadcasted through the P2P network to all other peers,
- It is received by the other peers,
- 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 adpats the linear text P2P synchronization algorithm detailed in [15] to take in consideration the semantic data as detailled in [9]. SWooki synchronization algorithm ensures the CCI (Causality, Convergence and Intention Preservation) consistency model [21] on the wiki text and the semantic data.

4 Recommender Systems for Annotation Suggestion

4.1 Recommender systems

Recommender systems [1, 12] are one way to provide personalization to users to cope with the well-known problem of overload of information. Among the possible approaches in recommender systems are content-based [16] and collaborative filtering approaches [8].

Content-based approaches use the content of the resources to compute recommendations for users. The content of the resources that a given user has already consulted is compared to the content of all the resources the system knows, and resources that are similar to the ones seen by the user are recommended. These approaches have the advantage to be accurate. However the content of all types of resources cannot be automatically analyzed (videos, audio, etc.), thus this analysis often requires human interventions. Moreover, there is a large variability in the human tagging, thus due to this variability, recommending resources based on this tagging may not be accurate. Last, only resources directly linked to the resources the user has consulted can be suggested: no "novelty" can be recommended to users, users may thus be frustrated.

Collaborative filtering (CF) approaches do not take into account the content of the resources. Only the usages of these resources are considered to compute recommendations. The usage of a resource can be the consultation made by users, the votes given by users, etc. A CF-based recommender thus exploits the traces of usage to deduce information about the resources. CF-based recommender can either compute similarities between resources [19] or exploit data mining techniques to learn relationships between the resources [24]. As in content-based recommender systems, given a user, his/her previously consulted resources are used and are linked/compared to all possible resources. The comparison in that case is no more made in terms of content (or tags) but by using the similarities or relastionships computed between resources, based on their usage. Resulting resources are recommended to the user. This approach has the advantage to no require any tagging about resources neither any other information; only the id of the resource is known *a priori*. The usage of the resources made by the users of the system is a more subjective information about the resources, but it directly reflects the interests of the resources for the users. Moreover, this approach allows to recommend "original" resources: resources that are not semantically linked to the past resources consulted by the user (but that are similar in terms of usage) can be recommended.

4.2 Recommender systems for Semantic Wikis

We propose in this article to consider CF-based recommender systems as a way to provide automatically resources with additional annotations in semantic wikis.

Let us recall that one drawback of current semantic wikis is the lack of annotations provided by humans (HA). A tool that automatically suggests annotations for the wiki pages to the users would be benefit for the quality of semantic wikis as, if the users validate these suggested annotations to annotate pages, the wiki pages would contain a larger number of annotations. The validation (or refuse) action for a suggested annotation is simpler for a user than proposing a new annotation on a given wiki page. Thus, we assume that a larger number of annotations will thus be integrated in pages if annotations are suggested to users.

Recommender systems usually suggest resources to users. In the frame of semantic wikis, we do not directly transpose recommenders to suggest wiki pages to users but to suggest annotations to wiki pages.
We propose, as in classical CF-based recommender systems, to exploit the usage of wiki pages: which users consulted which wiki pages and which page(s) is(are) frequently consulted after a given page ? to deduce the links/relationships between pages, by using approaches similar to the ones presented in section 4.1.

Given the relationships between pages and the annotations given by users (HA), the recommender system will suggest additional annotations (the Computer Annotations (CA)) to the wiki pages (to the users). These annotations can be made on pages that either already have HA or not.

These Computer Annotations correspond to the implicit human collaboration level from section 2: the behavior/traces of users are exploited: users collaborate implicitely.

4.2.1 Suggestion of Semantic Computer Annotations

The question is: Which annotations suggest to a given page P_j?

We propose two algorithms to compute these annotations. The first one is similar to the one used in item-based approaches [19] and classification of pages based approach [14], the second one is based on the use of data mining techniques to perform recommendations [12].

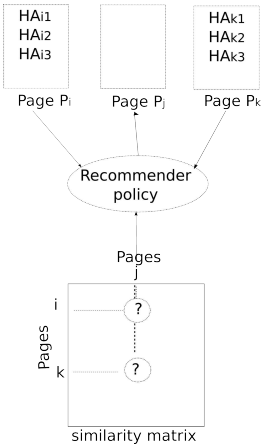

Figure 3: Automatic suggestion of SCA with the item-based approach

Item-based approach The algorithm first computes a similarity matrix of wiki pages [19]. This similarity matrix is computed based on the traces of usage of the wiki pages. Two pages with a high similarity value are considered as similar (in terms of usage).

This approach is based on the hypothesis that two similar pages may have similar semantic annotations. Thus, given two similar pages, the recommender suggests the semantic annotations of the first one to the second one and suggests the semantic annotations of the second one to the first one. Let us recall that these suggested annotations are CA.

Figure 3 presents the way the recommender computes candidate annotations. Given a page P_j, the recommender searches the pages that are similar to P_j. These pages are the ones with a high similarity value in the similarity matrix. The recommender collects the HA from the pages similar to P_j. The resulting set of CA suggested to P_j can be computed by several policies:

- The whole set of HA from the similar pages are suggested. By using this policy, the recommender may have the drawback of proposing too many annotations, and some of them may not be pertinent.
- The HA that are present in at least n similar pages are suggested. An appropriate value of n has thus to be fixed. This policy has the advantage to propose a lower number of annotations that are more "reliable" as they are present in several pages. However, according to the value of n, some pages may have no annotation.
- Given a HA, the similarity values of the pages that contain that HA are summed up. The HA with a sum of similarity values above a given threshold are suggested. This policy has the advantage to be more accurate than the second one as the similarity values are considered.

Classification-based approach The classification-based approach is similar to the one used in clustering-based recommender-systems [11].

In this approach, given a set of pages, the recommender first computed a classification of these pages in order to create classes of "similar" pages (see Figure 4). As in the item-based approach, the classification is computed based on the usage of the pages by the users, not on the content of the pages. Then, given a page P_j, the recommender searches its corresponding class, and exploits all the pages in this class. All the policies presented in the item-based approach can be used to compute annotations.

The advantage of the classification-based approach, compared to the item-based approach, is that the set of pages to use to compute annotations is predefined (the pages in the class) whereas it is dynamically computed in the item-based approach, that can take time.

Data Mining based approach In this approach, the algorithm exploits datamining techniques to extract information about the usage of the resources. These techniques study the sequences of consultation of resources by using, for example, association rules or Markov models to discover frequent patterns [2].

This algorithm is based on the following hypothesis: if two or more pages are frequently consulted in sequence, then the links used to traverse these pages are useful and it is important to annotate semantically

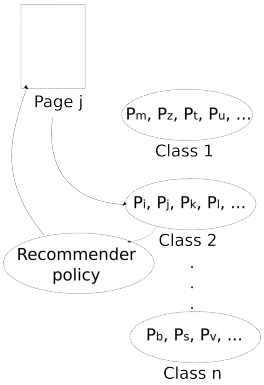

Figure 4: Automatic annotation of resources with the classification-based approach

these links. Thus, the recommender suggests CA to the users so as to annotate semantically the frequently passed links.

Let us specify that in that case the annotations provided by the recommender system are not semantic annotations, they are just annotations, as the type of the annotation cannot be automatically discovered by the system. The recommender, in that case, only suggests to the users that an annotation at a given place should be important. The recommender can also in that case, specify the label of the annotation. For example, given the example from Figures 1 and 2, and no semantic annotation between the pages France and Paris (may be there is a hyperlink), the recommender can learn that this link is highly passed, thus annotating semantically this link may be useful. Thus, the recommender suggests to the users the link "Paris". The role of the user will be not only to accept, modify, refuse or ignore this suggested annotation but also will have to type it (see section 3.1), with [HasCapital], for example. In that case, the annotation task is made easier as the system suggests the user where useful annotations should be, the user is guided.

4.3 When recommending annotations?

The recommender cannot suggest annotations (or compute a classification) at any moment. They can be computed only when a sufficiently large number of consultations on the pages has been made by the users. If this number is too low, similarity values, classes and frequent patterns may not be reliable, and the annotations proposed may not be adequate, leading to unsatisfied users and too many refusals about the suggested annotations. In that case, the system chooses to not suggest any annotations, the system is thus similar to usual semantic wikis.

5 Human-Computer Collaboration: HCA approach

Based on section 4.2, for every wiki page, the semantic wiki has two sources of annotations. Those added by humans (HA) that correspond to the explicit human collaboration, and that are the ones usually used in semantic wikis and those suggested by the recommender system: the Computer Annotations (CA), that come from implicit human interaction (exploited by the recommender). These annotations are original annotations, they do not exist in classical semantic wikis, they will be used to encourage the users to annotate semantically pages.

The HCA approach we propose in this article allows any user to accept (and/or type), modify (and/or type), ignore or refuse the CA annotations. Resulting annotations correspond to the Human machine collaboration from section 2. These actions will be possible thanks to the wiki facilities.

5.1 Peer to peer HCA

In the context of a peer to peer semantic wiki, several questions about the computer annotations remain: how the recommender suggests annotations (CA) to users? how to make the users validate (and/or complete), modify, refuse or ignore a CA? How to make the other users know these annotations? The way we propose to answer these questions is presented in Figure 5.

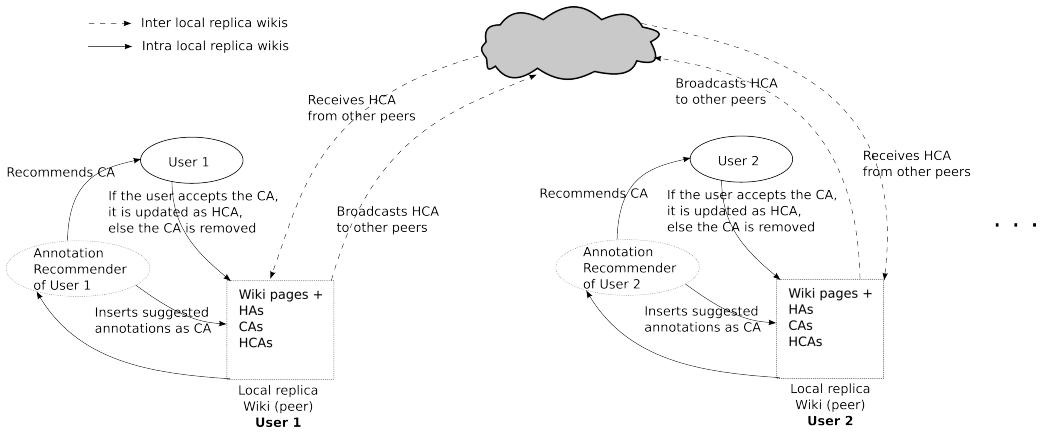

Figure 5: The way CA are proposed, validated (HCA) and propagated in a P2P semantic wiki

Name	Meaning	Status
HA	Usual semantic annotation	Validated
CA	Suggested by the recommender	Temporary (not yet validated)
HCA	Suggested by the recommender and validated by the users	Validated
RA	Suggested by the recommender and refused by the user for learning	Refused (could be re-suggested if enough modifications are done on the content of the wiki)

Table 1: Status of annotations in the semantic wiki

When new annotations are suggested by the recommender, these annotations are broadcasted to all the local replica with the status Computer Annotation (CA). These new annotations, labelled "CA" are proposed to the users, in a pop-up box, for example, so as to be differentiated from Human Annotations HA. There are four possible operations that the user can do on these annotations:

- Ignore the CA annotation
- Accept (and/or type) the CA annotation
- Modify (and/or type) the CA annotation
- Refuse the CA annotation

First, a user can not do anything on this pop-up box, in that case the annotations remain with a CA status. If the annotations are typed (from item-based or classification-based approaches), the user can either validate, modify or refuse each of them. If the annotations have no type (from data mining approach), the user can complete (and thus validate), or modify each of them. When a validation, completion or modification action is made, the local replica of the user is modified and the CA is updated so as to be a HCA (human validated computer annotation). The information about this action is broadcasted to the other local replica (as HA are classically broadcasted (see section 3.2)) and the annotation is thus suggested to users as a HCA. Let us notice that when a user does not agree a HCA that he received from another user, he can modify it as in the case of classical HA (section 3.2).

If the action made is a refusal, the annotation is discarded from the set of CA and is included in the set of RA and is also broadcasted to other users. This set is used by the recommender to avoid resuggesting annotations that have already been refused by users. These RA can however be resuggested in the case the content of the wiki page has been highly modified. An overview of the possible annotations status is presented in Table 5.1.

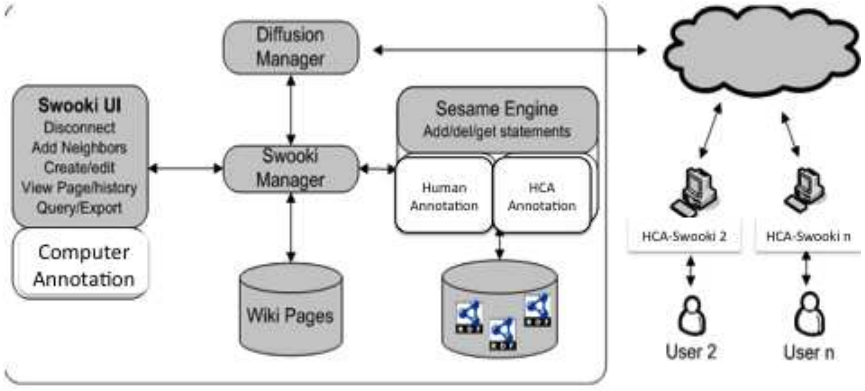

Figure 6: HCA-Swooki Architecture

6 *HCA* System Architecture

We propose to implement HCA as an extension of SWooki, called HCA_SWooki. SWooki is implemented in Java as servlets in a Tomcat Server and uses Sesame 2.0 [3] as RDF repository. HCA_SWooki peer has the components presented in figure 6. The grey boxes are Swooki components while white ones are the HCA_SWooki components.

- *User Interface.* The HCA_SWooki UI component is composed by the SWooki wiki editor and it incorporates the functionalities to make CA tagging.
- *Swooki Manager.* The Swooki manager implements the synchronizing algorithm.
- *Sesame Engine.* We use Sesame 2.0 [3] as RDF repository. Sesame is controlled by the Swooki manager for storing and retrieving RDF statements. HCA_SWooki use a different name space, one for the HA and another one for HCA. This allows to reuse the storing and retrieving facilities already implemented by Swooki.
- *Diffusion Manager.* The diffusion manager is in charge to maintain the membership of the unstructured network and to implement a reliable broadcast for the shared repositories.

7 Conclusion

In this paper, we propose an original system that aims at encouraging semantic annotations of users in semantic wikis. This work is based on the observation that users do not often semantically annotate pages in semantic wikis as this task is neither easy nor a valuable action for users as it is time consuming and not directly visible. Such a behavior leads to semantic wikis with few annotations, they are therefore less efficient than they could be.

The HCA system we propose has the role of suggesting annotations on the wiki pages to users. In that case, the role of users is no more to only create semantic annotations that they feel to be useful, they can also use the annotations suggested by the system to annotate semantically pages. Their task thus becomes easier and we assume that the implementation of the HCA system will result in the increase of the amount of annotations in the semantic wikis. This will help to make the Web of data a reality.

The HCA system we propose exploits the usage of the wiki pages by the users and is based on classical collaborative filtering recommender systems, it uses item-based, classification-based and data mining-based approaches. These approaches learn the similarities/links, in terms of usage, between the wiki pages. The HCA system exploits both these similarities/links and the semantic annotations provided by humans that are present on the pages, and suggests annotations to wiki pages. These annotations are not directly stored in the pages, they are suggested to users that can validate, modify or refuse these annotations. Some of these annotations may have no type in the case of the use of data mining approaches.

The annotations have various status so as to differentiate them, according to the way they have been registered in the page: Human Annotations, Computer Annotations, Human-Computer Annotations and Refused Annotations. The resulting set of annotations in the semantic wiki is thus based on several levels of collaboration: explicit humans collaboration when writing HA, implicit humans collaboration to suggest CA and human-machine collaboration to produce HCA.

As a future work, we intend to refine the way the HCA are obtained; we aim at not making a CA become directly a HCA when a user validates or modifies it, or being a RA if a user refuses it, but by waiting to have a consensus about the actions of the users. This approach, that will be based on a server of traces, will have the advantage that annotations will not change constantly.

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