Combining ontology and folksonomy:
An Integrated Approach to Knowledge Representation

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Abstract:

Technological advances dramatically changed the approaches in information representation and retrieval. There are two broad approaches to the knowledge representation; one is informal, dynamic, free, user-dependent and the other is formal, more stable, solid, static and system-dependant: Folksonomies a breed of the Web 2.0 and ontologies the backbone of semantic web (web 3.0) are two examples of those approaches. In this paper, we try to present two sub-models of an integrated system in which each technology has the opportunity to reduce its current limits, by exploiting the power provided by the other one. In order to develop sub-models, we present a simple ontology of folksonomy to show how different elements act in such a dynamic space, and how implicit relations emerge from implicit complex networks within the folksonomies**.**

Keywords: ontology, folksonomy, knowledge representation, integrated system, conceptual model

1. Introduction

1-1. Collaborative tagging

Technological advances dramatically changed the approaches in information representation and retrieval. Philosophically talking, there are two broad approaches to the knowledge representation; one is the most formal, solid, static, system-dependant model of knowledge like thesaurus and ontologies. On the other hand, we can see a shift to social, flexible, dynamic, lightweight, user-dependant content creation and classification as in ‘‘collaborative tagging’’ in a variety of prominent Web based services (e.g. del.icio.us: http://del.icio.us/, CiteULike: www.citeulike.org/, Flickr: www.flickr.com/, etc.) called foklsonomy.

Describing resources by means of a set of keywords is a very common way of organizing content for future use, including search and navigation. In the light of the Web 2.0 philosophy, the several social tagging systems available nowadays enable users to annotate their resources (web pages, images, videos, etc.) with a set of words, the so called “tags”, which they believe to be relevant to characterize the resource according to their own needs, without relying on a controlled vocabulary or a previously defined structure (Specia, Motta, 2007). Such tags are used to enable the organization of information within a personal information space, but are also shared, thus allowing the browsing and searching of tags attached to information resources by other users (Macgregor and McCulloch, 2006, p294).

In what we call "collaborative tagging", assigned tags are user-dependent and represent the knowledge, interest, or interpretation of the users, who did tagging, about the information contained in the folksonomy (Echarte, 2007). It also indicates their social or cultural backgrounds, expertise and perception of the world (Angeletou, Sabou, Specia, and Motta,2007). Users can very easily create, rename, group, split, merge and delete tags and thus categorize and classify their small universe (Spyns, Moor, Vandenbussche and Meersman, 2006).

However, these systems also suffer from problems, such as ambiguity in the meaning (polysemy), Tag variation (synonymy) and flat organization of tags (Pan, Taylor and Thomas, 2008; Passant, 2007). Due to these facts, two problems would arise: 1. reduced search capacity and 2. Limited exploration (Echarte, Astrain, Córdoba, and Villadangos, 2007). In other words, all these drawbacks lead to lack of precision and recall when executing a search.

1-2. Ontology: formal specification of a shared conceptualization

Contrary to folksonomies, ontologies provide a framework to handle structured information and to extract conclusions from such structured information (Echarte, Astrain, Córdoba, and Villadangos, 2007). The term ontology is used in information systems and in knowledge representation systems to denote a knowledge model, which represents a particular domain of interest. A body of formally represented knowledge is based on a conceptualization: the objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that is held among them (Lacasta, Nogueras-Iso, ,Be´jar, , Muro-Medrano , Zarazaga-Soria, 2007, p 947).

Comparing to folksonomies, ontologies has less drawbacks as a part of any information retrieval system. Ontologies by nature make implicit knowledge explicit, they describe relevant parts of the world and make them machine understandable and processable. Although ontologies are difficult to maintain, mainly in changing environments (Echarte, Astrain, Córdoba, and Villadangos, 2007) to be effective, they need to change possibly as fast as the parts of the world they describe (Haase, Volker, and Sure, 2005, p97). A new word can be invented on the spot when needed and immediately added to the vocabulary (Damme, Hepp and Siorpaes, 2007).

On the spectrum of knowledge representation systems, the most expensive in creation and maintenance is an ontology. It requires consensual agreement on its contents from community members, while the folksonomies are easier to create, edit, use and reuse. To be fair, it is clear that the both knowledge representation methods have their own benefits (advantages) and drawbacks (disadvantages).

Although the debate is ongoing about the pros and cons of folksonomies versus ontologies, still little attention is paid to the next step: what do the systems to be built on top of these approaches look like? (Spyns, Moor, Vandenbussche and Meersman, 2006).

2. Bridging between two ends of a range

Folksologies and ontologies are not two opposite ways of organizing a (more) meaningful Internet, but rather constitute two ends of a range (Spyns, Moor, Vandenbussche and Meersman, 2006).

Search both within and across folksonomy based systems is an open problem. A naive approach to folksonomy search, such as those provided by most tagging systems, results in unacceptable precision in domain specific searches (Pan, Taylor and Thomas, 2008). This problem becomes worse especially when the number of tags increases (Echarte, Astrain, Córdoba, and Villadangos, 2007). Angeletou, Sabou, Specia, and Motta (2007) believe that the content retrieval can be further improved by making the relations between tags explicit. The related tags provide a very basic way to continue the searching process or to query-refinement.

On the other hand, applications that really make use of complex semantic ontologies are still rare, and this is partly due to the high effort needed to develop and maintain sophisticated ontologies (Weller, 2007:112).

In principle, ontologies should be the result of a group-wise negotiation process (Spyns, Moor, Vandenbussche and Meersman, 2006). While most existing ontologies are designed by individuals or small groups of experts, and ontology users are not involved in the development process (Gendarmi, Lanubile, 2006). They are designed by experts and should be used for making the meaning of documents explicit and unambiguous, not only for interpersonal communication but also for human–computer and inter-computer interactions (Weller, 2007:109)

The insufficient involvement of users in the construction of ontologies is a significant cause for the current shortage of satisfying coverage found in domain ontologies (Damme, Hepp and Siorpaes, 2007: 57) For this reason, collaborative environments as provided in social tagging may inspire new ways of efficient ontology engineering (Weller, 2007:112).

Gruber, in his article “ontology of folksonomy: a mash-up of apples and oranges” presents the different roles of ontologies and folksonomies in semantic web. He shows that not only both techniques are not completely opposed to each other but it is possible to get them complement each other (quoted in Echarte, Astrain, Córdoba, and Villadangos, 2007).

Presently, there are some built ontologies available on the web. Semantic web tends to reuse ontologies whenever they are available so we can use the benefits of both ontologies and folksonomies to complete the process of knowledge representation on web. In this approach it is possible to have the flexibility of use and implementation of folksnomies and the structured model of knowledge in ontologies at the same time.

This means that Social Software can overcome its current limitations, by exploiting the power provided by semantic technologies in searching, navigation and integration of the information published on the Web. Semantic Web can benefit from the ability of Social Software in fostering collaboration among users, then lowering entry barriers to knowledge management. (Gendarmi, Lanubile, 2006).

Although the above analysis suggests that it would be convenient that proposed integrated systems could take advantage of the best of both worlds, there is a lack of an abstract model of such systems that could explain both the process of tagging in folksonomies and ontology evolution.

In this paper, we try to present two sub-models of an integrated system in which each technology has the opportunity to reduce its current limits, by exploiting the power provided by the other one. In order to develop sub-models, we present a simple ontology of folksonomy to show how different elements act in such a dynamic space, and how implicit relations emerge from implicit complex networks within the folksonomies**.** It is important to notice that we are neither going to propose a new approach in search expansion, nor to investigate a set of tags to extract concept and relations. We just intend to deepen the understanding of so called integrated approach in knowledge representation systems.

3. State of the Art

Papers in this area can be divided into three types: 1. focus on ontology supporting folksonomy, 2. focus on folksonomy supporting ontology and 3. focus on the both sides to achieve the benefits of both technologies.

Pan, Taylor and Thomas (2008) and Angeletou, Sabou, Specia, and Motta (2007) are in the first category. Pan, Taylor and Thomas (2008) propose an approach to address the problem of ambiguity in tagging systems by expanding folksonomy search with ontologies. Angeletou et al. (2007) propose the semantic enrichment of folksonomy tags with explicit relations by harvesting the Semantic Web, i.e., dynamically selecting and combining relevant bits of knowledge from online ontologies.

On the other category Mika (2005) illustrates ontology emergence by two case studies. he concludes while concept (tag)-instance (object) network, which is based on co-occurrence of tags, is more appropriate for concept mining, actor (user)-concept network, which is based on actors sharing concepts as interest, is more reliable to extract relations. Echarte, Astrain, Córdoba, and Villadangos (2007) focus on extraction of structured information from knowledge built in folksonomies.

Damme, Hepp and Siorpaes (2007) suggest applying the statistical analysis of online resources like dictionaries, WordNet, Google and Wikipedia, and also existing ontologies to derive ontologies from folksonomies. Gendarmi and Lanubile (2006) also focus on this trend and propose a collaborative ontology evolution system based on wiki technology. On the contrary to statistical approaches, Liu and Gruen (2008) suggest using a collaborative system which allows users to extend the system's ontology as they conduct their work.

Third category belongs to researchers who are interested in mixed and integrated approaches. Christiaens (2006) focuses on the gray zone between two restricted and free mechanisms, and demonstrates a possible approach in which tagging, taxonomy and ontology are mixed. Spyns, Moor, Vandenbussche and Meersman (2006) and Weller (2007) have slightly the same approach as he does.

More similar to our approach in this paper, Al-khalifa and Davis (2006) describe a novel tool called "FolkAnnotation" that creates annotation with educational semantics from the del.icio.us book marking service. They illustrate the FolkAnnotation system architecture to show how folksonomies are used to find the corresponding concepts in the ontology and how ontologies are used as the schema with the generated metadata. Although their system architecture is consisted of both ontology and folksonomy their focus is more on text extraction. On the other hand, Passan (2007) describes an approach that mixes folksonomy and semantic web technologies in order to solve information retrieval problems and also to enrich information retrieval capabilities among blog posts. This process of ontology maintenance can be seen as a socially-driven ontology population approach since ontology and its instances evolve thanks to the tags used in the SemiBlog.

In both two latter papers, authors give the system architecture they applied in their research. But to the best of our knowledge, no scholarly paper have built conceptual model of any integrated system to show how such systems will work and how users will treat them.

4. Towards the integrated system
4-1. Ontology of folksonomy

Any tagging system is constituted by three main elements: a. user (agent, actor, or tagger), b. object (resource) and c. tag. It is shown in figure 1 that during the tagging process, a user *annotates* an object by *assigning* a tag. A tag *is assigned by* a user and it *is assigned to* a specific object. Any object *has tag* and it *is annotated by* a user. As a result there are six different relations between these three elements.

Figure 2 indicates the visualized view of a simple ontology of folksonomy designed in the Protégé[1], an open source ontology engineering software which is developed by Stanford Medical Informatics[2]. In this simple ontology, there are three main entities called tag, user and object. These entities are related to each other by specified relations; *assigns, IsAssignedBy, Annotates, IsAnnotatedBy, HasTag,* and *IsAssignedTo,* which are expressed with colored dashed arrows.

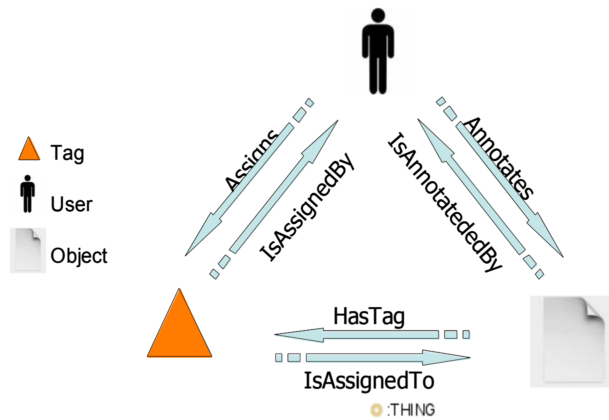

Fig.1: Tagging process triangle

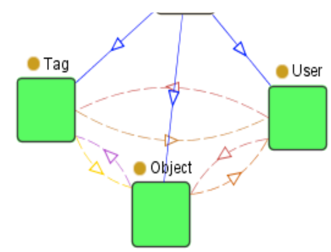

Fig.2: Simple ontology of folksonomy

4-2. Emerging Explicit Semantics

Figure 3 shows that the tag space in social tagging system encompasses semantic aspects of the system that are not explicitly defined.

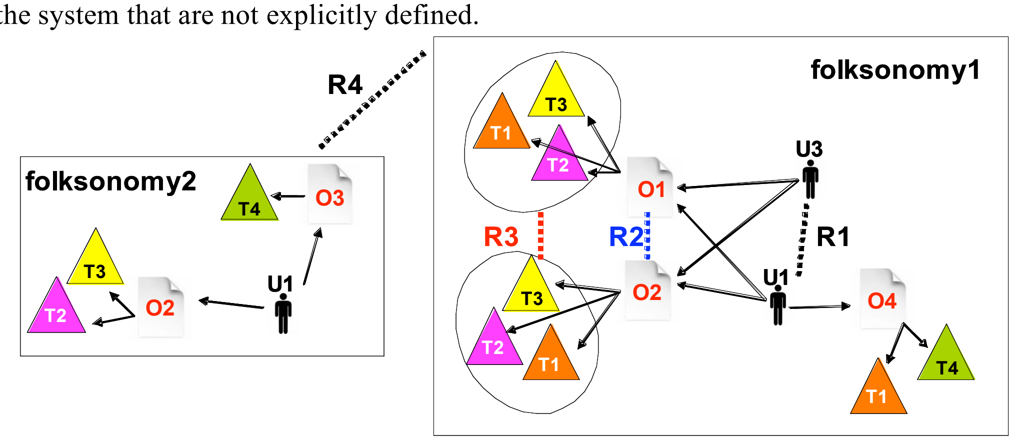

Fig. 3: Explicit interconnections

[1] http://protege.stanford.edu
[2] http://smi.stanford.edu/

The semantic of the resources and the used tags are included in a collaborative way (Echarte, Astrain, Córdoba, and Villadangos, 2007). According to figure 3, four different relationships can be identified. These relationships are indicated in figure 3 (R1, R2, R3, and R4). Also it can be possible to identify implicit corresponding networks within the folksonomy; a. network of related users, which also called sub-community, b. network of related objects, which relates similar objects together, c. network of related tags, and d. networks of related folksonomy systems, which groups tagging systems according to their goals or users.

Besides establishing a relationship between a resource and a concept in the user's mind, tags can be thought of as the connecting element between resources and users, with these connections defining (even implicitly) relationships among users (several users may use the same tags) and among resources (resources can be tagged with the same words) (Specia, Motta, 2007).

In other words, users can indirectly become related to each other (R1) by tagging the shared object, by assigning the shared sets of tags or by the combination of both. This implicit relationship makes sub-communities explicit. Group/Network feature in some social systems (e.g. Bibsonomy, del.icio.us) make it possible to define explicit groups with shared interests and expertise. These sub-communities are valuable resources of information. Mika (2005) argues that meaning is necessarily dependent on a community of agents and it is possible to extract a hierarchy based on sub-community relationships.

Objects can be identified as similar by the same assigned tags or by the same users, who are interested (R2). Some tags are always used together. In figure 3, tag set (T1, T2 and T3) are likely related (R3). As Mika (2005) suggests, the weights of the links between tags are expressed as the number of people who make that association. Consequently, co-occurrence of tags could be used to build clusters of related tags and make use of built clusters to support search expansion. On the other hand analyzing such data might reveal relevant relations that can help us in reconstructing an ontology for the respective domain of interest.

Finally, Systems are implicitly connected through shared sub-communities of interest or common objects. Sub-communities are not exclusively related to just one system (Damme, Hepp and Siorpaes, 2007: 61)

In a nutshell, it is apparent that by aggregating the results of folksonomy production it is possible to see how additional value can be created (Anderson, 2007: 17). Although there are several kinds of relations hidden within the folksonomies, Integrated systems tend to exploit the hidden information and brings the emerging semantics to the surface.

5. Modeling the integrated system

5-1. Preliminaries

Modeling the integrated system, we have some basic Assumptions:

1. Folksonomies hold more semantic value than keywords extracted using statistical approaches (it is concluded in some papers e.g. in Al-Khalifa and Davis, 2006)

2. Implicit knowledge can be derived by means of a statistical analysis of the annotations combined with pragmatic information provided by the semantic web and additional clues given by external resources.

It is also important to note that the proposed model is split into two sub-models, each describing two different processes: 1. knowledge (or better say information) acquisition and representation (figure 4) and 2. knowledge discovery (figure 5). These sub-models are based on the literature described above, as well as our own experience working with current folksonomies.

5-2. Sub-models

Most users are simply information providers and they are not familiar with ontologies. Consequently, the insertion of new contents [concept, relationship (property), instance] is a very difficult process for most users, because several criteria must be taken into account, and users are neither familiar with these criteria nor with the tools to work with ontologies (Echarte, Astrain, Córdoba, and Villadangos, 2007).

As highlighted by Pan, Taylor and Thomas, (2008), a key question remains open: how to exploit the benefits of ontology without bothering untrained users with its rigidity.

In integrated approach, knowledge engineering is implicitly integrated with tagging process of the end users. The community collaboratively shapes the formal domain definitions through sharing and negotiation (Liu, Gruen, 2008: 361). There is no need for establishing a common agreement on the meaning of a tag because it gradually emerges with the use of the system (Gendarmi, Lanubile, 2006). Through the integrated system, new tags can be introduced on the spot when needed and the construction and maintenance of the tags is closely linked to their actual usage (Damme, Hepp and Siorpaes, 2007: 58). Folksonomies can then react quickly to changes and be responsive to new user needs.

Different levels of collaboration are possible. On a basic level, a community may work with an already existing ontology and simply suggest new concepts or instances missing in the ontology. On this level users may support ontology engineering and may contribute their individual knowledge to broaden and update the ontology (Weller, 2007: 113). However, Users can still annotate an object with freely chosen tags if they choose the uncontrolled way of tagging process.

With the presumption that user is interested in annotating an object without looking for previous tags referring to that object, he starts tagging process from the first step in figure 4 and he decides whether to annotate an object with or without control. Considering one chooses the controlled approach, he then inputs a candidate tag, which he thought would better describe the object (step2). The repository is there to help him with tag/concept recommendation. The repository provides links to semantic search engines or portals (e.g. Swoogle[3], OntoSearch[4], DAML Ontology Library[5], Protégé Ontology Library[6]) to find related elements in per-constructed ontologies available on the web. It also contains the folksonomy database to recommend proper tags due to the pre-defined available tags.

An important consequence is that this semantic repository is needed to recommend proper tags/concepts and to steer a tag user into selecting the most appropriate tag among the recommended ones. A candidate tag can be associated to different ontology concepts (Passant, 2007) or different ontologies in case more than one ontology is found. It is shown as step 3, when probable results are shown.

Clustering of the tags recommended in this step, could be based on the similarity among tags by their co-occurrence. This clustering algorithm is run and evaluated by some researchers (e.g. Specia and Motta, 2007; Hotho, Jaschke, Schmitz, Stumme, 2006; Damme,

[3] http://swoogle.umbc.edu/
[4] http://www.ontosearch.org/
[5] http://www.daml.org/ontologies/
[6] http://protege.stanford.edu/download/ontologies.html

2007; Angeletou, Sabou, Specia, and Motta ,2007). Visualization of ontology concepts is also needed to display.

At this step, user would decide which option best fits his needs. Then he decides whether to assign a tag from the list of recommended tags or to refine the candidate tag to reach better results. He may shift to another way to suggest a new tag or concept to the system. This would happen when no result is found in the previous step. User may confirm the candidate tag (step 4), if the results in step3 are desired. As a result, users are empowered to extend the ontology to capture new concepts on demand.

Given initial ontologies, we show how collaborative ontology evolution system allows community members to add, modify, or delete existing and new ontology classes, according to their own needs.

Ontology evolution starts when two sorts of automated algorithms - concept and relation extraction, and mapping the tags into concepts / instances / properties of ontologies- start to run. Specia and Motta (2007) successfully examined the automated mapping process. How these two sorts of algorithms apply to the data sets is beyond the scope of this paper. Dashed lines in this sub-model indicate that both extraction and mapping are under the effects of the repository.

Through the growth of folksonomy-based data collections on the web, the influence of single users will fade in favor of a common understanding provided by huge numbers of users (Hotho, Jaschke, Schmitz, Stumme, 2006) and consensus about which tags best describing some certain Web resources can be stabilized (Pan, Taylor and Thomas, 2008).

In order to the meaning agreement happens unconsciously, (Spyns, Moor, Vandenbussche and Meersman, 2006) reduce future problems, we set Experts to check whether the tags are correctly mapped into elements of the ontologies or not, and also whether the extracted concepts and relations are accurate enough to be added as ontology elements or not. Tags can refer to the following elements: concepts, instances, or properties. Experts' confirmation. This mechanism will provide the experts' confirmation to reduce probable mistakes. So user would not directly create a concept, instead one suggests new tag/concept to the system. However, applying this method the resulting ontology is more likely to be accepted as accurate by the community itself.

By being dynamically updated by large masses of people, folksonomies reflect the newest terminology within several domains (novel terminology) (Angeletou, Sabou, Specia, and Motta, 2007). This dynamism makes ontology evolution dynamic as well.

On the other hand, if one chooses the uncontrolled approach, then he would go directly from step 2 to step 4; suggesting the new tags. In this approach, other steps, except for experts' confirmation, would be taken automatically. As a result user has no direct role in ontology evolution.

At the end, results of the previous steps will use to update the repository as it is shown in figure 4. It should be considered that through this process both ontologies and folksonomies developed dynamically.

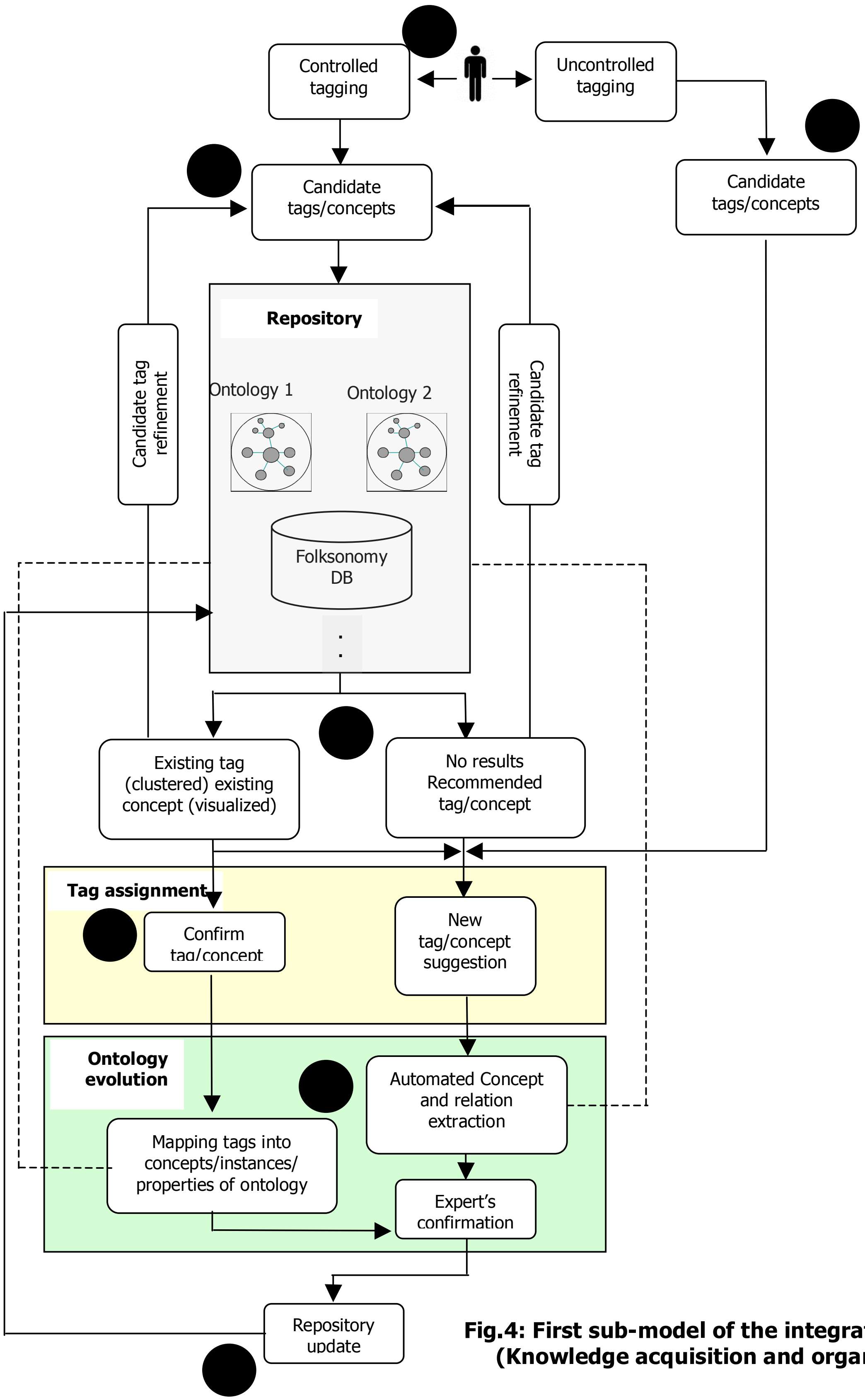

Fig.4: First sub-model of the integrated system (Knowledge acquisition and organization)

While figure 4 shows the ontology-based tagging process, figure 5 illustrates the ontology-based folksonomy search expansion.

The more folksonomy-based systems grow larger, the more retrieval facilities are needed. The internal structure of folksonomies has to become better organized. An obvious approach for this is semantic web technologies (Hotho, Jaschke, Schmitz, Stumme, 2006). Apart from weak search facilities of folksonomies, right now, the navigation process is based on clouds of words and/or users. Any popular word or user has a bigger size cloud. It is clear that this kind of navigation is not sophisticated enough to find valuable information.

It has been argued that folksonomy structure can be enhanced by ontologies (Pan, Taylor and Thomas, 2008). As it is shown in figure 5, alphabetic list of tags, concepts, actors and groups could be developed thanks to existing ontologies and folksonomies databases. It is also possible to have visualized view of concepts as well as tag and actor clouds. These help user to browse intelligently.

If one decides to search a query, ontologies embedded in or related to the system would lead to improved precision and recall. It is argued that ontology-based folksonomy search expansion methods help reducing ambiguity (Pan, Taylor and Thomas, 2008). In this approach, the user envisaged tag space enrichment with semantic relations by exploring online ontologies.

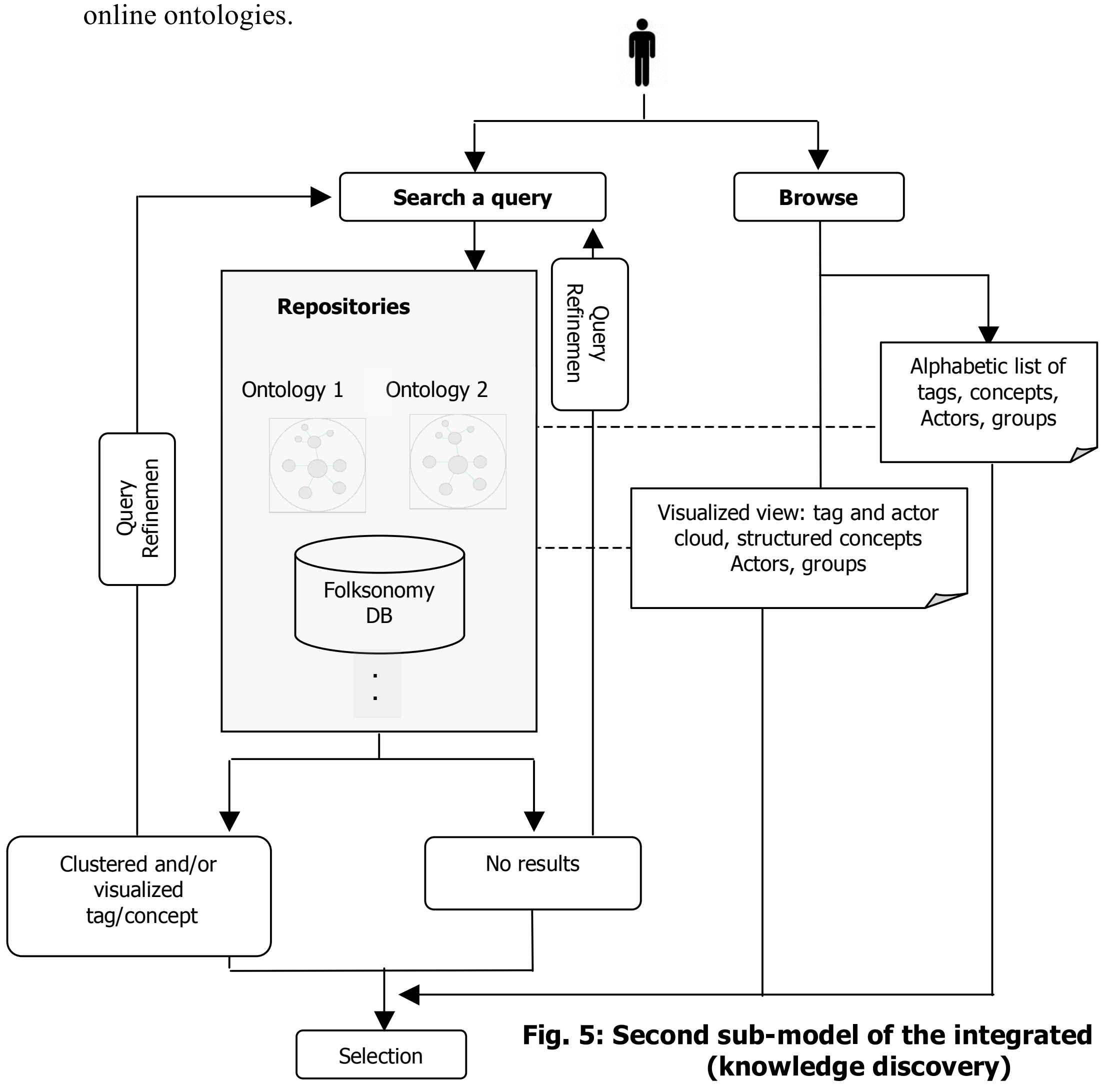

Fig. 5: Second sub-model of the integrated system (knowledge discovery)

These two sub-models provide web users with an existing ontology and tell them to annotate documents on this basis. It also uses existed ontologies in query expansion as it is illustrated in figure 4.

6. Conclusions and future work

The differences between folksonomies and ontologies (such as novel terminologies emerging in several languages) can be used to evolve the Semantic Web. This valuable knowledge available in folksonomies could allow keeping online ontologies up to date, extending them with multi-lingual information and evolving them towards truly shared conceptualizations of a much broader range of domains (Angeletou, Sabou, Specia, and Motta, 2007).

On the other hand, How to apply Semantic Web technologies to improve folksonomy based systems and social networks have been a pressing issue for the Semantic web community (Mika, 2005). Enhanced information retrieval could be the result of any ontology-based folksonomy systems.

In this paper, we try to present two sub-models of an integrated system. First, we drew the triangle of main elements of any folksonomy system. Then we showed how implicit interconnections exist in the world of folkonomies. In order to deepen the understanding of the integrated systems, we have presented two sub-models. However, it is simplified to some extend.

Ontology-based folksonomy tagging process is modeled in figure 4. It is shown how one user can enrich tagging process by the available ontologies. In figure 5 ontology-based folksonomy search expansion is modeled. Search expansion would happen under the indirect effects of ontologies linked to the system.

It is highlighted by Hotho, Jaschke, Schmitz, Stumme (2006) that intelligent techniques may well be inside the system, but should be hidden from the user. So users in such integrated systems can exploit the benefits of ontology enhanced folksonomy search without the knowledge of the existence of neither the ontology infrastructure nor the related ontologies. They also help ontology evolution thanks to one more step (step 3 in figure 4) compared to other tagging systems.

with this approach to integrating folksonomies and the semantic web, as Specia and Motta (2007) have mentioned, we intend to show ultimately both (1) that the ontologies provided by the semantic web can be used to structure folksonomies semantically and (2) that the dynamic knowledge provided by folksonomies can be used as a resource for bottom up knowledge acquisition to support ontology evolution.

While we are only at the beginning of realizing these benefits, there is a clear magic as we see semantics emerge from the individual actions of a community (Mika, 2005) during their real activities as a member in social networks.

In the future we plan to improve and modify these two proposed sub-models. In order to achieve this goal we will also need to negotiate with professionals from different related fields, such as Computer science and Semantics. We believe that only cooperation among subject specialists can help overcome current problems.

On the other hand, it is evident that surpassing some of the current limitations of such systems is a matter of time as many of them will be solved as more ontologies will appear online. Library and Information specialists in cooperation with other specialists can help speed up the movements towards the semantic web.

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