TagSorting: A Tagging Environment for Collaboratively Building Ontologies

Leyla Jael García-Castro[1], Martin Hepp[1], Alexander García[2]

[1] Universität der Bundeswehr München, Werner-Heisenberg-Weg 39,
85779 Neubiberg, Germany
leyla.garcia@ebusiness-unibw.org, mhepp@computer.org
[2] University of Bremen, Bibliothekstrasse 1,
28359 Bremen, Germany
cagarcia@uni-bremen.de

Abstract. Social Tagging Systems (STS) empower users to classify and organize resources and to improve the retrieval performance over the tagged resources. In this paper we argue that the potential of the social process of assigning, finding, and relating symbols in collaborative tagging scenarios is currently underexploited and can be increased by extending the meta-model and using this extension to support the emergence of structured knowledge, *e.g.* semantic knowledge representations. We propose a model that allows tagging as well as establishing relations between any pair of resources, not just objects and tags. Moreover, we propose to use this extension to enrich and facilitate the process of building semantic knowledge representations. We (1) provide a formal description for our approach, (2) introduce an architecture to facilitate semantic knowledge derivation, and (3) present a preliminary experiment.

Keywords: Social Web, Semantic Web, tagging, folksonomies, meta-model, emergent semantics, Web 3.0, collaborative ontology engineering

1 Introduction

Social tagging systems (STS) have become increasingly popular and useful within the Web 2.0; simplicity and immediate benefits for end users are amongst the likely rationales behind this broad adoption [1]. STS allow agents, *i.e.* users, to freely associate terms, *i.e.* tags, to resources; these systems also facilitate the classification and organization of such resources. Tags gathered in this way are mainly used to improve retrieval performance over the tagged resources [2], and also to promote social interaction by enabling the construction of social networks based on the common interests that they represent [3].

Despite major advancements, ontology engineering still faces the challenge to properly involve broad audiences and to integrate and reuse existing knowledge [4-7]. Although STS have proven to provide significant benefits, deriving semantic knowledge representations, *e.g.* ontologies and taxonomies, from STS is still difficult [8-10]; typical problems are rooted in variations amongst tags as well as the heterogeneity of systems [3]. On one hand, tags can be ambiguous. For instance *sf* could mean both *San Francisco* and *Science Fiction*. Also, links amongst different but related tags (synonyms and spelling and morphological variants) are scant. Furthermore, tags introduce heterogeneity of aggregation, *i.e.* different levels of granularity or expertise, which leads to data precision conflicts [2, 11-13]. On the other hand, STS do not share a common representation for the tagging activity, making it difficult to share and reuse tagging data across them [14].

In this paper we propose a novel approach aiming to facilitate the emergence of richer semantic structures from the information gathered by means of STS. We have reused and extended previously proposed meta-models representing STS [1, 15-17] improving the use of both the social and the tagging process. Our model explicitly supports the representation of relations amongst taggable objects, *i.e.* resources, tags, and agents. For instance, it is possible to represent the relation *isCapitalOf* between the tags *Munich* and *Bavaria* as well as adding meaning to numerical tags, *e.g. IBM wasFoundedIn 1896*. The application of our model facilitates deriving baseline ontologies, *i.e.* a draft version containing few but seminal elements of an ontology form inputed contributed by broad user audiences.

This paper is organized as follows: In Sections 2 and 3 we present our main approach, in particular the model and architecture. In Section 4 we describe a preliminary experiment and evaluation. In Section 5 and 6 we summarize and discuss related work. In Section 7 we conclude our work and point to future extensions.

2 TagSorting: Ontologies from Social Tagging Systems

Our approach, named *TagSorting*, is based on Card Sorting, a knowledge acquisition technique that has been used to facilitate the ontology building process, mainly those tasks related to the concepts hierarchy. In our case, *tags* and *relations* act as cards that have to be organized. TagsSorting is built upon the *HyperTag* model [18] that allows establishing relations as tags on any duplet of tags. We aim at (1) obtaining a taxonomy and (2) also *ad hoc* and other useful relations by the application of the Card Sorting approach.

The *HyperTag* model is built upon existing meta-models representing STS data so they can easily interoperate. Those models share the structure (*subject*, *predicate*, *object*) to represent tagging, more specifically (*agent*, *tag*, *resource*): they also share relations such as *associatedTag*, *taggedBy* and *taggedResource* [1, 14-17, 19, 20], see left side of Fig. 1. *HyperTag* introduces a simple, yet likely very effective, extension to the common arrangement in existing meta-models. As illustrated on the right side of Fig. 1, our model introduces a wider understanding for *Resource* and *Tag*. As in the traditional STS structure, the *subject* remains an *agent* and the *predicate* remains a *tag* but the *object* has been extended in our model: We have widened the range of taggable objects from single resources to resources, with agents and tags being also considered resources, plus duplets of such resources. With the tagged duplets, we can represent a relation between a pair of taggable objects, *i.e.* (*subject*, *object*). The HyperTag model ultimately aims to facilitate the process of building ontologies using STS as the primary source; in order to achieve this goal, we propose a layered architecture supporting a participative ontology building process in an incremental and iterative way, see Fig. 22.

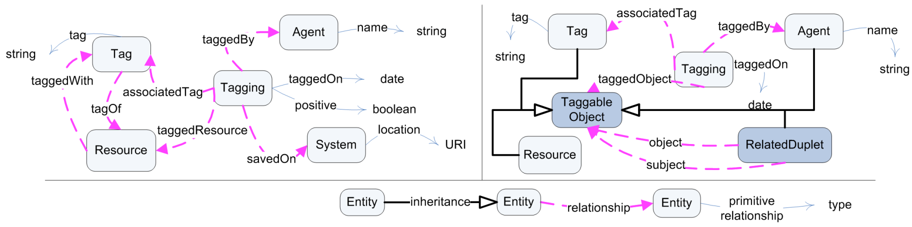

Fig. 1. Current meta-model and *HyperTag* meta-model for STS.

In the **first stage**, the project manager, *i.e.* a person or a group, defines a project: (i) the domain of the target ontology, (ii) the goals of building this ontology, (iii) the team participating in the project, (iv) a repository of local and online ontologies that will be used for suggestions, mappings, and disambiguations, (v) the set of rules to describe tags as Concept, String, Integer, Double, Boolean, Date, or URI, and (vi) the set of rules to categorize tags and relations as entities defined in the ontologies in the repository. In the **second stage**, the project manager generates the tags that will be used as seed entities, mainly representing concepts and primitive types, *i.e.* numbers, dates, and strings. The seed generation uses regular STS providing APIs to access their data, *e.g.* Delicious (http://delicious.com/) and Connotea (http://www.connotea.org/), and takes advantage of methods and statistics in order to include those tags that are more representative: the project manager can filter by agents, tagging dates, related tags, most used tags, and minimum length of tags.

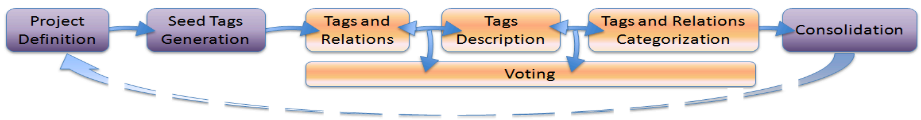

Fig. 2. *TagSorting incremental and iterative process.*

The next three stages correspond to the ontology building process and are carried out by the team, they can be done in a sequential or parallel way, and thus every person can do it in its own way. In the **third stage,** the participants take seed tags and relate them by attaching a tag to a duplet; whenever they feel the need, they can also create new tags. Participants are provided with suggestions based on: (i) predefined relations commonly used in mapping approaches, (ii) predefined relations selected from one or more ontologies in the repository, (iii) online ontology mining by using approaches such as SCARLET [21], and (iv) auto-complete from the initially typed letters. In the **fourth stage** the participants describe tags as Concept, String, Integer, Double, Boolean, Date, and URI, following a scenario-specific meta-model, while in the **fifth stage** they attach categories to tags and relations, *i.e.* they tag the tags and relations with terms from a predefined vocabulary; these two stages are optional because they can be done automatically based on rules defined by the project management. The **sixth stage** is done in parallel and consists in voting for tags and relations; anytime a participant uses/adds a tag a new vote is counted, optionally, they can also attach short explanations. The **seventh stage** is done by the project manager and consists of a consolidation process. Initially a consolidation is automatically generated taking into account all participants' taggings and votes; then the project manager does a final review and the approved ontology version is released. This version can be part of the process for a new version or a new ontology by including it into the repository and categorization rules.

TagSorting annotates agents, tags, relations, and taggable objects by means of the *HyperTag* model, which makes it possible to publish tagging data as RDF and thus optionally as Linked Open Data. In this way, it is possible to use SPARQL queries to extract useful information, and similarly to LODr, the tagging data becomes part of the Semantic Web so semantic search engines, *e.g.* Watson (http://watson.kmi.open.ac.uk), and SPARQL endpoints, *e.g.* Virtuoso (http://virtuoso.openlinksw.com/) can make use of it.

3 Preliminary Experiment

We conducted an experiment to find out whether our approach is a feasible way to collect meaningful data within a tagging environment in order to derive models in a specific domain. We wanted to evaluate (i) whether people are able to think in graphs and triplets, (ii) whether participants understand the *TagSorting* process, and (iii) how they use the process to perform specific modeling tasks. The goal of the experiment was to manually model the Google Nexus One phone as a product and was explained to the participants by means of written instructions and supported by a practical example from a different domain. All participants were students from the Universität der Bundeswehr in Munich. They received cards for the seed tags, descriptors, categories, and some suggested relations taken from the GoodRelations ontology. Three participants were from the business management degree program, and five from business information systems, all of them with at least basic command of social Web platforms such as wikis and tagging systems. Some had basic knowledge in modeling UML class and Entity-Relation diagrams. Participants had two weeks to achieve the goal, and they were allowed to work individually or by pairs as well as to comment, share, and compare their models.

The seed tags where generated during the second week of February 2010 using data from Delicious and the search facility that it offers. The keywords where *nexus* and *one* and the relevant time-frame was from January 1^{st} to 31^{st} of 2010, the first month of Nexus One in market. We obtained a total of 2555 tags and took 25% of them (875 tags reported on the first 35 pages of results) and used as seed tags only those returning at least one hit on http://www.google.com. The 26 resulting seed tags were: android, buy, cellphone, design, flash, gadget, google, hardware, info, iphone, mobile, money, network, news, nexus, nexus_one, nexusone, one, opensource, phone, phones, product, smartphone, technology, web, and wishlist. From the eight initial participants we got five models since some of them decided to merge their models, thus we got two individual models and three collaborative models. One of the individual models was dismissed since the participant did not attend the intial instructions and decided to model the social process behind buying a phone instead modeling the Google Nexus One phone as a product based on his lack of task understanding.

In the four collected models, we identified a total of 94 concepts, 31 strings, 6 booleans, 6 floats, 8 integers, 2 dates, and 70 relations. The four models mainly showed: (i) physical characteristics (buttons and dimensions), additional features (camera) and applications; (ii) name variants, similar phones, and applications; (iii) hierarchy (smartphone, cellphone, phone), physical characteristics (dimensions), additional features (camera and GPS), and applications; and (iv) hierarchy information, and applications. All participants agreed that seed tags facilitated the modeling task; however two participants felt forced to use all seed tags, which we did not intend. All of the 26 seeds where used, 17 in at least two different models as well as 4 new tags. For those tags used in at least three models and described at least once as concepts, we analyzed the descriptors and classified them as correct, arguably correct, and wrong; as an example, we present the first five classifications in Table 1.

Table 1. Frequency and classification for more common tags.

Tag	Frequency	Classification 1			Classification 2		
		Desc.	Freq.	Analysis	Desc.	Freq.	Analysis
google	100%	Concept	50%	Correct	String	50%	Wrong
iphone	100%	Concept	75%	Correct	String	25%	Wrong
smartphone	100%	Concept	50%	Correct	Boolean	25%	Arguably correct
android	75%	Concept	66.6%	Correct	Boolean	33.3%	Arguably correct
cellphone	75%	Concept	33.3%	Correct	Boolean	33.3%	Arguably correct

As far as the relations are concerned, similarities were harder to find, mainly because of lexical variations. From the four models we identified 70 relations corresponding to 54 different relations that could be narrowed down to 45 by means of specialized algorithms, *i.e.* lexical proximity and distance, see Table 22 for a summary of lexical variations on relations. We observed that consolidating descriptors before relating entities could facilitate consensus; also, we found that recommendation and social mechanisms could facilitate the consolidation of relation types, *i.e.* object or datatype, domains, and ranges, as well as relations reuse.

Table 2. Lexical variations on relations.

Relation	Used in # models	Variations
hasAManufacturer	2	hasManufacturer
hasApp	3	has Applications, hasApps
hasHeight	2	hasHight
hasReleasedDate	2	isReleasedOn
hasVariant	3	hasAVariant, isVariantOf

The experiment showed that concepts are easier to identify and consolidate than relations. Descriptors, *i.e.* concept, boolean, date, integer, float, and string, were more used than categories likely since those require a deeper knowledge of the domain; descriptors also facilitated distinguishing between object and datatype properties.

From the collected models it is possible to semi-automatically derive an ontology: first we identified entities, *i.e.* hypertag:tag, and relations, *i.e.* hypertag:relatedDuplet; then we use descriptors, *i.e.* tags on tags, to define entities as classes or primitive types, which is also useful to decide whether a relation is an object or a datatype property. This first version of the domain model can be refined by the project manager and the final version can evolve by repeating the TagSorting process.

4 Related Work

Work related to our approach can be grouped into two main categories:

Representing Social Tagging Systems. STS have been represented by means of meta-models and ontologies. In both cases, approaches involve agents (A), tags (T), resources (R), and tagging (TA), which represent an agent assigning a tag to a resource; some of the models also add other dimensions such as time and systems on which the annotations took place.

Mika [15] proposed a basic meta-model that represents STS as a graph where A, T, and R are the vertices and TA are the arcs. Hotho *et al.* [1] adds a component ($\prec$) to allow sub/super-ordinate relations between tags. Tanasescu & Streibel [20] do not distinguish between R and T (RT); they allow tagging tags in order to add meanings, thus they consider a direction (D) that represents directional annotations of relations between entities (RT).

Newman [17] proposes a basic ontology where TA is a triplet; he also offers object properties between tags to represent similarity: *relatedTo* and *equivalentTo*. Knerr's ontology [22] aims to provide a single entry point to different STS: *Time* refers to the tagging date, *Domain* specifies the STS, *Visibility* can be private, public, or protected, and *Type* is related to the resource nature, *e.g.* video, image, and website. Gruber [16] shares the basic Newman's model and includes the system (S) on which annotation took place; also agents are allowed to vote [+/−] for tags in order to reduce spam. The Meaning-of-a-tag ontology (MOAT) extends Newman's ontology and provides a way for users to attach meanings (M) to their tags; a meaning relies on a resource and is part of the tagging (TA). Finally, the semantic cloud of tags ontology (SCOT) represents the structure and semantics of tagging data by means of a cloud of tags and facilitates importing and exporting amongst different systems (S).

Consolidating Knowledge in Social Tagging Systems. Consolidation of tagging data has been used to facilitate emergent semantics and semantic mapping; it has also been used to allow agents to maintain and transport their personal tagging vocabulary.

Folksontology [23], Tang *et al.* [9] and Folks2Onto [8] propose semi-automatic approaches in order to derive ontologies from STS. Folksontology [23], proposes an approach to derive ontologies from STS by means of (i) datasets obtained from STS in order to determine pair of related tags, enriching tags with hierarchical relations, and agents and tags clusters, and (ii) disambiguation and cleaning techniques based on online lexical resources usage as well as concepts and relations, e.g. homonyms and synonyms. Tang *et al.* [9] introduce a learning approach to derive ontologies capturing the hierarchical semantic structure from STS. The authors propose a probabilistic model for tags and tagged resources, which is jointly used with some divergence measures to quantitatively distinguish relations amongst tags. The hierarchical structured is derived from those relations; with this approach is possible to identify synonymy as well as hypernym relations. Folks2Onto [8] proposes a software-based approach to turn STS into ontologies by means of mappings. It supports Technorati (http://technorati.com) and Delicious as STS, and WordNet (http://wordnet.princeton.edu) and DublinCore (http://dublincore.org/) as ontologies. Folks2Onto first employs a retriever and a trainer in order to establish mappings, which will be used for the mapper to generate an RDF representation of the target ontology. Tanasescu & Streibel [20], Braum *et al.* [24], Golov, Weller & Peters [25], and Sharif [26] propose specific STS in order to facilitate ontology derivation. Tanasescu & Streibel [20] propose Extreme Tagging, which aims to extend STS in order to allow the collaborative construction of knowledge bases; this is achieved by means of allowing agents to tag resources as well as tags. In this way it is possible to obtain hierarchy relations as well as other kinds of semantic associations. Similarly to Extreme Tagging, the Mature Project [24] aims to use STS to allow emergent semantics and deriving ontologies; in this project, Braun *et al.* do not extend the basic STS meta-model but define an ontology building process supported by an STS-based application: The first phase is the emergence of ideas by means of tags introduced by agents; the second one is the consolidation of data and the emergence of a common vocabulary through the reuse and adaption of tags; in the third phase the tags are organized according to a hierarchy and ad hoc relations; the last phase deals with the axiomatization and is carried out by domain experts. It captures semantics by adding background knowledge. Same as the Mature Project, TagCare [25] also offers a STS but the purpose here is allowing agents to maintain and transport their personal tagging vocabulary across different platforms. It aims to help agents to apply the same tags uniformly in different platforms based on a so-called "personomy", *i.e.* a cross-platform personal tagging vocabulary. In TagCare, agents are allowed to consolidate their tagging data as well as to create their own vocabulary hierarchy, synonyms relations, and cross-references. Finally, Sharif's [26] approach aims to use the flexibility from STS and the structured model of knowledge from ontologies in order to complete the process of knowledge representation on the Web. He proposes to improve searching, navigation, and integration and retrieval in STS, and lowering entry barriers in ontology building, which is achieved by means of a model, *i.e.* an ontology representing STS, and two sub-models, one for the knowledge acquisition and organization and the other one for knowledge discovery.

5 Discussion

Several positive effects of STS have been reported in the literature, e.g. by [2, 23, 24]: (i) Tags facilitate the navigation over tagged resources without imposing predefined categories on users; (ii) the social process on STS allows discovering implicit relationships, and similar skills, tasks, or interests; and (iii) collaborative filtering and recommendations support the emergence of consensus and the consolidation of meta-data. Our approach takes advantage of all those mentioned strengths.

Our *HyperTag* conceptual model is built upon the work by Mika [15] and byNewman [17] and is compatible with the work by Gruber [16] and by Passant & Laublet [19]. It allows tagging tags as described by Tanasescu & Streibel [20], as well as defining hierarchical relationships as those available in Bibsonomy (http://www.bibsonomy.org/). It is also designed to remain compatible with (i) existing approaches to derive formal structures from tagging data such as FLOR [11] and SCARLET [21], (ii) normalization and disambiguation techniques such as [27-29], (iii) the addition of meaning to tags by using URIs [19], and (iv) techniques and tools for tag data consolidation amongst platforms [14].

The *TagSorting* approach is comparable to others also aiming to build ontologies based on social Web platforms such as the Maturing Project [24], STYLid [30], and MyOntoloy [31]. The *TagSorting* architecture aims to facilitate building conceptual models including mappings, whereas the other approaches focus only on taxonomies and hierarchies. Similarly to the other approaches, *TagSorting* allows the participation of regular users, domain experts, and ontology engineers; it is also suitable for building domain ontologies, which are considered dynamic and evolving. Consensus, convergence and strategies for identifying concepts also rely on social mechanisms. The consolidation of knowledge takes into account privileged users [24, 31], usage and popularity [30], as well as online knowledge mining. *TagSorting* facilitates the reuse of knowledge in STS as well as online ontologies by harvesting existing knowledge as proposed by [11, 21, 32] while the others reuse mainly their own knowledge representations [24, 30] or specific sources such as Wikipedia and eClassOWL [31].

6 Conclusions and Future Work

In this paper we (1) analyzed the advantages of using the *HyperTag* conceptual model to represent tagging and relations between an extended set of taggable objects, (2) presented and discussed our *TagSorting approach* to support ontology building within a STS environment in a collaborative way, and (3) compared it with similar approaches, illustrating the advantages and limitations, (4) reported on a preliminary experiment and associated results.

The *HyperTag* model and the *TagSorting* approach rely on STS characteristics, *e.g.* architecture of participation, collaborative environment, and support for the emergence of consensus and consolidation of meta-data. *HyperTag* allows agents to establish free relations between any pair of taggable objects, thus facilitating the reuse of semi-structure knowledge, *i.e.* tagging data, in the ontology building process. Our model exploits the potential and strengths of STS, keeping the simplicity and offering new possibilities to agents by means of the proposed extension of the taggable objects. This facilitates capturing and establishing morphological and semantic variations for tags [16], building hierarchical and *ad hoc* relations, building and maintaining semantic-social networks based on tagging, and improving the search & retrieval, and knowledge reuse by exploiting the tagging structure [33].

TagSorting facilitates the process of building ontologies based on information gathered on STS environments; however a further evaluation is required to improve and tune our approach and to overcome some difficulties related to the consolidation and lexical variations in both entities and relations by means of community consensus based on use, popularity, and voting mechanisms. Another feasible applications of the *HyperTag* model will also be evaluated, *e.g.* explicitly interlinking tagging communities by combining relations across agents, controlled vocabularies, taxonomies or ontologies, and inference rules; for instance, knowing that Lisa *is mother of* Maria, and Maria *is married to* Nathan, it would be possible to infer that Lisa *is mother in law of* Nathan. Using the *HyperTag* model and the *TagSorting* architecture in different scenarios, we expect to achieve: (i) consolidation and interlinking knowledge and communities amongst STS, (ii) deriving lightweight ontologies from STS, and (iii) establishing an STS environment to facilitate ontology building.

7 References

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