Position Paper: Ontology Learning from Folksonomies

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Abstract

The emergence of collaborative tagging systems with their underlying flat and uncontrolled resource organization paradigm has led to a large number of research activities focussing on a formal description and analysis of the resulting "folksonomies". An interesting outcome is that the characteristic qualities of these systems seem to be inverse to more traditional knowledge structuring approaches like taxonomies or ontologies: The latter provide rich and precise semantics, but suffer - amongst others - from a knowledge acquisition bottleneck. An important step towards exploiting the possible synergies by bridging the gap between both paradigms is the automatic extraction of relations between tags in a folksonomy. This position paper presents preliminary results of ongoing work to induce hierarchical relationships among tags by analyzing the aggregated data of collaborative tagging systems as a basis for an ontology learning procedure.

1 Introduction

A fundamental aspect of knowledge management is often the establishment of structure within a set of information resources, e.g., PDF documents, bookmarks or photographs. Most traditional approaches address this issue by decomposing the domain under consideration into interrelated classes or categories, which are intended to model exhaustively the underlying knowledge structure. Each available information resource is then assigned to one or more classes. Ontologies are a well-known formalism for this purpose. The hierarchical topic category structure of, e.g., a web directory like the Open Directory Project[1] can be seen as an example of a taxonomy, which constitute a core component of ontologies [Staab and Studer, 2004]. Their widespread use is however hindered by the expertise and cost required for their creation and maintenance.

Collaborative tagging systems feature another structuring paradigm: Each user can assign one or more arbitrary keywords (or *tags*) to each of his resources, facilitating a flat "by-keyword" access to personal or public resources. The resulting structure of users, tags and resources became known as *folksonomies* [Mathes, 2004]; refer to [Hotho *et al.*, 2006] for a formal definition. Due to their inherent simplicity and immediate usefulness, these systems are able to overcome the previously described knowledge acquisition bottleneck. However, this comes at the cost of a lack of precision (see [Golder and Huberman, 2006]), which is exactly the strength of ontological approaches.

As a first step towards unleashing synergies by automatically learning ontologies from folksonomies, this position paper proposes an algorithm to induce hierarchical relationships among tags. The algorithm has been tested with real-world user data from the social music sharing platform *Last.fm*[2], and the outcome has been evaluated against a gold-standard music style hierarchy taken from the comprehensive online music directory *MusicMoz*[3].

2 Inducing Hierarchical Relations among Tags

The goal of this work is to automatically induce a concept hierarchy, i.e., a tree structure, whose nodes (representing concepts) each consist of one or more tags from a folksonomy. Concept specificity increases with increasing depth in the tree, and there exists only a single type of relation, whose semantics resembles closely the one of the taxonomic relation [Bozsak *et al.*, 2002].

Data foundation The most often used information source is based on two types of so-called *tag-tag-cooccurrence networks*, which can be extracted from a folksonomy. Each existing tag corresponds to a node, and there exists a undirected edge with weight w_{ij} between two tags t_i and t_j if

- there were w_{ij} users who have used both t_i and t_j to annotate any of their resources (*user-based tag-tag-cooccurence, UTC*)
- there were w_{ij} resources both annotated with t_i and t_j by any user (*resource-based tag-tag-cooccurence, RTC*)

Classes of approaches Existing approaches based on tag cooccurrence information can be assigned to one of the following three classes:

- *Social Network Analysis:* [Mika, 2005] pioneered in applying centrality and other measures like the clustering coefficient coming from social network analysis to the UTC and RTC networks in order to identify broader and narrower terms. [Heymann and Garcia-Molina, 2006] proposed betweeness centrality as tag generality measure. The latter approach will serve as a basis for the proposed algorithm.

[1] http://www.dmoz.org

[2] http://www.last.fm

[3] http://www.musicmoz.org

- *Statistical approaches:* The work of [Schmitz, 2006] and [Schmitz *et al.*, 2006] is based on statistical models of tag subsumption, the latter is corroborated with the theory of association rule mining.
- *Clustering approaches:* Starting from a similarity measure between tags, clustering approaches like [Begelman *et al.*, 2006] identify groups of highly related tags. Depending on the chosen clustering algorithm, a hierarchical relationship between the tag clusters is established.

Proposed Algorithm The proposed algorithm is an extension of the work of [Heymann and Garcia-Molina, 2006]. It comprises the following steps:

1. Filter the tags by an occurrence threshold τ_{occ}
2. Order the tags in descending order by generality (measured by degree centrality [Hoser *et al.*, 2006] in the UTC network)
3. Starting from the most general tag, add all tags t_i subsequently to an evolving tree structure:
   - identify the most similar existing tag t_{sim} (using the weights w_{ij} in the UTC network as similarity measure)
   - decide whether t_{sim} and t_i are synonyms or form a compound expression (using an adapted statistical model of subsumption from [Schmitz, 2006] based on the RTC network)
   - if yes → merge t_{sim} and t_i, otherwise append t_i as a less general term underneath t_{sim}.

Compared to the original algorithm, the first extensions consists of applying a computationally much less complex centrality measure (namely degree centrality) as tag generality measure. The original measure is based on betweenness centrality, whose computation requires $O(nm + n^2 \log n)$ time [Brandes, 2001], whereby n is the number of tags and m is the number of edges in the weighted cooccurrence network. This dimension becomes problematic when applied to real-world large scale folksonomy systems. As a further extension, tag synonymy and compound expressions (e.g., *"open"* and *"source"*) are considered.

3 Assessing the Quality of Learned Relations

Choosing a gold-standard based evaluation paradigm, it is a non-trivial task to judge the similarity between a learned concept hierarchy and a reference hierarchy, especially regarding the absence of well-established and universally accepted evaluation measures. As a detailed description of the similarity measures used is beyond the scope of this paper, the reader is referred to [Dellschaft and Staab, 2006] for an overview. Two of the described measures, namely taxonomic precision / recall / F_1-measure and the OntoRand-Index were adapted to compare two hierarchies on an instance-based level: The underlying idea is that two concept hierarchies are very similar if they structure the resources in question in a similar manner.

4 Preliminary Experimental Results

In order to validate the proposed algorithm, experiments were conducted with a dataset crawled from the social music sharing website *Last.fm*[4]. It consists of 978 resources (i.e., music artists), 3585 users and 7283 tags, connected by 162406 tag assignments. As a gold standard, a music style hierarchy (built by volunteer music fans) consisting of 548 styles was downloaded from *MusicMoz*[5]. Each artist from the Last.fm dataset was assigned to 1-3 MusicMoz style categories.

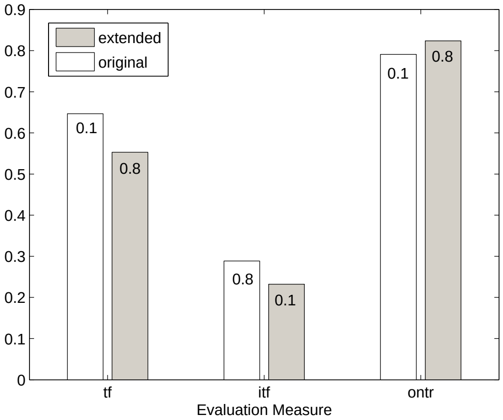

Figure 1: Experimental Results: Comparison of the performance of the proposed algorithm with the original version. The numbers in the bars correspond the optimal parameters for each algorithm as found in the first test phase.

The experimental setup consisted of two phases:

1. parameter optimization for both the original and the proposed algorithm
2. comparison of the performance of both algorithms with the obtained optimal parameters, compared by the taxonomic F_1-measure (tf), the instance-based taxonomic F_1-measure (itf) as well as the extended OntoRand-Index $ontr$.

Figure 1 displays the results. For none of the given measures, there is a clear winner. An important issue when interpreting the differing assessments of the measures is their respective basis: The taxonomic F_1-measure (tf) compares two hierarchies based on matching concept names, while the instance-based taxonomic F_1-measure (itf) and the extended OntoRand-index are based on the assignment of information resources to each concept. It is obvious that the two latter measures are strongly influenced by the chosen assignment strategy.

Considering the fact that the proposed algorithm is computationally much less complex (see Section 2) compared to its original version, the results are acceptable. To get a better impression of the capabilities of the proposed algorithm, Figure 2 illustrates its outcome. Following paths from the hierarchy root towards the leafs, the styles become more and more specific. Starting from the *ROOT* node in the center of the image, one nice example is the path *rock* → *metal* → *death metal* → *progressive death metal* towards the lower left corner.

5 Conclusions and Further Work

This paper presented preliminary results of ongoing work on inducing hierarchical relationships among tags in a folksonomy as basis for an ontology learning procedure. Experiments with real-world data suggest that the proposed

[4] http://www.last.fm

[5] http://www.musicmoz.org

algorithm is able to produce a consistent hierarchical category scheme, which comes close to a handcrafted scheme. An open issue for future research is how to assess the quality of the gold-standard the outcome of the learning procedure is compared with. A deeper theoretical understanding of the interaction of the algorithm's building blocks (i.e., tag generality measure, tag similarity measure and tag subsumption measure) is needed in order to further improve the results. Another aspect that needs consideration is how the resources of the folksonomy are assigned to the resulting hierarchical structure.

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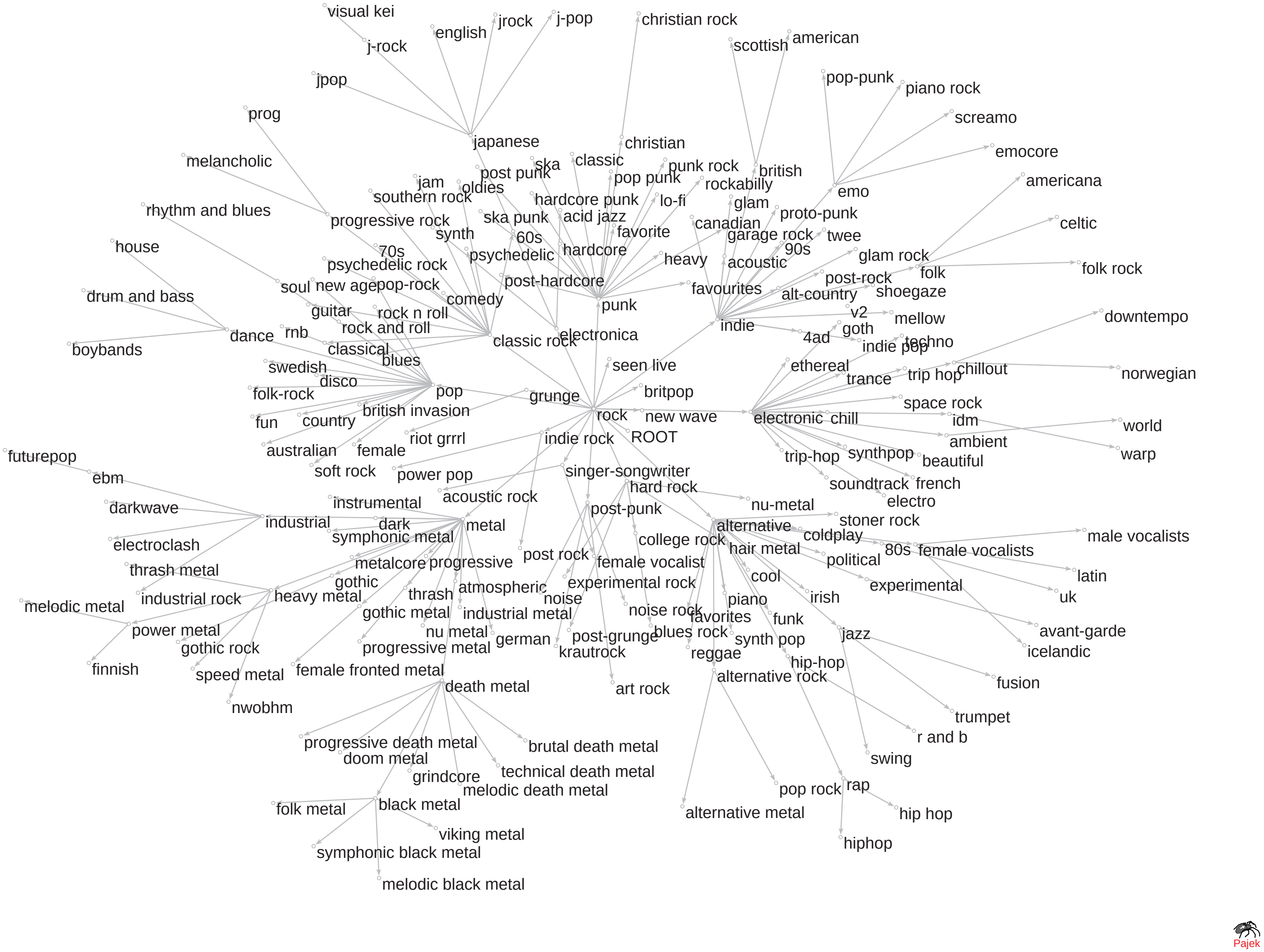

Figure 2: Music style hierarchy extracted from Last.fm dataset by the proposed algorithm.