Folksonomy as a Complex Network

Kaikai Shen, Lide Wu
Department of Computer Science
Fudan University
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Abstract
Folksonomy is an emerging technology that works to classify the information over WWW through tagging the bookmarks, photos or other web-based contents. It is understood to be organized by every user while not limited to the authors of the contents and the professional editors. This study surveyed the folksonomy as a complex network. The result indicates that the network, which is composed of the tags from the folksonomy, displays both properties of small world and scale free. However, the statistics only shows a local and static slice of the vast body of folksonomy which is still evolving.

Keywords: Folksonomy, Tag, Complex network, Small world, Scale free

1 Introduction
1.1 Folksonomy and Tags
The etymology of the word Folksonomy shows that it’s a portmanteau of the words folks and taxonomy coined by Thomas Vander Wal[1], which implies that it could be understood as an organization by folks, especially of the contents over the world wide web. Being different from the traditional approaches to the classification, the classifiers in folksonomy are not the dedicated professionals, and Thomas Vander Wal described this as a "bottom-up social classification"[4]. Adam Mathes explains folksonomy that users of the documents and media create metadata - data about data - for their own individual use that is also shared throughout a community[2].

Del.icio.us (http://del.icio.us), Furl (http://www.furl.net) and Flickr (http://www.flickr.com) are three most popular folksonomies. Their users describe and organize the content (bookmarks, webpages or photos) with their own vocabulary and assign one or more keywords, namely tags, to each single unit of content. The folksonomy is thus implemented through the tags assigned.

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Therefore, tags are now the mainstream approach to the application of folksonomy, and folksonomy is currently often understood as tagging.

1.2 Folksonomy as Network

As was mentioned above, folksonomy enables users to share their individual use of tags in the community. Users share various contents under one same tag, or share different tags assigned to one piece of content. Thus tags are linked to each other and so are the contents. Such a feature makes it possible to understand the folksonomy a network of tags or contents.

Besides the network of folksonomy, some similar networks were reported to display the properties of small world or scale free. It is possible to measure the graph properties of World Wide Web in order to quantify the information therein and give out an explanation or its evolution. In 2001 Ferrer i Cancho and Solé defined a network in English language. Another study by Yook, Jeong and Barabási constructed a network based on the synonym according to Merriam-Webster Dictionary. They observed a small average path length clustering coefficient and power-law degree distribution, and indicated that language also forms a complex network in some respects. Rosa Gil et al. model and analyze the semantic web as complex system.

In the light of these works and results, the network of folksonomy can be defined and constructed. While comparing this network with that modeled by Rosa Gil et al., the difference lied mainly in the difference between the tags and the ontologies in the DAML Ontology Library.

2 Properties of Folksonomy Network

In order to learn the conformation of the folksonomy network realized through tags, to see whether it displays such properties of small world or scale free and to measure the folksonomy, the model of the network must be defined first. Folksonomy can be considered as a graph where nodes represent the tags and different tags assigned to one piece of content are linked by edges. This graph is an undirected graph. Regardless of multiple contents covering two tags, the graph is not a weighted graph.

Degree distribution For an selected node $i$ in the folksonomy network, its degree $k_i$ represents the number of tags which share at least one piece of content with the tag (or node) $i$. For each network, the spread in node degree follows a distribution function $P(k)$. For scale free networks, the degree is in a power-law distribution

$$P(k) \sim k^{-\gamma}.$$

Clustering coefficient For node $i$ with the degree $k_i$, it is connected with $k_i$ nodes in the network. There are $E_i$ edges in this subgraph of $k_i$ size, and
could be at most \( C^2_{k_i} = \frac{1}{2}k_i(k_i - 1) \) edges between these \( k_i \) nodes. The ratio

\[
C_i = \frac{2E_i}{k_i(k_i - 1)}
\]

is the clustering coefficient of the node \( i \). The clustering coefficient \( C_i \) measures the interrelatedness of \( i \)'s neighbors.

**Average path length** For two nodes \( i, j \) in the same connected component, \( l_{ij} \) is the minimum length of path between them. The average path length \( l \) is the average value of all \( l_{ij} \).

3 **Experiment**

The data set of the experiment is based on the records of the bookmarks submitted to Del.icio.us during 26 Mar. to 27 Mar., 2005. Del.icio.us provides the service that enables users to categorize their bookmarks or links with tags.

All the data used in this experiment is available through the subscription of RSS feed of Del.icio.us (http://del.icio.us/rss). For each entry of the bookmarks, only the information of the URL, the time of submission and the tags were recorded. Other information as the creator, the title was ignored in the experiment.

For every distinct URL, all the tags attributed to it will be linked to each other with edges. The network is thus constructed.

3.1 **Folksonomy as a Small World Network**

Random networks were first defined by P. Erdős and A. Rényi in 1959. In such a random network of Erdős-Rényi model, the average path length \( l_{\text{random}} \) is small with regard to the size \( N \) of the network,

\[
l_{\text{random}} \simeq \frac{\ln N}{\ln \langle k \rangle}
\]

and its clustering coefficient

\[
C_{\text{random}} \simeq \frac{\langle k \rangle}{N}.
\]

The small world network of Watt-Strogatz displays\cite{9,10}, as the random network with the same \( N \) and \( \langle k \rangle \), the similar property of small average path length

\[
l \simeq l_{\text{random}}
\]

however with a relatively high clustering coefficient

\[
C \gg C_{\text{random}}.
\]

The properties of the network of folksonomy tags in experiment turns out as follows.
- Nodes (the number of tags) $N$: 9804
- Average node degree $\langle k \rangle$: 11.0
- Clustering coefficient $C$: 0.06
- Average path length $l$: 3.40

For the network in the experiment, its average path length $l = 3.40$ is approximately the length $l_{\text{random}} \simeq 3.83$ of the corresponding random network. And its clustering coefficient $C = 0.06$ is much larger than the prediction $C_{\text{random}} \simeq 0.001$ if the network is random. Therefore it can be concluded to be an small world network.

3.2 Folksonomy as a Scale Free Network

Lots of real networks are reported to be scale free [8], i.e. its degree distribution $P(k)$ is in power-law

$$P(k) \sim k^{-\gamma}.$$ 

While in Erdős and Rényi’s theory, the degree distribution $P(k)$ of a random network will follow Poisson distribution.

The property of scale free can be detected in the folksonomy network. Figure 1 indicates the distribution is linear in logarithmic scale, as well as its Complementary Cumulative Distribution Function, CCDF, in Figure 2. The result from the folksonomy network (see Figure 1) shows its degree distribution decays at the rate of $k^{-\gamma}$, where the power-law exponent $\gamma$ is 1.418.

Table 1 is a top-20 list of tags involved in experiment with the most degree in the network, namely, those have the most contacts with the other tags.

4 Conclusion and Future Work

The experiment samples a part of the folksonomy at Del.icio.us, which demonstrated above that the folksonomy as a network formed by tags displays both nature of small world and scale free.

However the folksonomy network is said to be small world and scale free as local properties. The body of folksonomy is much larger than this fragment. All tags over WWW indexed by Technorati are more than 1 million[11]. It is possible that the panorama of folksonomy and the parameters of the whole network would differ from the present local ones.

Since users and authors over WWW submits their contents to folksonomy every minute, the network of folksonomy evolves over time. The work in the experiment surveyed the static properties of a folksonomy network, but the network is dynamically increasing every moment. The study of dynamics on the complex networks will be applied to the further analysis of folksonomy’s structure, behavior including its forming mechanism. Since folksonomy is a classification system of web contents, its properties both static and dynamic can also serve to search and retrieve the related information.
Figure 1: Degree distribution of folksonomy network. In logarithmic scale. $R$ is the correlation coefficient.
Figure 2: Degree Complementary Cumulative Distribution Function, CCDF. In logarithmic scale. $R$ is the correlation coefficient.
| Degree | Tag’s Name |
|--------|------------|
| 1504   | blog       |
| 1465   | web        |
| 1297   | software   |
| 895    | music      |
| 724    | design     |
| 631    | art        |
| 467    | programming|
| 326    | reference  |
| 265    | tools      |
| 205    | news       |
| 188    | cool       |
| 163    | linux      |
| 162    | mac        |
| 115    | internet   |
| 111    | howto      |
| 108    | blogs      |
| 94     | technology |
| 86     | fun        |
| 81     | science    |
| 47     | tech       |

Table 1: Top 20 degree tags

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