LaFT-Explorer: Inferring, Visualizing and Predicting How Your Social Network Expands*

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ABSTRACT

The study of social network evolution has attracted many attentions from both the industry and academia. In this paper we demonstrate LaFT-Explorer, a general toolkit for explaining and reproducing the network growth process based on the friendship propagation. LaFT-Explorer presents multiple perspectives for analyzing the network evolution process and structure, including LaFT-Tree, LaFT-Trace and LaFT-Flow. Upon that we build LaFT-Rec, a new visualized interactive friend recommendation service based on the friendship propagation. LaFT-Rec not only shows whom one may make friends with, but also tells the user that why you should make friends with him and how you can reach him. We demonstrate our system built upon the academic social network of DBLP.

Categories and Subject Descriptors

H.2.8 [**DATABASE MANAGEMENT**]: Database Applications—*Data mining*; H.5.2 [**Information Systems**]: Information Interfaces and Presentation—*User Interfaces*; J.4 [**SOCIAL AND BEHAVIORAL SCIENCES**]: Sociology

Keywords

LaFT-Explorer; LaFT-Tree; Transitivity of Friendship; Friendship Propagation; Social Networks Evolution

1. INTRODUCTION

Online social networks attract many attentions from both the academia and industry. Given a social network, an interesting question is: how does the social network grow as it is? Answering this question can benefit many applications, for example, to understand the evolving structure of the social network, to predict how the social network will evolve in the future, and to recommend friends for users, etc.

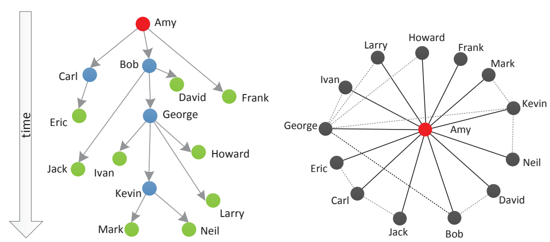
While much work has been done and many patterns about network growth have been discovered [1][2][3], most of them focus on the structural patterns of network evolution. The behavioral patterns, which describe the social behaviors of users, haven't been investigated deeply. As the network evolution can be regarded as the result of the users' social behaviors, mining the knowledge hidden in the user behaviors may benefit our understanding about the network evolution.

It is thus a promising direction to combine the sociological principles and data mining techniques for behavior-driven social network evolution analysis. As the first step, here we introduce the transitivity of friendship [6], a well-known sociological principle which states that two persons with common friends are more likely to become friends in the future. In other words, people are more likely to make friends with the friends of their friends. We call this phenomenon as *friendship propagation*.

The behavior-driven social network evolution analysis based on the transitivity of friendship presents a set of challenges:

- Can we explain and reproduce the social network growth process based on the friendship propagation?
- Can we clarify how one has contributed for the expansion of others' social network?
- Can we depict how the friendship propagates in the social networks?
- Can we predict how the network will grow based on the friendship propagation?

In this paper, we present LaFT-Explorer, a general toolkit which studies the social network evolution from the behavioral perspective. We employ LaFT-Tree [7] for describing the growth process of one's egocentric network driven by the friendship propagation. Let's illustrate the LaFT-Tree with an example. A LaFT-Tree with *Amy* as the ego, is shown in Fig. 1(a). It shows how *Amy* expands her social network via her current friends, i.e. the *intermediaries*.



(a) *Amy*'s LaFT-Tree (b) *Amy*'s egocentric network

Figure 1: *Amy*'s LaFT-Tree and corresponding egocentric network. In the LaFT-Tree, nodes are labeled and arranged vertically according to the time when they became friends of *Amy*.

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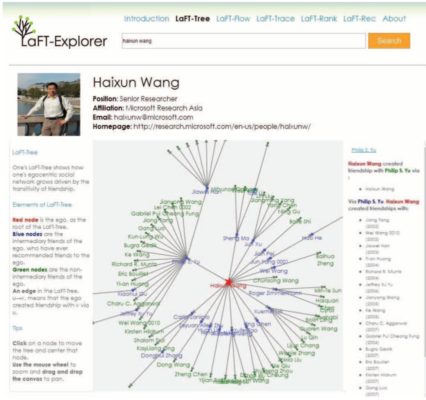

Figure 2: The LaFT-Tree of *Haixun Wang*.

In this figure we see that *Amy* makes friends with *Bob* and *Carl* directly first, and then via *Bob* she makes friends with *David* and *George*, via whom she meets more new friends including *Howard*, *Ivan*, *Kevin* and *Larry*, etc. In this tree each non-root node is a friend of the ego, and each blue node is meanwhile an intermediary via whom the ego has ever made new friends. By keeping making new friends along the paths in the LaFT-Tree, *Amy* gets her egocentric network, as shown in Fig. 1(b). As LaFT-Tree provides a new perspective for explaining the network growth and analyzing the network structure in a hierarchical view, it's beneficial and interesting to infer the LaFT-Trees for the given social networks.

LaFT-Explorer is a general toolkit for analyzing the network evolution and structure based on the latent friendship transitivity (that's why our system is named as "LaFT"). Given a social network, LaFT-Explorer provides multiple views of the network, including the LaFT-Tree and its derivants. Specifically, the major features of LaFT-Explorer include:

- *LaFT-Tree*, shows how one's egocentric social network grows driven by friendship propagation;
- *LaFT-Trace*, i.e. the path in LaFT-Tree, shows specific friendship propagation histories among friends and reveals their relative positions in the LaFT-Tree of others;
- *LaFT-Flow*, shows the potential friendship propagation in the social network;
- *LaFT-Rec*, a new tree-based, visualized interactive friend recommendation service based on the friendship propagation, which enables users to see not only whom is recommended, but also why one is recommended and how to reach him.

We summarize our main contributions as follows:

- We present a novel behavior-driven network evolution analysis problem and introduce how to analyze the network evolution process in a behavior modelling approach based on the transitivity of friendship.
- We build LaFT-Explorer, a general toolkit for inferring and visualizing the evolution process in multiple perspectives for a given social network.
- In LaFT-Explorer, we provide an interactive friend recommendation service based on the friendship propagation learned from user behaviors.

2. DEMONSTRATION

We'll demonstrate the concepts, usage and user interaction of LaFT-Explorer through scenarios on understanding the evolution process of an academic social network built upon DBLP[1], which contains about 329 thousands authors (nodes) and 1 million co-author relations (edges).

[1]http://dblp.uni-trier.de

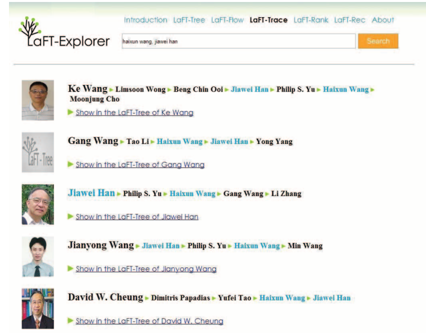

Figure 3: The LaFT-Traces containing both *Haixun Wang* and *Jiawei Han*.

2.1 LaFT-Tree

Our system enables users to find their LaFT-Trees given their names as queries in the LaFT-Tree page. For example, input "*Haixun Wang*" in the search box, and then our user will see his LaFT-Tree, as shown in Fig. 2. In the LaFT-Tree, the red node is the ego, as the root of the LaFT-Tree. Blue nodes are the ego's intermediary friends, via whom the ego has made new friends, and green nodes are the non-intermediary friends. In this figure, our user can see that *Philip S. Yu* is an important intermediary via whom *Haixun Wang* has created co-author relationships with many researchers, including *Jiawei Han*, another important intermediary for *Haixun Wang*.

When our user clicks on any node in the LaFT-Tree of *Haixun Wang*, say *Philip S. Yu*, more details about his position are displayed in the right panel, telling the intermediary via whom *Haixun Wang* created relationship with *Philip S. Yu* and the new friends with whom *Haixun Wang* has created relationships via *Philip S. Yu*. In this figure we can see *Haixun Wang* created relationship with *Philip S. Yu* directly and via *Philip S. Yu* he further created relationship with *Ke Wang*, *Jiawei Han*, *Jeffrey Xu Yu*, etc. Our user can also navigate to the LaFT-Tree of the selected researcher by clicking the link in the right panel.

2.2 LaFT-Trace

One may also be interested in that how he has participated in the historical friendship propagations and helped others to expand their social networks. Each historical friendship propagation path is named as a LaFT-Trace, represented by a path from the root (ego) to any other node in the LaFT-Tree. The LaFT-Explorer provides a LaFT-Trace search service which allows one to input the name(s) of one or more person(s) to search the LaFT-Traces involving them.

For instance, our user may be interested in that the role that *Haixun Wang* and *Jiawei Han* played together in the growth of the network of other researchers. Our user may input the two names in the search box in the LaFT-Trace page, and then the LaFT-Traces that contain both of them are shown, as in Fig. 3. From the figure, our user can see their relative positions in the LaFT-Trees of other researchers, including *Ke Wang*, *Gang Wang*, *Jianyong Wang*, etc. From the perspective of the ego, the LaFT-Traces show the paths along which s/he keeps making new friends via new intermediaries. From that of the intermediaries, the LaFT-Traces can show how one has participated in the friendship propagation and promoted the growth process of others' social circles.

By clicking on one of the LaFT-Traces, our user can navigate to the corresponding LaFT-Tree page and see the position of the selected LaFT-Trace in the LaFT-Tree.

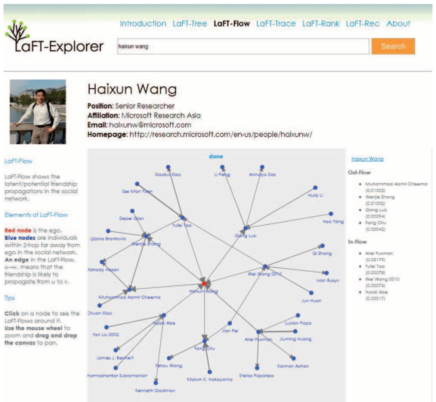

Figure 4: The LaFT-Flow around *Haixun Wang*.

2.3 LaFT-Flow

While LaFT-Tree shows how one's social network has grown, LaFT-Flow depicts the latent friendship propagations in the network. In other words, LaFT-Flow models the trends that one's friendship with someone will "propagate" or "flow" to any of her current friends. For each ego, the inward propagation is called her "*In-Flow*", and the outward propagation is her "*Out-Flow*". By depicting and visualizing the LaFT-Flow, we can easily see how the friendship will propagate in the network and predict the future shape of the network.

Our user can view the LaFT-Flow around *Haixun Wang* in the LaFT-Flow page, as illustrated in Fig. 4. Each edge in LaFT-Flow indicates a possible friendship propagation direction. By clicking on an individual, our user can see the detailed information of his top out-flows and in-flows. From the figure our user can see that the friendship from *Haixun Wang* is likely to propagate to *Gang Luo*, *Wenjie Zhang*, *Fang Chu* and *Muhammad Admir Cheema*, and the friendship that propagates to *Haixun Wang* is most likely from *Wei Wang*, *Naoki Abe*, *Ariel Fuxman* and *Yufei Tao*. The weights of each potential friendship propagation are shown in the right panel.

2.4 LaFT-Rec

LaFT-Tree tells not only how the network has grown, but also how it will grow. Each node in the LaFT-Tree is a potential expansion point, i.e. an intermediary, via whom the ego can make more new friends. Upon LaFT-Tree and LaFT-Flow, we provide LaFT-Rec, an interactive recommendation service in a tree-view. The recommended friends are shown as sub-nodes of the corresponding intermediary nodes in the LaFT-Tree. The new tree with recommendations is called the LaFT-Rec Tree.

The LaFT-Rec Tree of *Haixun Wang* is shown in Fig. 5. Each recommended friend is marked as yellow. By clicking on any intermediary, one can see the top candidate friends with whom *Haixun Wang* may make friends via this intermediary. In this figure, we can see *Xuemin Lin* is among his most preferable intermediaries. Via *Xuemin Lin*, he is most likely to build relationships with *Bolin Ding*, *Guoren Wang*, *Lu Qin*, etc., the researchers that *Xuemin Lin* often recommends to others and that via *Xuemin Lin* others usually make friends with.

Traditional recommender systems usually only give the results and don't tell the user that why they are recommended. On the contrary, LaFT-Rec Tree provides a natural way to recommend friends based on the potential friendship propagation, and reasonable explanations for the recommendation. Thus the user can understand how it works and further provide more targeted feedback to the recommender system to improve the recommendation. Furthermore, besides the recommended friends, the LaFT-Rec also recommends

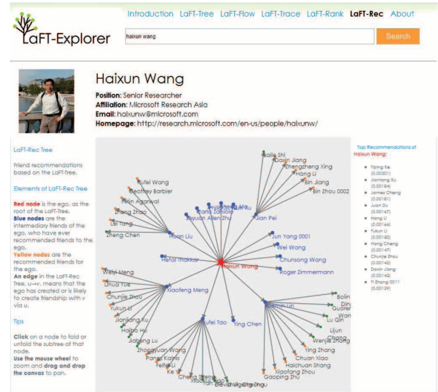

Figure 5: The LaFT-Rec Tree for *Haixun Wang*.

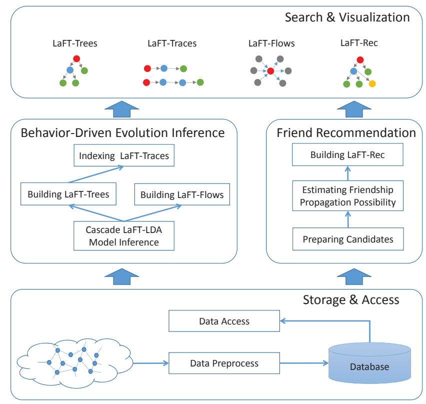

Figure 6: The architecture of LaFT-Explorer.

the intermediaries via whom one can reach the new friends. This is really beneficial and important in many real social networks, like academic social network, where one'll find it easier to invite a researcher as co-author if someone who is close to both of them would like to introduce them to each other.

3. TECHNICAL SPECIFICATION

In this section, we introduce how we build the system.

3.1 Architecture

The key components of our system are shown in Fig. 6. The system takes the evolution log of a given social network as input. The log contains friend-making log and interaction log, in the triple format of $< initiator\_id, receiver\_id, time >$. The triples are sorted by time and split into multiple periods. Then for each period we apply and infer the LaFT-LDA model [7] in cascade, and afterwards we build the LaFT-Trees and LaFT-Flows from the learned model. Given the LaFT-Trees, we index all the LaFT-Traces and provide a search interface. Furthermore, based on the LaFT-Trees and LaFT-Flows we build the LaFT-Rec, an interactive friend recommendation service for each user. All of them are then visualized and can be accessed by a browser.

3.2 Behavior-Driven Evolution Inference

A LaFT-Tree consists of an ego as the root and her friends as non-root nodes. An edge $z \rightarrow v$ in the LaFT-Tree of ego u indicates that u makes friends with v via z. In other words, z is the intermediary for u and v. Thus the key problem for learning LaFT-Tree is the inference for the intermediary of each friendship.

To learn the intermediaries, we adopt LaFT-LDA [7], a generative model of social behaviors. LaFT-LDA models one's friend-making behaviors using such process: Each time the ego selects

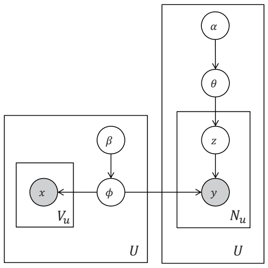

Figure 7: The LaFT-LDA Model

one of her current friends as the intermediary first, and then chooses one of the intermediary's friends as her new friend. The interaction behaviors are also modeled as extra evidence. The graphical representation of LaFT-LDA is shown in Fig. 7. In LaFT-LDA, the *intermediary preference distribution* θ describes one's preference for intermediaries when making new friends, while the *friend recommendation distribution* ϕ models one's tendency to recommend her friends to others. We split the friend-making and interaction event logs by time and apply LaFT-LDA in cascade. The model can be inferred using Gibbs sampling, as stated in [7].

After the model inference on all the intervals, we can get all the intermediaries for each friendship and then build the LaFT-Trees for each ego. Then we index all the LaFT-Traces, i.e. the paths in the LaFT-Trees, by nodes, and provide a search service. As ϕ in LaFT-LDA also models the probability that one's friendship with someone will "propagate" or "flow" to any of her current friends, we build *LaFT-Flow* utilizing ϕ.

3.3 Friendship Propagation based Friend Recommendation

Although it's common to recommend the friends of current friends as candidate friends, traditional approaches usually don't take the various influence of different current friends into consideration. With LaFT-LDA, we can learn one's preference for both intermediaries and friends from the network growth history. Such knowledge can be utilized to improve the friend recommendation. For a pair of candidate friends u and v, the *promotion* from an intermediary z is defined as $\theta_{u,z} \cdot \phi_{z,v}$. Combining the promotion from all possible intermediaries we get *LaFT-Proximity* [7], a score indicating the possibility that u and v will become friends based on the 2-hop friendship propagation. According to the scores of all candidate friends, we can give the top-k recommendations.

Based on the LaFT-Flow, we can provide better friend recommendation by considering the friendship propagation in the global network. We propose *LaFT-RW*, a simplified version of the *LFPN-RW* [8]. In LaFT-RW, for a pair of candidate friends u and v, the *promotion* from an intermediary z is defined as the product of $\theta_{u,z}$ and $RW(z, v)$, the probability that a random walker starting from z arrives at v finally in the network defined by LaFT-Flow. Thus *LaFT-RW* score between u and v is defined as:

$$\textit{LaFT-RW}(u, v) = \sum_{z} \theta_{u,z} \cdot RW(z, v) \quad (1)$$

where z enumerates each of the possible intermediaries.

Upon LaFT-Tree, we build LaFT-Rec, an interactive recommendation service which shows both the candidate friends and the intermediaries for the ego to know the candidates in a tree-structure.

3.4 Evaluation

To evaluate the performance of our friend recommendation algorithm based on the friendship propagation, we conduct the link prediction experiments on 5 datasets, including *dblp*, *astro-ph*, *cond-mat*, *hep-lat* and *hep-ph*. The first one is built from DBLP while the others are from Arxiv[2]. We compare our algorithm with some popular methods, such as Adamic/Adar [4], Jaccard Coefficient [4], RWR (Random Walk with Restarts) [5]. We evaluate them using the AUC (Area Under the ROC Curve) and the results are shown in Table 1. We can see that *LaFT-RW* consistently outperforms other methods on our datasets.

Table 1: The friend recommendation performance.

Dataset	Adamic/Adar	Jaccard	RWR	LaFT-Proximity	LaFT-RW
dblp	0.8022	0.8088	0.8492	0.8147	0.8524
astro-ph	0.8029	0.7918	0.8511	0.8119	0.8704
cond-mat	0.7781	0.7789	0.8103	0.7896	0.8211
hep-lat	0.7291	0.8252	0.8349	0.8224	0.8395
hep-ph	0.7764	0.7611	0.8002	0.7812	0.8102

4. CONCLUSION

In this paper we present LaFT-Explorer, a general toolkit for analyzing the network evolution based on the transitivity of friendship. Given the logs of a social network, LaFT-Explorer infers how the network has evolved as it is, visualizes how the friendship may propagate in the network, and predicts how the network will become in the future. Since the LaFT-Explorer is designed as a general toolkit, in the future we'll apply it on more real-world social networks, including Facebook, Twitter, LinkedIn, etc.

5. ACKNOWLEDGMENTS

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