Detecting Zombie Followers in Sina Microblog based on the Number of Common Friends

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Abstract

Microblog have become very popular in recent years. Sina Weibo is the top microblogging network in China. The popularity of Sina Weibo has attracted a large number of companies to do marketing on it. However, the Weibo marketing suffers from zombie followers, a kind of fake accounts.

In this paper, ZDACF (zombie follower detection approach based on the number of common friend), a social graph based approach is proposed to detect zombie followers. ZDACF uses the feature of social graph to detect zombie followers. ZDACF crawls Sina Weibo using Sina Weibo API to collect the follower dataset, and calculates the Nearest Neighbor Homology to distinguish the zombie followers from normal ones. We measure the effectiveness of ZDACF, the result of evaluation shows that the detection rate of ZDACF is better than the previously work on different classifiers respectively.

Keywords: Online Social Network, Microblog, Security, Zombie Followers;

1 Introduction

Microblog become more and more popular in recent years[1-3], Twitter is the most popular Microblog in the world, and Sina Weibo is the top Microblog in China which has 324 million registered accounts in 2012. Now the total number of Microblog registered users in China has exceeded Twitter globally.

The same as twitter, Sina Weibo employs a Microblog model called “following”[4], in which a user can follow any other user without seeking any permission. On Weibo, being a follower means that the user receives all the messages from those that the user follows, and these messages are called tweets. In an instance of “following” relationship, the Weibo user whose updates are being followed is called the “friend”, while the one who is following is called the “follower”.

The problem

As Weibo becomes increasingly popular in China, it is a great platform for companies to promote their products and services, broaden their business network and build their brand. Sina Weibo, announced that nearly 5000 companies had opened accounts. Weibo marketing becomes the main economic value which Weibo create in China.

People usually measure user influence by the number of followers [5, 6], the high influence means high value for companies to do Microblog marketing. Now the followers selling business is hottest among online services, a lot of users buy the fake followers to make them seem extremely popular. The fake followers are called zombie followers. Zombie followers become the major threat of Microblog marketing.

Similar to Sina Weibo, Twitter is also trouble with the problem of zombie followers. As “The New York Times” reports, 70% of Obama's crowd includes "fake followers", 71% of Lady Gaga's nearly 29 million followers are "fake" or "inactive."

Our approach

We propose ZDACF (zombie follower detection approach based on the number of common friend), a social graph based zombie followers approach. ZDACF does not rely on the profile features of Weibo account; instead, our approach is focused on the social graph structure.

ZDACF’s design principle, is motivated by a fundamental practice in zombie followers, there are many common friends in the zombie followers of a user. That is, a seller created numerous fake Weibo
accounts, and then sold them to different purchasers who want more followers. Therefore, in the social graph these fake accounts usually have many common friends who are the purchasers.

In the paper, we plan to give the formal description of common friends feature, and propose a social graph based zombie followers approach, then we validate the efficacy of the classification system based on the feature of the number of common friends.

Contributions
This paper makes the following contributions:
1. We introduce the concept of Common Friends Graph in order to study the social graph feature of zombie followers;
2. We propose a social graph based zombie followers approach (ZDACF);
3. We have implemented a prototype of ZDACF using the Sina Weibo API;
4. A series of classifiers are compared and applied in our approach. The results show that our zombie follower detection system has at least 96.0% detection rate on different classifier, and the detection rate is better than the profile feature based approach on each classifier respectively.

2 Background
The development of the Internet industry in China over the past decade has been impressive, the number of Internet users in China as of 2012 was reported to be 457 million. The newly emerging online services, Microblog, are developing rapidly in China and provide greater convenience for Chinese citizens to communicate online. Actively participating in online information communication and content creation, netizens have greatly enriched Internet information and content.

2.1 Sina Weibo
Sina Weibo was launched by the Sina corporation, China’s biggest web portal, in August 2009. Sina Weibo now has 250 million registered accounts and generates 90 million posts per day. Currently, Sina Weibo is preparing for launching an English version website to set foot in the US market as well. Meanwhile, Sina Weibo has become a big competitor of Twitter. The research result shows that Sina Weibo takes 56.5% market share on active user basis and 86.6% market share on browsing time basis. Both data prove that Sina Weibo is the current Microblog leader in China.

Similar to Twitter, a user profile on Sina Weibo displays the user’s name, a brief description of the user, the number of followers and follows the user has, and the number of tweets the user made. A user profile also displays the user’s recent tweets and retweets. The same as twitter, Sina Weibo employs a Microblog model called “following” which described in section 1.

As Weibo grows two times faster than Twitter [7], and it’s hard for us to use Twitter’s Application Programming Interface (API) to crawl Twitter in china, we chose Sina Weibo as the research platform.

2.2 Zombie followers
With the explosive growth of Weibo, it attracts companies, content provider, celebrity and government join the Weibo camp. Specially, Weibo is a unique network platform for company marketing. Weibo can attracts the target customers for the company, and the companies can build their brand images and gain large number of customers very quickly. As the convenient propagation of information of Weibo, network marketing staff can make rich and creative network marketing activities. Companies may get benefits in a short time with very low investment. In a summary the rapid development of Weibo provides a excellent marketing platform.

In Weibo, the better your tweets are, the more followers you will have. So the number of followers usually used to measure the influence of a user, but this measurement can easily be deceived by zombie followers. The zombie follower sellers create numerous fake Weibo accounts, sending their contact numbers to users who may need to boost their popularity. The “zombie followers” on Weibo have developed themselves into an interesting micro economy in China. By paying just US $50, one can immediately become a popular Microblog user with 50,000 followers. The low-lever zombie followers
take no part in Microblog discussions but merely raise the status of users, while the high-lever zombie followers can post several original zombie tweets per day in addition to about 10 to 100 mechanical retweets. The high-lever zombie followers are more expensive than the low-lever zombie followers. The production of zombie followers is simple, vendors working in teams create huge numbers of new accounts with fake names and email addresses in a couple of hours sitting at their computers.

The profile feature based detection approach can detect low-lever zombie followers very well, but it can’t detect high-lever zombie followers. In the paper, we propose a social graph based approach to detect all the zombie followers, and then we evaluate the efficacy of system on Sina Weibo.

3 Models and Assumptions

We now introduce our system and threat model, and our design assumptions and goals.

3.1 System and threat model

We consider social relationships and model the Weibo as an directed graph $G = (V, E)$ which consists of a set $V$ of nodes representing user accounts and a set $A$ of directed edges that connect node. An directed edge $e = (i, j)$ is directed from $V_i$ to $V_j$ which stands for the user $i$ is following user $j$, following on Sina Weibo is not a mutual relationship. Anyone can follow you and you do not have to approve. In this way, Sina Weibo is modeled as a directed graph. If $V_i$ is the follower of $V_j$, then $V_j$ is the friend of $V_i$.

In our threat model, a zombie follower seller creates many fake accounts, fraudulent users can purchase zombie followers from a zombie follower seller, we call fraudulent users as zombie follower purchaser. A zombie follower seller sells his zombie followers to many different zombie follower purchaser in order to get more profit.

![Figure 1 Threat Model](image)

A simple zombie followers graph example is shown in Figure 1. User b, user c and user d are zombie followers; user a and user e are zombie follower purchasers. User a has purchased two followers which are user b and user c. User e has purchased three followers which are user b, user c and user d. User b and user c has two common friends which are user a and user e.

On Weibo, there are two types of zombie followers: 1) purchased zombie followers: these zombie followers are purchased from the sellers; 2) non-purchased zombie followers: zombie follower sellers add some normal users to be their friends without requirement in order to make the zombie followers look like normal user.

In generally, the purchased zombie followers are the main type of zombie followers, and usually has a high ratio in the purchaser’s followers, it endanger the Weibo marketing. Therefore, we chose the purchased zombie followers as the detected object in this paper.

3.2 Assumptions

We make the following assumptions based on the social graph features of zombie friends.
High ratio in Follower List  In order to benefit from the Weibo marketing, the number of zombie followers usually accounted for high ratio of the total followers of a purchaser, we assume that the minimal value of ratio is 50%. We do not believe that a lower ratio is worth to purchase from the standpoint of the purchaser, and a low ratio can’t affect the Weibo marketing significantly.

Repeat sale For the purpose of profit, a zombie follower seller usually sell his zombie followers to many different zombie follower purchasers simultaneously. For example in the Figure 1, the zombie follower seller sell his zombie followers to user a and user e. Sell each zombie follower to different purchasers simultaneously can increase the profit of signal zombie follower, and can lower the price of signal zombie follower. So we assume each zombie follower has been sold to different purchasers repeatedly.

4 Approach

In this section, we describe the basic idea of zombie follower detection, formalize the problem of zombie follower detection, and provide an algorithm for detecting zombie followers.

4.1 Basic idea

In social network analysis, it is reasonable to consider that two individuals in a social network have something in common if they share many same friends, two vertices are considered structurally equivalent if they share many common neighbors[6].

As described above, a zombie follower seller sells his zombie followers to many different purchasers repeatedly, then these zombie followers will have many common friends. As a result, the number of common friend among zombie follower purchaser is usually greater than those of the normal ones significantly.

Based on the observation, we construct the social graph based detection approach in which we calculate the common friends of among the followers of a user to detect zombie followers.

4.2 Formalization

Definition 1 Common Friend  In the Weibo social graph, we use set F(i) denoting the vertex which is the friend of vertex i: F(i)={j|vertex j is the friend of vertex i}; then the common friends of vertex i and vertex j can be defined as: C(i,j)=F(i)∩F(j).

Definition 2 Common Friends Graph

For a Weibo social graph G(V, E), we define Common Friends Graph as GC (VC, EC). The VC isthe vertices set which is identical to the V of graph G(V, E). An weighted edge EC = (i,j)is linking V_i and V_j, which stands for there are common friends between V_i and V_j, and the weights of EC is equal to the number of common friends of V_i and V_j. The equation is shown as follow:

Given a EC = (i, j), Weights (EC) = C(i, j).

In a summary, social graph G(V, E) is unweighted directed graph, while Common Friends Graph GC (VC, EC) is weighted undirected graph.

Definition3 Follower List

Weibo arrange the followers of a user in a linear list. When you visit the follower page of a user on the web, the followers of a user appear in chronological order when he becomes your follower. We defined the Follower List as List_{Followers}={F_1, F_2,..., F_N} . For 1<=i<j<=N, F_i becomes the follower of the user in previous to F_j.

Definition4 Nearest Neighbor Homology

To create a Common Friends Graph, it need to calculate the common friend of each pair of vertices in the social graph G(V,E),the complexity is O(|V|^2). The |V| can reaches millions; it’s not fit the goal of efficiency in section 3.3. As the followers of a user appear in chronological order in the Follower
List, the zombie followers usually are neighbor nodes in the Follower List. In this paper we use the Nearest Neighbor Homology (NNH) in the Follower List instead of Common Friends Graph to identify zombie followers.

If $i$ is a node in the Follower List, its $2k$ nearest neighbors are $F_{i-k}, F_{i-k+1}, \ldots, F_{i-1}, F_{i+1}, \ldots, F_{i+k}$.

we calculate the NNH of $F_i$ as:

$$\text{NNH}(i) = \frac{\sum_{j=1}^{k} (C(i, i-j) + C(i, i+j))/2k}{2k} \quad (1)$$

4.3 Algorithm

The algorithm of zombie follower detection is based on the equation 1, which is described as follow:

**Algorithm 1** Zombie follower detection based on the Number of Common Friends

**Inputs:**
List\(_{\text{Follower}}\) = \{F\(_1\), F\(_2\), \ldots, F\(_N\)\}

**Outputs:**
List\(_{\text{Zombie}}\) = \{

for \(i = 1\) to \(n\) do

\(\text{NNH}(i) = \frac{\sum_{j=1}^{k} (C(i, i-j) + C(i, i+j))/2k}{2k}\),

if \(\text{NNH}(i) > \text{Threshold}_{\text{NNH}}\)

Add \(i\) to List\(_{\text{Zombie}}\)

end if

end for

Output List\(_{\text{Zombie}}\)

The algorithm of zombie follower detection has a input parameter List\(_{\text{Follower}}\), for each node in the set of List\(_{\text{Follower}}\), it calculate the Nearest Neighbor Homology (NNH) using equation 1; if the NNH of the node is a greater than the threshold of NNH(Threshold\(_{\text{NNH}}\)), add the node to the set of List\(_{\text{Zombie}}\); at last, it output the set of List\(_{\text{Zombie}}\). The Threshold\(_{\text{NNH}}\) is used to distinguish zombie followers and normal ones, it is generated from training, which will be described in section 5.2

The complexity of the algorithm is \(\mathcal{O}(kN)\), where \(N\) denote the number of the nodes in the Follower List. If the parameter \(k\) reaches \(N/2\), the algorithm takes worst-case \(\mathcal{O}(N^2)\) time, while if \(k\) is far less than the \(N\), the algorithm takes \(\mathcal{O}(N)\) time. In the practice, the \(k\) is usually far less than the \(N\).

5 Evaluation

This section discusses how we evaluate our system. First, we introduce data set collecting methods. Second, we give the evaluation framework. Third, we show the result of evaluation.

5.1 Datasets

Weibo offers an API on June, 2010[7], and we use it to crawl and collect data. Given a user ID, we collected his Follower List with the use the Weibo API “getFollowersIdsById”. In addition Weibo offer another API getCommonFriends (String uid, String sid), which can get the common friend information between two users. We use this API to calculate the NNH of each friend in the Follower List based on equation 1.

The sample set contains two subsets: benign followers set and zombie followers set. Benign followers set consist of 5,000 known, benign followers crawled from 5 seed ID which is randomly select, the zombie followers set 5,000 zombie followers which we purchased from 5 different sellers on Taobao site(Chinese version of Ebay).

5.2 Evaluation

To validation to improve the reliability of classifier evaluations, the classifier was performed using 5 fold cross validation. In 5-fold cross-validation, the original sample is randomly divided into 5 equally-sized subsamples. 4 sub-samples are used as a training set and the remaining one is used as a testing set;
the classifier is evaluated, then the process is repeated for a total of 5 times. Each sub-sample is used as a testing set once in each evaluation. The final evaluation result is generated by averaging the results of the 5 evaluations[8].

In the calculating of the Nearest Neighbor Homology, we set the parameter k from 5 to 50. In this evaluation, we use the famous Native Bayes classifier. Figure 2 shows the impact of k on the detection rate. When k increase, the detection rate climb up. It implies that even though we mixed the with the benign followers set and zombie followers set randomly to build the Follower List, the detection rate is still high if increase the k.

![Figure 2](image2.png)

**Figure 2** Detection rate vs. k

To eliminate the affect of the rate limit of Weibo on measuring the performance overhead of ZDACF, we saved the dataset crawled from the Weibo to a local file, and implement the algorithm 1 using the dataset in the local file directly.

All measurements have been carried out on a machine with an Intel Core Duo processor running at 3.30 GHz and 3.0 GB of main memory.

Figure 3 shows the impact of k on the performance overhead. When k increase, performance overhead climb up, and there is a good linear relationship between parameter k and performance overhead. That’s because the complexity of the algorithm 1 is O(kN).

![Figure 3](image3.png)

**Figure 3** performance overhead (sec) vs. k

Combining Figure 2 and 3 we can see that in the practice, it should determine a optimal k, makes detection rate reach a high level while performance overhead a low lever.

To further validate the effectiveness of our correlation features, we make the comparison of the profile feature based approach and our social graph based approach with the same datasets on different classifiers. These classifiers are provided by the WEKA package [9]. In our evaluation, we set the k=20. Table 1 shows that for each classifier, the detection rate of social graph based approach is higher than those of profile feature based approach. This observation implies that the social graph based approach
has better detection rate. This is due to the fact that profile feature based approach can’t detect high-lever zombie followers while the social graph based approach can detect all the zombie followers.

<table>
<thead>
<tr>
<th>Classifier</th>
<th>Profile feature based approach</th>
<th>Social graph based approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision Tree</td>
<td>95.1%</td>
<td>97.9%</td>
</tr>
<tr>
<td>Neural Network</td>
<td>95.1%</td>
<td>97.9%</td>
</tr>
<tr>
<td>Support Vector Machines</td>
<td>96.0%</td>
<td>97.0%</td>
</tr>
<tr>
<td>Naive Bayes</td>
<td>86.3%</td>
<td>98.1%</td>
</tr>
</tbody>
</table>

6 Related work

The success of Microblog has attracted the attention of attackers. Zombie followers, spam and sybil are three different types of automated program attack in Microblog.

Spammers have utilized Microblog as the new platform to achieve their malicious goals such as sending Spam, post malicious links, hosting botnet command and control (C&C) channels, and performing other illicit activities[10].

Most existing Spam detection work can be divided into two classes: machine learning based detection and URL-based detection.

Machine learning based detection mainly utilizes machine learning techniques to classify legitimate accounts and Spam accounts according to their collected training data and their selections of classification features.

URL-based detection[11], detects Spam accounts by examining whether the URLs or web domains posted in the tweets are tagged as malicious by the public blacklists. Especially, to collect training data, both[8] and [12] utilize social honey accounts to identify Twitter Spammers.

Sybil attacks is known to be a fundamental problem in the design of peer-to-peer systems, Social Network are also vulnerable to Sybil attacks[13].

In a Sybil attack, a malicious user obtains multiple fake identities and pretends to be multiple, distinct nodes in the system. The malicious Sybil identities can comprise the system in a variety of tasks, including online content ranking, Distributed Hash Tables (DHTs)[14], file sharing, reputation systems, and Byzantine consensus[15].

There are two schools of Sybil defense mechanisms, the centralised defense mechanisms and decentralised defense mechanisms.

Centralised defense assume the existence of an authority that is capable f doing admission control for the network[14]. Its role is to rate limit the introduction of ‘fake’ identities, to ensure that the fraction of corrupt nodes remains under a certain threshold. The practicalities of running such an authority are very system-specific and in general it would have to act as a Public Key Certification Authority as well as a guardian of the moral standing of the nodes introduced a very difficult problem in practice. Such centralized solutions are also at odds with the decentralization guiding principle of peer-to-peer systems.

Decentralised approaches recognize the difficulty in having a single authority vouching for nodes, and distribute this task across all nodes of the system.

Different from existing studies, our work focuses on the zombie follower detection, the different behavior features may lead to different approach. To the author's knowledge, there is no previous work on zombie follower detection. In practice, there is a standard to detect zombie followers: the number of follower or tweets is less than 5. As the zombie followers evolved from the low-level to high-level, this standard can’t detect the zombie followers now. This paper proposes a machine learning approach to detect the zombie followers on multiple features, the result of evaluation shows that it has a high detection rate on the zombie followers which is the wild now.

7 Discussion

In this section, we analyze the robustness of the ZDACF system design by discussing various evasion tactics that knowledgeable adversaries may pursue to circumvent ZDACF. For each attack strategy, we discuss the effect of these evasion tactics on ZDACF.
Assuming that ZDACF gains a high degree of user acceptance, we expect that zombie follower sellers will acquire ZDACF’s strategies and design circumvention strategies to evade detection. To this end, we see three avenues that future zombie follower sellers may explore to evade ZDACF.

**Adding followers in batches**—Currently, when a purchaser buy some zombie followers, the sellers add all the zombie followers to the purchaser’s Follower List in one time immediately. As a result, the zombie followers are consecutive adjacent serial in the Follower List. When the sellers know that we use the value of Nearest Neighbor Homology (NNH) to distinguish the zombie followers and normal ones, they may add the zombie followers in batches in order to lower the value of Nearest Neighbor Homology of zombie followers.

**Effect** : When the seller adds his zombie followers in batches, the zombie followers will are not consecutive adjacent in the Follower List. In the section 5.3, we mixed the zombie sample and normal sample to build Follower List completely randomly, which is quite hard for sellers to implement in practice, but the result of the shows that the detection rate is still high if we increase the k.

**Purchasing followers from multiple sellers**—At present, the purchaser usually purchase the zombie followers from one seller; the number of common friends in the followers from the same seller usually is great. In order to reduce the value of it, purchaser would purchase the zombie followers from multiple sellers.

**Effect** : As long as each seller adds their zombie followers in one time, the zombie followers from the same seller are consecutive adjacent serial in the Follower List, it does not affect the value of NNH significantly.

**Multiple sellers adding followers in batches alternately**—The purchaser buys the zombie followers from different sellers, and meanwhile the seller add the zombie followers in batches alternately.

**Effect** : For this evasion tactic, the value of NNH between zombie followers and normal ones are not distinguish obviously, then the detection rate of our approach will be low. To accomplish this evasion tactic, it need different sellers cooperate with each other, that is the sellers add a batch of zombie followers one after the other. Although it’s hard to accomplish it, we plan to study how to counter with the evasion tactic in the future.

**8 Conclusions**

Sina Weibo is the top microblogging network in China; its popularity makes it being a great platform to do marketing. Zombie followers become the major threat of Microblog marketing. The zombie followers is in evolution, previous work can detect low-lever zombie followers but not high-lever zombie followers. To this end, we have proposed ZDACF, a social graph based approach to detect zombie followers, which use the feature that the number of common friends among the zombie followers from a purchaser is usually greater than that of the normal users.

ZDACF uses the Sina Weibo API to crawler the Follower List of a user from Weibo, and measure the Nearest Neighbor Homology of every node in the Follower List, using the classifier to distinguish the zombie followers from normal followers. The result of evaluation shows that, when the parameter k in the Nearest Neighbor Homology is increasing, detection rate is climbing up, at the same time performance overhead is climbing too.

We compared the detection rate of social graph based approach and profile feature based approach using traditional classifiers like Decision Tree, Neural Network, Support Vector Machines, and Naïve Bayesian schemes using the Weibo dataset we have collected. The results show that the detection rate of social graph based approach is higher than that of profile feature based approach on all the classifiers.

In our future work, we plan to extend ZDACF to be more robustness to Evasion Tactics, and we plan to the study the zombie follower crawler, which can crawler the zombie followers on the Weibo automatically.
9 References


