Recommendation in Social Website: A Method Based on Social Learning and the Strength of Ties

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Abstract. In this paper, a method based on the strength of ties and the social learning for online reviews to recommend products to a consumer. The strength of ties between the consumer and each of his friends are firstly calculated based on the background of the consumer’s friends. Then, the ratings of the products are obtained based on social learning and the strength of ties. Further, according to the ratings of products and the weights of the products attributes, the overall utilities of the products and a ranking of the products are determined. Finally, we propose a computational experiment to explain the proposed method.

Introduction

Owing to the development of e-commerce, consumers are increasingly willing to share their reviews on social website after they bought and experienced the products. When sellers recommend products to consumers, they consider that the consumers will view the product reviews and infer the quality of the product by social learning for the online reviews. Existing research suggests that online reviews have a significant effect on consumer’s purchase decision [1-4]. Chevalier and Mayzlin [1] empirically examined the impact of consumers’ reviews on the sales of books and found customers’ online communication can influence consumers’ behaviors. Till now, many scholars have proposed recommendation methods based on online reviews [5,6]. Guerreiro and Rita [5] empirically proved that online reviews and providers’ abilities can affect the accuracy of recommendation. In this paper, we construct a model of recommendation based on the contents of online reviews, and help the consumer to select desired products.

Besides, the number of online reviews is huge, it is difficult for the consumer to directly make the purchase decision based on the online product reviews [7]. Therefore, some social websites, like douban (https://movie.douban.com/), allows consumers to view their friends’ reviews. But, among the friends’ online reviews, the impact of a classmate’s online review and an unknown friend’s online review on the consumer is different, although they are both consumer’s friend on the social website. The strength of ties proposed by Granovetter [8], he divided the strength of ties into strong ties and weak ties, and many scholars further discovered the impact strong and weak ties on the economy [9, 10]. In recent years, with the rapid development of social networks, some scholars find the strength of ties has significant impact on friends’ recommendation [11,12], purchase decision making [13,14], and information dissemination [15]. Xu et al. [11] combined researchers’ characteristic and relationship information to design a heterogeneous network-based scholar-friend recommendation method. Zhu et al. [13] developed a model to investigate the impact of consumer-to-consumer communication on consumers’ purchase decision. Wei et al. [15] proposed that crisis information dissemination is more effective in network with weak ties, and found the spread of crisis information dissemination is positively related to the credibility of information dissemination. In this paper, we consider that
consumers may trust online reviews differently because of the strength of ties when they view online reviews, therefore, to support recommending a desirable product to consumer, the strength of ties between the consumer and each of his friends should be determined.

According to the strength of ties and the social learning for online reviews, this paper develops a method to recommend products to the consumer. The proposed method can be divided into three parts, i.e., the part of identifying the strength of ties between the consumer and each of his friends, the part of rating the attributes of products and the part of ranking the products.

Description of the Problem

The problem of recommendation in social network is shown in Figure 1. We assume a social website recommend a product to a customer, several similar products in the consideration set should be considered. And the consumer can select several attributes based on his preference. The attribute values are ex ante unknown, and the consumer cannot know the values of the attributes until they have experienced. And the consumer always tries to infer the values of the attributes by learning the reviews posted by his friends on the social networks. In addition, the weights of the attributes can be given directly by the consumer according to his preference or determined using some decision methods (such as AHP and so on). For the consumer, the reviews from the close friends are more important than the ordinary friends, the consumer will pay more attention to the reviews given by the close friends when he learning the online reviews, therefore, the strength of ties between the consumer and each of his friends should be considered. According to the values of the attributes and the strength of ties between the consumer and each of his friends, how to accurately recommend a product to consumer? We have established a method to solve the problem.

![Figure 1. The Problem of Recommendation in Social Network.](image)

![Figure 2. The Social Network between the Consumer \( z \) and His Friend \( u_h \).](image)

Let \( M = \{1, 2, \ldots, m\} \), \( N = \{1, 2, \ldots, n\} \), \( L = \{1, 2, \ldots, l\} \). Let \( P = \{P_1, P_2, \ldots, P_m\} \) be the consideration set of products, where \( P_i \) represents the \( i \)th product, \( i \in M \). Let \( C = \{C_1, C_2, \ldots, C_n\} \) be the set of product attributes, where \( C_j \) represents the \( j \)th product attribute, \( j \in N \). Let \( u = \{u_1, u_2, \ldots, u_l\} \) be the set of friends, where \( u_h \) denotes the \( h \)th friends. And the friends comprise two parts: the friends who care about the consumer and the friends who are concerned by the consumer. Let \( r = (r_1, r_2, \ldots, r_l)^T \) be the vector of the strength of ties between the consumer and each of his friends. And let \( w = (w_1, w_2, \ldots, w_n)^T \) be the attribute weight vector, where \( w_j \) represents the importance degree of
attribute $C_j$ such that $\sum_{j=1}^n w_j = 1$ and $0 \leq w_j \leq 1$, $j \in N$.

Let $Q = [q_{ij}^b]_{m \times (n-n_i)}$ be a decision matrix for the attributes of the products, where $q_{ij}^b$ is the attribute value for product $P_i$ with respect to attribute $C_j$, $i \in M$, $j \in N$. $q_{ij}^b$ is ex ante unknown to the consumer and he can infer the value of $q_{ij}^b$ by learning product reviews posted by his friends who have experienced product $P_i$. In this paper, we consider that $q_{ij}^b$ is a crisp number. Other formats of decision data, such as interval numbers, linguistic information and ordinal numbers, can be converted into the form of crisp numbers by some decision methods.

The problem concerned in this paper is how to rank the products or recommend the first product from the consideration set $P$ based on the strength of ties $r$ and social learning for online reviews posted by the friends.

The Method Based on the Strength of Ties and the Online Reviews

Identifying the Strength of Ties between the Consumer and Each of His Friends

Firstly, we consider the situation where the website requires users to complete the information. So, we can obtain the information of the consumer and his friends’ background, includes the gender, location, occupation, education experience, notes as $UB(z) = \{\text{gen}_z, \text{loc}_z, \text{occ}_z, \text{edu}_z\}$. As we know, people with the same background information are more likely to be friends in reality. Then, we can use the Jaccard formulas to calculate the similarity of background information.

\[
sim(z,u_h) = \frac{UB(z) \cap UB(u_h)}{UB(z) \cup UB(u_h)}, \quad h \in L
\]

(1)

The value $\sim(z,u_h)$ denotes the similarity of the background information between consumer $z$ and his friend $u_h$.

Secondly, in the social websites, the consumers connect other consumers by the “follow” behavior and build the complex social networks with each other. The social network is shown in Figure 2. Based on the background of the consumers crawled from the social website, we can also get their followers list and the people list they follow. Thus, the people list of consumer $z$ follows can be expressed by $\varphi(z)$, and the followers list of consumer $z$ can be denoted by $\theta(z)$, according to Ju et al. [16], the proportion of mutual friends among all friends of $z$ and $u_h$ is determined by

\[
cnp(z,u_h) = \frac{|\varphi(z) \cap \varphi(u_h)| + |\theta(z) \cap \theta(u_h)| - |\varphi(z) \cap \varphi(u_h) \cap \theta(z) \cap \theta(u_h)|}{|\varphi(z) \cup \varphi(u_h) \cup \theta(z) \cup \theta(u_h)|}, \quad h \in L
\]

(2)

Then, the strength of network structure connection is given by

\[
LS(z,u_h) = cnl(z,u_h) \times cnp(z,u_h), \quad h \in L
\]

(3)

Where $cnl(z,u_h)$ denotes the number of connected edges among the mutual friends.

Finally, the strength of ties between user $z$ and $u_h$ is given by

\[
r_h = \alpha \times \sim(z,u_h) + \beta \times LS(z,u_h), \quad h \in L
\]

(4)

Where $\alpha + \beta = 1$, $0 \leq \alpha \leq 1$, $0 \leq \beta \leq 1$.
Rating the Attributes of the Products

Identified the Sentiment Level of the Friends’ Online Reviews

First, the online reviews of the consumer’s friends are crawled from the social websites using the crawler software, and online reviews can be preprocessed by word segmentation and part-of-speech tagging. Then, remove the stop words.

Second, according to the method of Liu et al. [17], we can get the friends’ sentiment level of the product attributes through the online reviews $LV^i_j, LV^b_j \in \{ -3, -2, -1, 0, 1, 2, 3, "-" \}$. And then, after the sentiment level of attribute $C_j$ for product $P_i$ in the $t$th online reviews can be determined, the strength of ties $r_{hz}$ between consumer $z$ and friend $u_{zh}$ should be considered, so the friend’s rating of product $P_i$ concerning attribute $C_j$ in the $t$th online review can be expressed by $Y_{iz}^t$, i.e.,

$$Y_{iz}^t = r_{hz} \times LV^i_j \quad i \in M, \quad j \in N.$$  (5)

Finally, the mean $R_{ij}$ and variance $D_{ij}$ of the rating of product $P_i$ concerning attribute $C_j$ can be determined, respectively, $i \in M$, $j \in N$.

Updating the Customers’ Prior Beliefs

According to Papanastasiou and Savva. [18], we assume that the ex post quality perceptions in the population follow normal distribution, denoted as $q_y \sim N(q_y, \sigma^2_y)$, where $q_y$ is the mean of the attributes value for product $P_i$ with respect to attribute $C_j$, and $\sigma^2_y$ captures the degree of heterogeneity in consumers’ ex post evaluations of the product. Before purchase, the consumer usually has a prior belief over the products, which may be shaped by advertising efforts, media coverage and prerelease expert reviews. We assume a symmetric information structure in all consumers. Let $q_{ij}^a$ be all consumers’ common prior belief of product $P_i$ concerning attribute $C_j$, which is expressed in the form of normal random variable, that is $q_{ij}^a \sim N(q_{ij}^a, (\sigma_{ij}^a)^2), \quad i \in M, \quad j \in N$.

To infer the values of the products attributes, the consumer usually views the products’ online reviews posted by his friends who have purchased or experienced the product $P_i$ and then updates his belief from prior belief $q_{ij}^a$ to posterior belief $q_{ij}^b$ through social learning. The consumer’s posterior belief is also normally distributed, denoted as $q_{ij}^b \sim N(q_{ij}^b, (\sigma_{ij}^b)^2), \quad i \in M, \quad j \in N$. Let $K_i = \{k_{i(n+1)}, k_{i(n+2)}, \ldots, k_m\}$ denotes the set of number of online reviews for each attribute, where $k_{ij}$ denotes the number of reviews for product $P_i$ concerning attribute $C_j$, $i \in M, \quad j \in N$. According to Bayesian updating rule proposed by Degroot [19], the social learning model is built to update the consumer’s prior beliefs. The way of updating the prior belief is described by

$$q_{ij}^b = \frac{\left(\sigma_{ij}^a\right)^2}{k_y(\sigma_{ij}^a)^2 + (\sigma_y)^2} q_{ij}^a + \frac{k_y(\sigma_{ij}^a)^2}{k_y(\sigma_{ij}^a)^2 + (\sigma_y)^2} q_y^a,$$

$$(\sigma_{ij}^b)^2 = \frac{\left(\sigma_{ij}^a\right)^2}{k_y(\sigma_{ij}^a)^2 + (\sigma_y)^2}, \quad i \in M, \quad j \in N. \quad (6)$$

The posterior mean $q_{ij}^b$ is a weighted average between the prior mean $q_{ij}^a$ and the actual quality $q_y^a$. In this paper, we assume that $q_y^a = 0$, it means that consumers do not know the products qualities before buying. Since the mean $R_{ij}$ of the rating represents the actual perception and the variance $D_{ij}$ captures the degree of heterogeneity in consumers’ ex post evaluations of product $P_i$ concerning
attribute $C_j$, then Eq. (6) can be further expressed as

$$q^b_{ij} = \frac{k_q(\sigma^a_{ij})^2}{k_q(\sigma^a_{ij})^2 + D_q} R_q, \quad i \in M, \quad j \in N. \quad (7)$$

Based on the above analysis, $q^b_{ij}$, the consumer’s belief of product $P_i$ concerning experienced attribute $C_j$ can be determined, which is the attribute value for product $P_i$ with respect to experienced attribute $C_j$. Then, the decision matrix for the attributes, $Q = [q^b_{ij}]_{m \times n}$, can be constructed.

### Ranking the Products

Based on the above analysis and the weight of attribute given by user $z$, the overall utility of the product can be calculated, i.e.,

$$U_i = \sum_{j=1}^{n} w_j q^b_{ij}, \quad i \in M, \quad j \in N. \quad (8)$$

The product in the consideration set will be ranked according to the overall utilities, and the product with the largest $U_i$ will be the desired product.

### Computational Experiments

In this section, a data experiment is used to illustrate the use of the proposed method. We assume a consumer $z$ wants to purchase a smartphone, there are three smartphones in his consideration set: MI 8 ($P_1$), Honor 10 ($P_2$), MEIZU 16th ($P_3$). And the attributes he mainly considered are camera ($C_1$), battery life ($C_2$), system ($C_3$). The attribute weight vector is given by consumer $z$, i.e. $w = (0.3, 0.3, 0.4)^T$.

To obtained the strength of ties between consumer $z$ and each of his friends, the background of consumer’s friends and the online reviews posted by consumer’s friends are crawled from the social websites Zhihu (see: https://www.zhihu.com/), and the online reviews are obtained from May 2018 to September 2018. Based on the method proposed above, we can first obtain the strength of ties among consumer $z$ and friends using Eqs(1)-(4), there we assume $\alpha = \beta = 0.5$, and then, according to Eqs(5)-(7), we get the ratings of the product attributes through social learning. The number of online reviews $k_{ij}$, the mean $R_{ij}$ and the variance $D_{ij}$ of the rating and the aspirations provided by consumer $z$ are shown in Table 1.

**Table 1. The Means, Variances and Aspirations of Consumer $z$ for the Attributes.**

| Attributes | $C_1$ | $C_2$ | $C_3$ |
|-----------|-------|-------|-------|
| Products  | $P_1$ | $P_2$ | $P_3$ |
| $r_i$     | 0.96  | 1.05  | 1.06  |
| $D_i$     | 0.74  | 0.76  | 0.96  |
| $k_i$     | 166   | 177   | 122   |

The decision matrix of the attributes is constructed. i.e.,

$$Q = \begin{bmatrix} 0.92 & 0.77 & 0.98 \\ 1.01 & 0.68 & 0.89 \\ 0.98 & 0.57 & 1.12 \end{bmatrix} \quad (9)$$
The overall utilities of the smartphones are obtained using Eq(8), i.e., \( U_1 = 0.899 \), \( U_2 = 0.863 \), \( U_3 = 0.913 \), so the ranking of the smartphone is \( U_3 \succ U_2 \succ U_1 \). Obviously, MEIZU 16th is the most desirable mobile phone for consumer \( z \).

Summary

This paper develops a new method based on the strength of ties and the social learning for online reviews to rank the products. In the method, firstly, according to the background of the consumer’s friends, the strength of ties between the consumer and each of his friends are obtained. Secondly, the sentiment levels of the product attributes are identified based on the processing of online review, then, the ratings of the product attributes are obtained through social learning for online reviews. Finally, a ranking of products is determined. In this paper, the major contribution is to recommend products to consumer based on the strength of ties and social learning for online reviews on social website. In future studies, in order to obtained a more accurately result of recommendation, a system based on the method needs to be designed. Besides, the similarity of interests among the consumer and his friends to recommend consumer can also be considered.

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