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Zhaohao Sun

*University of Ballarat, z.sun@ballarat.edu.au*

John Yearwood

*University of Ballarat, j.yearwood@ballarat.edu.au*

Sally Firmin

*University of Ballarat, s.firmin@ballarat.edu.au*

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## A Technique for Ranking Friendship Closeness in Social Networking Services

Zhaohao Sun

School of Science, Information Technology and Engineering (SITE)  
University of Ballarat, Australia  
Email: z.sun@ballarat.edu.au

John Yearwood

School of Science, Information Technology and Engineering (SITE)  
University of Ballarat, Australia  
Email: j.yearwood@ballarat.edu.au

Sally Firmin

School of Science, Information Technology and Engineering (SITE)  
University of Ballarat, Australia  
Email: s.firmin@ballarat.edu.au

### Abstract

*The concept of friend and friendship are critical to both theoretical and empirical studies of social relations, social media and social networks. Measuring the closeness among friends is a big issue for developing online social networking services (SNS) such as Facebook. This paper will address this issue by proposing a technique for ranking friendship closeness in SNS. The technique consists of an algorithm for ranking need-driven friendship closeness and an algorithm for behaviour-based friendship closeness in online social networking sites. The former is based on Maslow's hierarchy of needs, while the latter is based on behaviours of users on Facebook and TOPSIS. Examples provided illustrate the viability of the proposed algorithms. The research in this paper shows that ranking friendship closeness will facilitate understanding of needs and behaviours of friends and of friendships in SNS. The proposed approach will facilitate research and development of social media, social commerce, social networks, and SNS.*

### Keywords

Social networks, social media, friendship, online social networking services (SNS), Facebook.

### INTRODUCTION

Online social networking services (SNS) such as Facebook and Twitter have reshaped communication and interaction among people, and have had a profound impact in the way people connect with each other, and created a new world. Online friendships are one of the most important social relationships to SNS. People come to SNSs to create, collaborate, cooperate, and contribute their expertise and wisdom. They help, support, and entertain each other in terms of information sharing, updating, disseminating, consulting, recommending, delegating through comments, discussion, instant messaging, tweets, information (video, audio, and text) uploading and game playing (Cheung & Lee, 2010). Hence, the new world consists of a variety of friend communities. Friends and friend communities are at the centre of SNS in general and Facebook in particular, and therefore, investigation into friend behaviours and friendship closeness is significant for further development of SNS and incorporation of SNS with e-business, mobile commerce, and cloud commerce.

The study of friend, friending and friendship has a long history in social psychology (Fischer, 1982), but the recent meteoric rise of interest in social media, social networks, SNS, as well as social commerce. For example, Fischer (1982) examines the meaning of friend, close friend and friendship based on an inductive study. Bryant and Marmo (2012) examine friendship rules on Facebook in terms of close, casual, and acquaintance friendships. Moreover, friend as a relation has been studied to some extent in social network analysis (Wasserman & Faust, 1994). Friend as a service has also drawn some attention in integrating e-business and SNS (Sun, Firmin, & Yearwood, 2012). Friend and friending are a focal point with the exciting emergence of social computing, social media, social technologies (Cheung & Lee, 2010), and SNS. The reason behind this interest into the study of friend, friending and friendship is that as social media functions and marketing means they have played an important role in developing Facebook into a giant SNS with more than a billion active users (Facebook, 2013).

The study of friend, friending, friendship and friend behaviours is also important part of understanding online customer behaviours to develop mobile commerce, social commerce, and cloud commerce (Sun, Firmin, & Yearwood, 2012), because 81% of customers receive product purchase advice through their friends via a SNS when undertaking online buying (IBM, 2013; Petersen, 2011). However, friend and friendship are very difficult to understand from a business viewpoint. Therefore, understanding friendship and friend behaviours in SNS becomes significant for developing SNS and social commerce (Sun, Firmin, & Yearwood, 2012). Moreover, understanding friendship closeness from a need and behaviour viewpoint is still a big issue for understanding friends in a SNS context. This paper will address the above issues by proposing a technique for ranking friendship closeness in SNS. The technique consists of two algorithms for ranking need-driven friendship closeness and behaviour-based friendship closeness. One algorithm is based on Maslow's hierarchy of needs, and the other is based on behaviours of users on Facebook and TOPSIS, a multi-criteria decision analysis method (Hwang & Yoon, 1981). The key ideas behind these two ranking algorithms are that needs and behaviours are an important basis for friending and friendships. The remainder of this paper is organised as follows: After providing some background on friend, friending, friendship for this research, this paper proposes an algorithm for ranking need-driven friendship closeness in SNS. Then this paper examines behaviours of friends on Facebook and presents an algorithm for ranking behaviour-based friendship closeness based on the TOPSIS. After discussion and some related work, the final section ends with a few concluding remarks and the research directions of our future work.

## **FRIEND, FRIENDING AND FRIENDSHIP IN SOCIAL MEDIA AND SOCIAL NETWORKS**

The term friend is very ambiguous. This ambiguity creates difficulty in trying to interpret friendships and friending in social involvement (Fischer, 1982). The term friend is defined as "one attached to another by affection and esteem" (Fischer, 1982). Affection and esteem are associated with the social needs of a person. The term friend is also defined as "a person you know well and like, and who is not usually a member of your family" (Oxford, 2005). "Like" as the core of "friending" has been successfully used by Facebook as a marketing operation (Sun, Firmin, & Yearwood, 2012). People "friend" one another to gain access to information on Facebook (Turban & Volonino, 2011, p. 223).

Friendship is a relationship that involves voluntary or unconstrained interaction behaviours to fulfil important personal needs such as inclusion, affection, intimacy, and identity affirmation (Bryant & Marmo, 2012). Friendships, different from "friendly relations", are relations that are beyond the workplace or neighbourhood (Fischer, 1982). In other words, in American culture, the relations of co-workers and neighbours are not friendships. Reaching intimacy, trust and reciprocity through social interaction is important to make a close friendship between any two persons (Fischer, 1982).

A 'close' friend is generally considered the intimate special aspect of the friend relationship (Fischer, 1982). Similarly, Mesch & Talmud (2006) suggest 'friendship' is a deeper level of closeness and intimacy to being "just friends". Personal and intimate communication can strengthen the closeness between friends (Mesch & Talmud). Based on the research of Fischer (1982), friendships do not appear to involve material exchanges to any great extent, whereas close friendships usually involve intimacy, discussing personal matters, seeking advice, and on a steady date. For example, Monica and Peter are friends on Facebook. Monica and Peter like each other (intimacy). Monica discussed with Peter her plans to travel to China over Facebook (discussing personal matters) requesting advice from Peter where she should travel when in China because Peter has visited China many times. Monica and Peter have been Facebook friends for six months, they chat with each other on Facebook regularly (on a steady date). Then Monica and Peter are 'close' Facebook friends.

An SNS is a service offered via a website where individuals, who are defined by a profile, can interact with others (Turban & Volonino, 2011, p. 223). The web users in SNS can express themselves by posting blogs or experiences or photos, interact with each other, share information and multimedia, and establish their social networks (Lu, Zhao, & Wang, 2010). Social media emphasises creation, sharing and exchange of information (e.g. photos, texts, and messages), thoughts, opinions and experiences (e.g. comments, opinions, ratings and playing games) among individual users (Smyth, Briggs, & Coyle, 2009; Kaplan & Haenlein, 2010). Facebook is selected in this paper as the example of online social networking sites, because it is the most populous SNS.

## **NEEDS DRIVEN FRIENDSHIP CLOSENESS RANKING**

This section first applies Maslow's hierarchy of needs to social media and social networks. This is followed by a technique for ranking needs-driven friendship closeness.

### Applying Maslow's Hierarchy of Needs to Social Media and Online Social Networks

Maslow (1943) originally introduced the hierarchy of needs to facilitate research in the area of human motivation. Maslow (1954) believed that people have five levels of needs, and that these needs formulate a positive theory of motivation. The original hierarchy of needs five-stage model includes (McLeod, 2007):

1. Biological and physiological needs - air, food, drink, shelter, warmth, sex, sleep.
2. Safety needs - protection from elements, security, order, law, limits, stability.
3. Social needs - belongingness and love, - work group, family, affection, relationships.
4. Esteem needs - self-esteem, achievement, mastery, independence, status, dominance, prestige, managerial responsibility.
5. Self-actualization needs - realizing personal potential, self-fulfilment, seeking personal growth and peak experiences.

This hierarchy of needs can be simplified to 1. basic needs, 2: safety needs, 3: social needs, 4: esteem needs, and 5: growth needs (self-actualization). Maslow (1954) stated that people are motivated to achieve certain needs. When fulfilling one level's needs, every person will seek to fulfil the next one level's needs until the top level: self-actualization needs. Although the hierarchy of needs has evolved and extended in the 1960s and 1970s, the above one is still most widespread version (McLeod, 2007). For brevity, we use the classic five stage model for the hierarchy of needs. The hierarchy of needs can be illustrated as hierarchical levels within a pyramid, as shown in the left part of Figure 1.

Maslow's theory has been applied in many disciplines for example, psychology, management, and homemakers (Greenberg, 2010). Bennett (2012) has briefly illustrated the relationships between Maslow's hierarchy of needs and social media. In what follows, we extend his discussion by examining the correspondence between each of Maslow's hierarchy of needs and netizens' needs within a social media, online social networks, and social commerce context (Sun, Firmin, & Yearwood, 2012).

Figure 1 is a model for applying Maslow's hierarchy of needs to social media or online social networks. The original model of hierarchy of needs was introduced in the 1940s. At the time, a person did try to achieve biological and physiological needs through obtaining air, food, drink, shelter, warmth, sex, sleep. However, in the Internet age, a person tries to achieve information as her/his basic needs through various social media or social networks. A netizen also uses SNS to buy physiological needs such as cosmetics, cloths, and books, etc. All these belong to the Level 1 corresponding to social media, online social networks and social commerce.

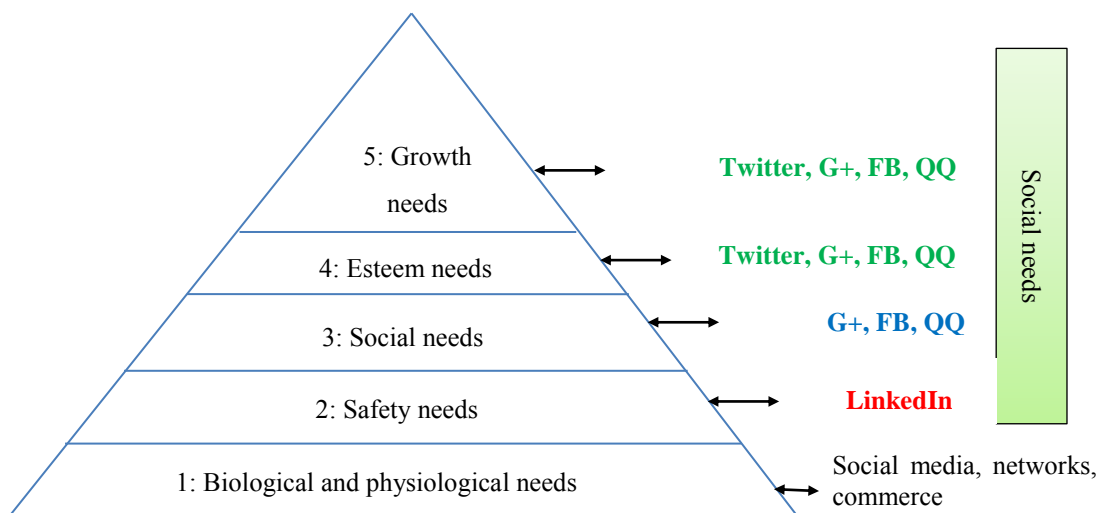


Figure 1: A model for applying hierarchy of needs to social media

Different from that in the physical world, a netizen's safety needs in social networks, social media and social commerce is security of his or her privacy and information as well as safety of employment. All these have been met by secure networks, such as LinkedIn and other social networking websites.

Similar to the traditional social needs, a netizen can enjoy the belongingness and love in work group, family and affection through active engagement in online SNS such as G+, Facebook, and QQ. The social networking companies have made significant success to meet the social needs of netizens at this level.

It is difficult for a person in the physical world to achieve esteem needs. However, a netizen can achieve esteem needs using SNS. For example, a netizen can have hundreds of friends on Facebook, s/he can dominate her/his own space on Facebook, publishing whatever s/he likes, and can receive positive comments from her/his friends through sharing media and text. As a consequence s/he receives respect and social esteem from others in the micro-community that s/he establishes and manages. SNS such as G+, Facebook, Twitter, QQ have had significant success in meeting the esteem needs of every netizen, whereas no techniques and systems can meet the esteem of an individual in the physical world.

It is complicated for a person in the physical world to achieve their self-actualization needs. However, a netizen can relatively easily achieve personal potential, self-fulfilment through blogging, publishing photos and sharing with friends on Facebook, Twitter and QQ. Therefore, a netizen has really found a self-realization place in SNS while possibility still meeting prejudice, unemployment, challenges for problem solving in the physical world.

It should be noted that all other needs above the basic needs in the hierarchy of needs belong to social needs as shown in Figure 1 (Bennett, 2012).

### An Algorithm for Ranking Needs Driven Friendship Closeness

We have reviewed Maslow's hierarchy of needs and its relevance to social media and social networks. In fact, everyone has a need distribution among the five needs stages. In a SNS context, the closeness of friends depends on this distribution, more similar the distribution is, the closer is the friendship. This can be used to explain friends' closeness in SNS such as Facebook. In what follows, we elaborate on this point.

Maslow's needs suggest that "the things that one requires in order to live in a comfortable way or achieve what s/he wants" (Oxford, 2005). In his hierarchy of needs, Maslow (1954) stated that when one need is fulfilled a person seeks to fulfil the next one, and so on. In fact, an individual has different percentages for each level's needs. For example, (0.4, 0.3, 0.2, 0.2, 0.1) may represent the needs of Peter. We call it the life needs distribution of Peter, that is, Peter requires 40% level 1's needs, 30% level 2's needs, 20% level 3's needs, 20% level 4's needs, and 10% level 5's needs. If Monica requires 10% level 1's needs, 20% level 2's needs, 40% level 3's needs, 20% level 4's needs, and 10% level 5's needs, then Monica's life needs distribution is (0.1, 0.2, 0.4, 0.2, 0.1).

More generally, assume that a netizen has  $N$  Facebook friends  $F = \{f_1, f_2, \dots, f_N\}$ , where  $N$  is an integer. The question is: which is the closest friend of Peter on Facebook? To address this question, we assume Peter as  $f_0$ , his own and his Facebook friends' life needs distribution is  $f_i^d = (d_{i1}, d_{i2}, d_{i3}, d_{i4}, d_{i5})$ ,  $i = 0, 1, 2, \dots, N$ . Then the closeness between this netizen  $f_0$  and his friend  $f_i$  can be measured using the following mathematical formula

$$C(f_0, f_i) = \sqrt{\sum_{l=1}^5 (d_{il} - d_{0l})^2} \quad (1)$$

The idea behind this measure is that in the friend cycle, two friends sharing similar life needs distribution have a close friendship. That is, two friends are close if they share commonality in terms of many life interests. For example, in Chinese culture, a necessary condition for a Chinese man to marry a Chinese lady is that they must follow the principle of "Perfect match" (*Men dang hu du*). This means that they should share common needs at each level of Maslow's hierarchy of needs. In a weak form, one calls someone a friend, if they both are similar in age (Fischer, 1982). Based on Equation (1), the closest friend of  $f_0$  among Facebook friends  $F$  is that there exists  $I \in \{1, 2, \dots, N\}$  and a friend  $f_I$  in  $F$  such that

$$CT(f_0, f_I) = \underset{i \in \{1, 2, \dots, N\}}{Min} (C(f_0, f_i)) \quad (2)$$

Now we assume that  $f_0$  has three Facebook friends  $F = \{f_1, f_2, f_3\}$ . His and their life needs distributions are as follows:

$$f_0^d = (0.4, 0.3, 0.2, 0.2, 0.1), f_1^d = (0.1, 0.2, 0.4, 0.2, 0.1)$$

$$f_2^d = (0.4, 0.4, 0.1, 0.0, 0.1), f_3^d = (0.5, 0.2, 0.3, 0.1, 0.0)$$

These life needs distributions can be represented using Table 1.

Table 1: Life needs distribution of friends

Friend	Basic needs	Safety needs	Social needs	Esteem needs	Self-actualization needs
$f_0^d$	0.4	0.3	0.2	0.2	0.1

$f_1^d$	0.1	0.2	0.4	0.2	0.1
$f_2^d$	0.4	0.4	0.1	0.0	0.1
$f_3^d$	0.5	0.2	0.3	0.1	0.0

Based on Equation (1), we have  $C(f_0, f_1) = \sqrt{0.3^2 + 0.1^2 + 0.2^2 + 0^2 + 0^2} = 0.374$ ,  $C(f_0, f_2) = 0.245$ , and  $C(f_0, f_3) = 0.223$ . Based on Equation (2), we have that  $f_3$  is the closest friend of the netizen  $f_0$ .

It should be noted that sometimes people are friends because they complement each other, rather than having similar life needs or similar interests or similar friend behaviours. Furthermore, similarity would not be a simple Euclidean distance (Finnie & Sun, 2002). We will address these two points in the future work based on fuzzy logic.

## BEHAVIOUR BASED FRIENDSHIP CLOSENESS RANKING

This section first looks at behaviours of friends in SNS. It then presents an algorithm for ranking behaviour-driven friendship closeness.

### Behaviours of Friends on Social Networking Sites

Facebook uses “like” to provide its users with an efficient way to share information. “Like” is the term used by Facebook for becoming a member of a page. “Like” is used by a team to show the members who “like” this page “have a positive opinion about the post or page made by a member or page moderator” (Zhivov, Scheepers, Stockdale, 2011). More generally, assume that  $f_1$  and  $f_2$  are two members on Facebook,  $g$  is a description of a good or service, for example,  $g$  can be an online game, a photo, a movie, a video program, and a posted comment,  $\sim$  is a similarity metric, then if  $f_1$  and  $f_2$  likes  $g$ , then  $f_1 \sim f_2$  with respect to  $g$ . If there are  $n$  members in the Facebook community who “like”  $g$ . Then they are similar with respect to  $g$  and we have (Sun, Firmin, & Yearwood, 2012)

$$F_g = \{f_i | f_i \text{ likes } g, i \in \{1, 2, \dots, n\}\} \quad (3)$$

$F_g$  is a community of Facebook. Every member in  $F_g$  likes  $g$ . Alternatively, all the members in  $F_g$  share same or similar interests with respect to  $g$  and can discuss with each other in this community. More generally, Facebook uses friending to develop its community. Friendship is a binary relation. If  $f_1$  and  $f_2$  are friends, then  $f_1$  and  $f_2$  have some common interests. If  $f_1$  and  $f_2$  have the common or similar interests in the Facebook community, then  $f_1$  and  $f_2$  have same or similar behaviours. That is, assume that  $\sim$  is a “friend” relationship,  $\approx$  is a similarity metric,  $b_1 \approx b_2$  means that behaviour,  $b_1$  is similar to  $b_2$ . Then we have

$$\text{If } f_1 \sim f_2 \text{ then } b_1 \approx b_2 \quad (4)$$

In other words, Equation (4) means that people with similar interests have similar behaviours. People with similar interests can be called friends. Then “friends have similar (online) behaviours”. If we limit the mentioned behaviours as online purchasing behaviours, then we have “Friends have similar purchasing behaviours” (Sun, Firmin, & Yearwood, 2012). This can also explain why the rich are getting richer because if you are rich, you can have more friends, and if you have more friends, you can find more ways and learn more from them to become richer (Christakis & Fowler, 2011).

The behaviours of friends in SNS including Facebook are governed by a specific set of friendship rules (Bryant & Marmo, 2012). That is, friends use different friendship rules in SNS will decide the characteristics of their friendships. The friend rules include communication rules, interaction rules, collaboration rules, and negation rules etc. For example, close friends interact with each other using numerous channels of communication (e.g. face-to-face, telephone, email, Facebook, and QQ) following communication rules and interaction rules. Facebook friends also attempt to negotiate friendships of various levels of closeness using negotiation rules. The interaction rules include trust rules and deception rules. For example, Peter and Monica have a close friendship on Facebook. They support each other in terms of suggestions and photos, and texts following a set of friendship rules on Facebook in order to maintain such a close friendship. More generally, the increasing or decreasing closeness of friendships on Facebook is a consequence of applying a set of friend rules. Close friendships involve high levels of interaction, self-disclosure, intimacy, engagement and interdependence. Close friendships are often in relationships which involve meaningful and significant behaviours of love, trust, caring and shared benefits and therefore, close friends usually invest themselves to achieve communal goals in terms of happiness, common value, social capital, and deep intimacy (Bryant & Marmo, 2012).

Bryant and Marmo (2012) summarise 36 friendship rules to provide a guide to manage and sustain friendships. Now we look at which five of these 36 friendship rules can manage and sustain positive friendships or increase friendship closeness? Which five of these 36 friendship rules might decrease the closeness of the friendship? These two sets of rules can be considered as positive friendship rules and negative friendship rules respectively. Based on the research of Bryant and Marmo (2012), the five most positive friendship rules are

1. If  $P$  always presents her/himself positively but honestly on Facebook, then  $P$  can increase friendship closeness with his friends.
2. If  $P$  respects her/his friend's time by not posting excess information on Facebook, then  $P$  can increase friendship closeness with her/his friends.
3. If  $P$  only writes on a friend  $Q$ 's wall, send a private message to  $Q$  and they are actually offline friends, then  $P$  can increase friendship closeness with  $Q$ .
4. If  $P$  only comments on a friend  $Q$ 's photos, uses Facebook to chat with  $Q$  and they are actually offline friends, then  $P$  can increase friendship closeness with  $Q$ .
5. If  $P$  communicates with a friend  $Q$  using other communication channels besides Facebook, then  $P$  can increase friendship closeness with  $Q$ .

where  $P$  and  $Q$  are any two Facebook friends. Each of the five rules are a summary of some of the mentioned 36 friendship rules proposed by Bryant and Marmo (2012). The five most negative friendship rules are that  $P$  breaks the friendship rule and decreases the closeness of friendship with  $Q$ , if  $P$

1. posts anything that will hurt a friend  $Q$ 's image or career, or relationships; or
2. tells lies to a friend  $Q$  on Facebook (because Facebook can expose lies one have told people); or
3. spends time trying to guess a friend  $Q$ 's motives for Facebook behaviors; or
4. says anything disrespectful about a friend  $Q$  on Facebook; or
5. posts information on Facebook that could be used against a friend  $Q$ .

These positive and negative friendship rules will be used in the proposed algorithm for ranking behaviour-based friendship closeness in next section.

### ARFC: An Algorithm for Ranking Behaviour Based Friendship Closeness

The technique for order of preference by similarity to ideal solution (TOPSIS) as a multi-criteria decision analysis method was originally developed by Hwang and Yoon (1981) to rank potential alternative decisions with multiple attributes or criteria (Peng, Zhang, & Li, 2011). TOPSIS has been extended over the years since its introduction (TOPSIS, 2012). TOPSIS finds the best decision with the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution (Peng, Zhang, & Li, 2011). TOPSIS has been also applied in many fields including incident information management (Peng, Zhang, & Li, 2011). In this section we propose a technique for ranking the behaviour-based friendship closeness in SNS (ARFC) based on TOPSIS.

The ARFC process is as follows:

Step 1: Create an evaluation friend matrix consisting of  $m$  friends and  $n$  criteria, with the intersection of every friend and criteria (attributes) given as  $x_{ij}$ , we then have a friend matrix  $(x_{ij})_{m \times n}$ .

Step 2: The matrix  $(x_{ij})_{m \times n}$  is then normalised to form the matrix  $R = (r_{ij})_{m \times n}$  using the normalisation method as follows:

$$r_{ij} = x_{ij} / \sqrt{\sum_{i=1}^m x_{ij}^2}, j = 1, 2, \dots, n \quad (5)$$

Step 3: Develop a set of weights  $w_j$  ( $j = 1, 2, \dots, n$ ) and calculate the weighted normalised friend matrix  $(v_{ij})_{m \times n}$ , where  $v_{ij} = w_j x_{ij}$ ,  $i = 1, 2, \dots, m$ .

Step 4

Determine the ideal friend  $f_{it}$  and the most unideal friend  $f_{mu}$

$$f_{it} = \{v_1^+, v_2^+, \dots, v_n^+\} = \{(\max_i v_{ij}) | j \in J_+, (\min_i v_{ij}) | j \in J_-\} \quad (6)$$

$$f_{mu} = \{v_1^-, v_2^-, \dots, v_n^-\} = \{(\min_i v_{ij}) | j \in J_+, (\max_i v_{ij}) | j \in J_-\} \quad (7)$$

Where  $J_+ = \{j = 1, 2, \dots, n \text{ and } j \text{ associated with the closeness having a positive behavior}\}$  and  $J_- = \{j = 1, 2, \dots, n \text{ and } j \text{ associated with the closeness having a negative behavior}\}$



Step 5: Calculate the Euclidean distance between the friend  $i$  and the ideal friend, and the Euclidean distance between the friend  $i$  and the most unideal friend respectively.

$$d_{iit} = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2}, i = 1, 2, \dots, m \quad (8)$$

$$d_{imu} = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2}, i = 1, 2, \dots, m \quad (9)$$

Note that the smaller the  $d_{iit}$  is, the closer is between the friend  $i$  and the ideal friend. Therefore, Equation (8) can be used to rank the closeness of friend  $i$  and the ideal friend under the criteria designated by the user. However, this ranking algorithm does not take the Euclidean distance between the friend  $i$  and the most unideal friend, which will be involved in Step 6 below.

Step 6: Calculate the closeness of friend  $i$  to the idealist friend using the following formula:

$$s_{ic} = d_{imu} / (d_{imu} + d_{iit}), i = 1, 2, \dots, m \quad (10)$$

Then the closeness degree of friend  $i$  to the ideal friend satisfies  $0 \leq s_{ic} \leq 1$ , and

1.  $s_{ic} = 1$ , if and only if  $d_{iit} = 0$ , that is, friend  $i$  is the closest friend, when  $d_{imu} \neq 0$ .
2.  $s_{ic} = 0$ , if and only if  $d_{imu} = 0$ , that is friend  $i$  is the most unideal friend.

Step 7: Rank the friend  $i$  according to the value of  $s_{ic}$  received from step 6, in a descending way to know how close the friend  $i$  is to the best friend,  $i = 1, 2, \dots, m$ .

Now we use an example to illustrate how ARFC process runs based on the positive and negative friend behaviours discussed in the previous section.

Based on the above positive friendship rules, the four positive friend behaviours are as follows:

- FB1.  $P$  always presents her/himself positively but honestly on Facebook;
- FB2.  $P$  respects her/his friend's time by not posting excess information on Facebook;
- FB3.  $P$  only writes on a friend  $Q$ 's wall, send a private message to  $Q$  and they are actually offline friends;
- FB4.  $P$  only comments on a friend  $Q$ 's photos, uses Facebook to chat with  $Q$  and they are actually offline friends;

where  $P$  and  $Q$  are any two friends on Facebook.

The three negative friend behaviours are as follows:

- FB5.  $P$  posts anything that will hurt a friend  $Q$ 's image or career, or relationships;
- FB6.  $P$  tells lies to a friend  $Q$  on Facebook;
- FB7.  $P$  spends time trying to guess a friend  $Q$ 's motives for Facebook behaviours.

For Step 1, we use an example of data set from five friends on Facebook which will be used to run the procedure of the proposed TRCF. We use likert scale (1 weak, 5 strong), and have the following table (note that the last column is used in Step 2).

Friend	FB1	FB2	FB3	FB4	FB5	FB6	F7	$\sqrt{\sum_{j=1}^m x_{ij}^2}$
$f_1$	5	3	5	5	3	1	1	9.746794345
$f_2$	4	5	2	4	3	1	2	8.660254038
$f_3$	3	5	1	4	2	2	3	8.246211251
$f_4$	2	5	4	3	2	2	2	8.124038405
$f_5$	1	2	5	4	1	3	1	7.549834435

For Step 2, we have the following friend matrix  $(x_{ij})_{5 \times 7}$  after calculation using Microsoft Excel 2010.

Friend	FB1	FB2	FB3	FB4	FB5	FB6	FB7
f1	0.512989176	0.307793506	0.512989176	0.512989176	0.307793506	0.102597835	0.102597835
f2	0.461880215	0.577350269	0.230940108	0.461880215	0.346410162	0.115470054	0.230940108
f3	0.363803438	0.606339063	0.121267813	0.48507125	0.242535625	0.242535625	0.363803438
f4	0.246182982	0.615457455	0.492365964	0.369274473	0.246182982	0.246182982	0.246182982
f5	0.132453236	0.264906471	0.662266179	0.529812943	0.132453236	0.397359707	0.132453236

For step 3, we assume the set of weights  $w_1 = 0.2, w_2 = 0.1, w_3 = 0.15, w_4 = 0.2, w_5 = 0.2, w_6 = 0.2, w_7 = 0.05$ , and calculate the weighted normalised friend matrix  $(v_{ij})_{m \times n}$ , where  $v_{ij} = w_j x_{ij}, i = 1, 2, \dots, 5, j = 1, 2, \dots, 7$ , and have the weighted normalised friend matrix  $(v_{ij})_{5 \times 7}$  below.

Table 2: The weighted normalised friend matrix  $(v_{ij})_{5 \times 7}$

Friend	FB1	FB2	FB3	FB4	FB5	FB6	FB7
f1	0.102597835	0.030779351	0.076948376	0.102597835	0.061558701	0.020519567	0.005129892
f2	0.092376043	0.057735027	0.034641016	0.092376043	0.069282032	0.023094011	0.011547005
f3	0.072760688	0.060633906	0.018190172	0.09701425	0.048507125	0.048507125	0.018190172
f4	0.049236596	0.061545745	0.073854895	0.073854895	0.049236596	0.049236596	0.012309149
f5	0.026490647	0.026490647	0.099339927	0.105962589	0.026490647	0.079471941	0.006622662

For Step 4, in our example,  $J_+ = \{FB1, FB2, FB3, FB4\}$   $J_- = \{FB5, FB6, FB7\}$ , then from Table 2, we have the ideal friend  $f_{it}$  and the most unideal friend  $f_{mu}$  respectively.

$$f_{it} = \{0.102597835, 0.061545745, 0.099339927, 0.105962589, 0.026490647, 0.020519567, 0.005129892\}.$$

$$f_{mu} = \{0.026490647, 0.026490647, 0.018190172, 0.073854895, 0.069282032, 0.079471941, 0.018190172\}.$$

From these results we can see that the ideal friend  $f_{it}$  and the most unideal friend  $f_{mu}$  are not in the set of Facebook friends  $\{f_1, f_2, f_3, f_4, f_5\}$ .

For Step 5, after simple calculation, we have  $d_{1it} = 0.002689043, d_{2it} = 0.00636846, d_{3it} = 0.008995042, d_{4it} = 0.0059214, d_{5it} = 0.010498775$ ; and  $d_{1mu} = 0.013794983, d_{2mu} = 0.009153363, d_{3mu} = 0.005233451, d_{4mu} = 0.006195382, d_{5mu} = 0.009581097$ . Then we have the ranking of the set of Facebook friends  $\{f_1, f_2, f_3, f_4, f_5\}$  based on the ascending order:  $f_1, f_4, f_2, f_3, f_5$ . The  $f_1$  is the closest friend.

For Step 6, we rank the friends taking into account the most unideal friend and obtain  $s_{1c} = 0.836869794, s_{2c} = 0.589709277, s_{3c} = 0.367814857, s_{4c} = 0.511305854, s_{5c} = 0.477149304$ . In this way, we have the ranking of the set of Facebook friends  $\{f_1, f_2, f_3, f_4, f_5\}$  based on the descending order (based on Equation (10)):  $f_1, f_2, f_4, f_5, f_3$ . In reality, any ranking of behaviour-based friendship closeness on Facebook should consider the impact of the negative friend behaviours. Therefore, the latter ranking is advised compared to the former one.

## DISCUSSION AND RELATED WORK

Ranking closeness among friends in social networks can be considered as 1) examining friends and friendships, and 2) friendship behaviours in SNS. In what follows, we review some related work taking into account what we have examined in our research. All the related work motivated us to undertake our research.

Bryant and Marmo (2012) examine 36 rules of Facebook friendship in terms of close, causal, and acquaintance friendships. However, they have not looked at the ranking of friendship closeness. Further, the difference between our friendship rules and their friendship rules is that ours are production rules in the form of If... Then. This is more useful for further processing using knowledge based systems (Russell & Norvig, 2010; Schalkoff, 2011).

Sakaki, Okazaki, and Matsuo (2010) state that discovery of the relations between friends is a key to understanding interaction in SNS. However, this is only at communication level, because Facebook uses friend or friending to build an online social networking platform for users, Facebook has not explored the ‘‘close’’ friendship among friends. Our proposed technique aims to fill this gap through ranking friendship closeness.

It is easy for anyone to enlist 1,000 Facebook friends within a year if s/he tries to do so. Christakis and Fowler (2011) consider ‘connected’ a surprising power of our social networks and how they shape our lives and looks at how your friends' friends' friends affect everything you feel, think, and do. However, they have not examined the friendship closeness in SNS. Based on the research of Dunbar (1993), the close friends number of an ordinary

person is about 150 in the physical world. It is important for anyone to know which friends are close, and closest among Facebook friends. Our proposed technique provides an answer to this question.

In the age of e-relationships, instant communication and the rules of behaviour are changing in terms of friendships. With clicking a mouse or touching a screen of a smartphone, a person can befriend and defriend, hook up and make up, all without leaving the computer or smartphone (Lavinthal & Rozler, 2008). Online social networks increase the quantity of communication, but not always the quality. When it comes to friendship in a social networking setting, it is often difficult to distinguish between close friends, friends, and frienemies. This is one of the reasons why we examine techniques for ranking friendship closeness in SNS.

## CONCLUSION

This paper proposed a technique for ranking friendship closeness in SNS. The technique consists of two algorithms for ranking need-driven friendship closeness and behaviour-based friendship closeness. The algorithm for ranking need-driven friendship closeness is based on Maslow's hierarchy of needs; the algorithm for ranking behaviour-based friendship closeness is based on behaviours of users on Facebook and TOPSIS, a well-known multi-criteria decision analysis method. The examples illustrate the viability of the proposed algorithms. The research in this paper shows that ranking the friendship closeness will facilitate understanding of needs and behaviours of friends in SNS.

The implication of this research for researchers and developers is that they might use the proposed technique to develop their own technique for ranking friendship closeness in SNS. The implication of this research for ordinary SNS users is that they might improve their understanding of friendship closeness and friendship rules in SNS. Therefore, the proposed approach will facilitate research and development of social media, social commerce, social networks, and SNS.

There are at least two limitations of this research. One is that this research has not examined the interrelationship between need-driven friendship closeness and behaviour-based friendship closeness. Another is that the examples for running the procedure of ranking need-driven friendship closeness and behaviour-based friendship closeness are only illustrative. In the future work, we will address these two limitations by further improving the proposed technique based on significant questionnaire and survey and data analysis. We will also develop a platform for attracting friends to participate in ranking of friendship closeness.

The theory and technologies of computational intelligence have been playing a vital role in the analysis, design, and interpretation of the architecture and functioning of social networks in general, online social networks in particular (Pedrycz & Chen, 2012). In future work, we will highlight the important facets of friend metrics, friend ranking and friend management based on computational intelligence, and develop a computational framework of friend management taking into account social commerce and cloud commerce.

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