Interplay between Social Selection and Social Influence on Physical Proximity in Friendship Formation

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ABSTRACT
People form social relationships based on certain characteristics they possess, called social selection. When people change their social behavior due to interaction with others, social influence is at work. Current friend recommendation systems are mainly based on common friends and similar profile characteristics, therefore the system may recommend unknown people. Recent advances improve the quality of friend recommendations by using shared content and interactions such as co-authored papers, patents, and comments, but neglect the physical interactions to associate how you may know that person. In this paper, the interplay between social selection and social influence on physical proximity in friendship formation is quantified in a mobile location-based social network deployed in an academic conference. Encounter is used to measure and record physical proximity between user pairs, then a friend recommendation system is built that uses these encounters to specify the reason why this person should be added as a friend. The cumulative average duration and average frequency of encounters are analyzed, before and after sending the friend request. The results present weak social selection and strong social influence on physical proximity in friendship formation and the reasons are explained. This work helps to improve the design implementation of friend recommendation in physical environments.

Author Keywords
Friend recommendation, social selection, social influence, physical proximity.

ACM Classification Keywords
H.5.3 Information Interfaces and Presentation: Group and Organization Interfaces - Collaborative computing; H.3.3 Information Search and Retrieval - Information filtering

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INTRODUCTION

Studying how new social links emerge and are formed with temporal information about individuals' activities and their interactions, is very important for understanding the underlying network evolution mechanisms. The intrinsic and immutable homophily between individuals such as similar characteristics, interests, beliefs and even common friends in the network itself, have been investigated with great effort and validated to contribute to the usual preferential ties [10, 21].

In addition, surrounding contexts in which a social network is embedded have great effects on the formation of social linking between pairs of individuals and the evolution of the network structure. The factors in surrounding contexts refer to activity features existing beyond individuals and their network, for example walking nearby and attending the same meeting in physical environments [10]. The phenomenon that people tend to connect and form social links with others who share the similar intrinsic homophily and contextual factors, is often called social selection.

In all social networks, individuals behave as a social atom and certainly are not alone and interact with others, friends or not friends. While the social selection rules play in friendship formation among people who are not friends before, another interesting rule is social influence. Social influence describes that, in the process of an individual's interactions with others who are already friends, her social behaviors and activities may change and converge to be in accordance with the behaviors of their friends. Social influence has been presented to be at work in many social settings [10, 27], especially in online social networks, for example, the influence from friends such as joining a community in LiveJournal [1], editing a Wikipedia article [6] and attending a DBLP conference [1].

Both social selection and social influence in daily life have a long history of study in sociology, from studying in a same school, working in a same company, to joining weight loss behaviors or even adopting risky behaviors such as drug and alcohol abuse [10, 21]. However, little work studies the social selection and social influence on physical proximity among individuals in daily life. In this paper, we try to understand their interplay and roles on physical proximity in friendship formation in physical

environments. We hypothesize that: (1) for social selection, more physical interactions will result in an increased probability for a person to add another as a friend, and (2) for social influence, being friends will result in an increased physical proximity between each other.

To test the hypothesis and understand the social behavior around tracking friendship formation in a physical environment, we built a mobile indoor location-based application called Nokia Find & Connect (NF&C) at an academic conference. We used encounters to measure and record physical proximity between two people, then built a friend recommendation system that used these encounters to specify the reason why this person should be added as a friend. Besides, in NF&C, a user can manually add another user who is not a friend by searching and visiting her profile page and then sending out the manual friend request. Through evaluating the system logs, we analyze the cumulative average duration and the frequency of physical proximity interactions between a pair of attendees A and B before A sends a friend request to B (either manually or from friend recommendation), and after the friend request (considering if the friend request is accepted or not).

From the analysis of the presented results, the hypothesis (1) is not supported while the hypothesis (2) is supported. In particular, before the manual add-as-friend request is sent, the cumulative average duration of encounters is very small and almost does not rise. At the same time, there are just a few encounters on average of per user pairs. These indicate that physical proximity in terms of cumulative average encounter duration and average encounter frequency has negligible effect on a user adding another as a friend. Thus, social selection on physical proximity has very little effect in the friendship formation process to prompt users to manually add others as friends, which negates the hypothesis (1).

Besides, the cumulative average encounter duration and the average encounter frequency both raise sharply within the first several hours after the add-as-friend request is sent, and then keeps increasing with moderate speed, for user pairs who send friend requests manually or from friend recommendation. For the user pairs whose friend requests are accepted, their values of the above two metrics are substantially larger than that for user pairs whose friend requests are not accepted. Especially, for user pairs who do not send friend requests to each other, there is scarcely any increase in cumulative average encounter duration. These results show clearly that the social influence on physical proximity in terms of encounter duration and encounter frequency in friend formation is strong, which validates the hypothesis (2).

The rest of the paper is organized as follows. Related work is discussed in the next section. Then the experimental setup about the system overview and features of NF&C is described. Next, the quantitative results of the temporal relationship between physical proximity and friend formation are presented in detail and the behind reasons are discussed. Finally, we conclude the paper, followed by a discussion on the potential design implementations of friend formation based on physical proximity information in the physical environment as well as future work.

RELATED WORK

Social Selection

Homophily principle [21] in the formation of network structures and ties, presents that we tend to connect with similar people and be friends with them. The intrinsic homophily between individuals such as similar characteristics, interests and beliefs, and the surrounding context factors like studying in the same school, have been validated to contribute to the usual preferential ties [21, 22]. The fact that people form social ties based on certain same characteristics they possess is often termed social selection [21]. In social selection, people may have more opportunities in the social environment to form friendships with other like-minded individuals, due to the shared characteristics [17, 24].

Work in [13] examines nine diverse information sources from three categories (“people”, “things” and “places”) to define user similarity, with which people form ties in social selection. Work in [2] utilities self-reported address data from Facebook users and their network ties to measure the relationship between geography and friendship. The authors find that in social selection, Facebook users’ probability of friendship is roughly inversely proportional to their distance at medium to long-range scale, while in shorter distance scale, the probability is less sensitive to the distance. Work in [9, 23] use Bluetooth technologies to define the relative physical closeness and infer the friendship in social selection through encounter duration and frequency.

However, previous works on social selection do not consider physical proximity information or consider the physical proximity in outdoor environments which is in rough granularity. Our work focuses on indoor physical environments and studies the social selection role on physical proximity in people connecting to each other.

Social Influence

In social environments, people not only tend to friend with like-minded individuals as indicated by the social selection principle, but they will adapt their activities and behaviors to be accorded with that of their friends, which is called social influence [10].

Social influence appears in almost every area, from daily life to adopt smoking [4] and losing weight [18], to virtual

goods purchases [19], consumer's desires and behaviors [8] and technology adoption [27]. Especially in online social networks and communities, people's probability of joining a community in LiveJournal [1], editing a Wikipedia article [6] and attending a conference listed in DBLP [1], increases linearly as the number of their friends who are already there increases. The social influences in these works in people's social behaviors are all so strong that a set of friends is about 100 times more powerful in influencing a user to join a group than the same number of strangers.

However, there is little research work on the role of social influence on physical proximity after friendship formation. We want to know if the physical proximity interaction in a shared physical environment increases if two people become friends. Understanding this is important to help to bridge the gap between physical offline co-location and friendship in the online world. Work in [7] studied the diverse location measurements and proposed location entropy to predict the friendship of two users by analyzing their co-location trace, which addresses some different problems.

Friend Recommendation

Web 2.0 centers on users and their relationships. Friend recommendation system is an effective channel to expand one's social circle [26]. Current friend recommendation systems such as "People You May Know" in Facebook and LinkedIn are mainly based on common friends and similar profile characteristics [15]. But the system may recommend unknown people and people often provide feedback like "I do not know this person, why the system recommends him to me" and "Even though there are several common friends, but I do not know the recommended person so I will not add him as friend". This is validated by work in [3], which showed that the more known people that were recommended, the more likely users will rate and consider the recommendations as good. Recent advances [14, 16] improve the quality of friend recommendations by using shared content and interactions such as co-authored papers, patents, and comments, but neglect the physical interactions to associate how you may know that person [9, 20, 25].

Due to a flourish of location-based social networks such as Foursquare and Gowalla, users behave and interact with each other in physical environments. Previous work [12-14] showed that the more social network information and sources integrated, the richer the result and the closer the returning people is to the ideal friend list. Thus, physical interactions within proximity may be utilized to recommend similar-minded people [5, 7, 23]. Work in [11] shows that there is positive correlations between physical place preference and visiting frequency and visit time. In our work, priority weight is given to physical proximity when recommending the potential friends, since the people nearby that you may see and listen to , may be talking with you in a conference environment.

EXPERIMENTAL SETUP

Our evaluation on the two proposed hypotheses is based on the analysis of system logs of NF&C about users' friend formation data and users' physical location with temporal information. NF&C system is an indoor location and proximity-based mobile social network solution to leverage efficient management of physical resources like meeting rooms through event scheduling to facilitate social linking for connecting people. NF&C was deployed in the 7th International Conference on Ubiquitous Intelligence and Computing (UIC 2010) and 7th International Conference on Autonomic and Trusted Computing (ATC 2010), in October 2010. During the conference, a total of 112 conference attendees participated in the NF&C system and each carried a phone with NF&C software installed. We now describe the system overview and social features in NF&C.

System Overview

NF&C in the UIC/ATC 2010 conference provides an integrated interface in the mobile phone to bridge the gaps between online social links among people and physical interactions like proximity and offline resources like session rooms. As an indoor location-based social network, NF&C utilizes WiFi wireless technology to offer the updated location of moving conference attendees.

A Client-Server architecture is leveraged in the NF&C positioning subsystem. The positioning client software installed in the mobile phone continually collects and sends WiFi signal strengths from nearby WLAN access points at a tunable time interval, to the positioning server to update current location. With the received WiFi signal strengths from the positioning client and the positioning model obtained from recording WiFi signal strength in the indoor environment, the positioning server can approximate the current position of the mobile phone which is carried by the NF&C user. Thus, every time a positioning client updates location, the positioning server can calculate and record the physical proximity between the user and other online NF&C users.

A web application is built to present the location-based social conference services in a mobile web browser on the mobile phone where the positioning client above is installed. The web application sends requests to and receives responses from the NF&C application server, which not only processes business data but also communicates with the NF&C positioning server to provide the physical proximity interactions between conference attendees and show where the conference resources like the session rooms are.

Social Features for Conference

To help attendees efficiently find the interesting papers and sessions in a large academic conference with multiple parallel sessions and reserve their time in by scheduling the conference program with their favorite papers and sessions, a conference navigator such as the one in [28] was created.

Establishing social links among conference attendees provides more valuable opportunities for them to talk with each other in a face-to-face manner. NF&C not only provides the basic functionalities to make the conference participation much easier, but also bridges and connects the conference attendees by helping to build the social links among the attendees through diverse channels. NF&C users can enrich their profile page by updating their status about what they do now and specifying their research interests and favorite papers and sessions. NF&C users can interact with others through visiting each other's profile, sharing their personalized conference schedule and favorite papers to others, sharing their location to others and viewing where others are and what others do now with the status and making comments to certain sessions and papers as a form of conference buzz. Then NF&C users may connect to each other by adding others as friends and becoming friends after a certain number of social interactions.

Furthermore, a friend recommendation system is built to help conference attendees easily find the like-minded people. The recommendation system utilizes several kinds of information about users' social activities and interactions in NF&C. The information includes the same research interests, the same favorite papers and sessions, buzzes to the same papers and sessions, the common friends and physical proximity. While the other information except the physical proximity (like research interests) can be faked, the physical position and the resulting proximity is of absolute reality because it comes from the NF&C positioning client in the mobile phone carried by conference attendees. *What you are interested in is what you see and listen at the place where you are*. This principle is some kind of voting with your footprint [11] and it is true especially in an academic conference scenario. Therefore, we give special importance weight to physical proximity when recommending the potential friends, since the people nearby may see and listen to what you are seeing and listening and as well the people nearby possibly are talking with you.

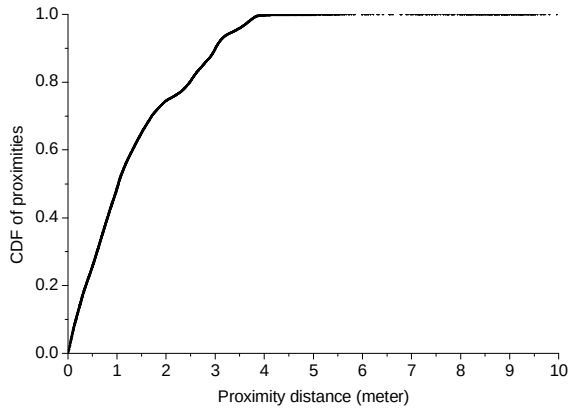

Figure 1. Physical proximity distribution of all users from the conference.

SOCIAL SELECTION AND SOCIAL INFLUENCE ON PHYSICAL PROXIMITY

We define that two users have an encounter if the physical distance of their proximity interactions at a time point is less than a certain threshold. Figure 1 shows the cumulative distribution function (CDF) of physical proximity interactions in the NF&C deployment at the UIC/ATC 2010conference. Clearly, for almost all the physical proximity interactions, the distances between any pair of two users in the proximity are within 4 meters. Therefore, in this paper, we consider a physical proximity interaction as an encounter when the physical proximity distance is less than 1 meter, 2 meters, 3 meters and 4 meters, respectively.

Results in Encounter Duration

Using the four representative encounter distance thresholds to define encounter, we study how friendship formation affects physical proximity and encounter between a pair of two users. We also investigate how the effect changes over time before and after the friendship formation. The time when one user sends the add-as-friend request to another user is recorded and used as time 0 in tracking the evolution with hours as the unit. For the pairs of two users that did not send add-as-friend requests to each other, the middle time of the UIC/ATC 2010 conference is used as time 0, i.e. 2010-10-28 00:00:00.

Since we provide a friend recommendation system in NF&C, there are two sources for the add-as-friend request to be sent out. One is to visit the friend recommendation (FR) page and add the recommended person as friend, which is denoted as FR-Yes. Another is to find someone in NF&C manually and if the person is not a friend then adding the person as a friend, which is denoted as FR-No. The add-as-friend request needs confirmation before the friendship is eventually formed. As a result, we denote the add-as-friend request that is accepted as Accept-Yes, otherwise as Accepted-No. In combination, we have four different types for user pairs, if they have sent out the add-as-friend request from one to another. For example, FR-Yes, Accepted-Yes stands for the type of pairs of users that one user sent out the add-as-friend request from the friend recommendation page and the request is

confirmed and accepted by another user, which means the two users are friends. Besides, we also have two types of pairs of users by checking whether they sent out the add-as-friend request.

Figure 2 shows the cumulative encounter duration averaged per encounter at each discrete hour unit before and after the reference time 0 point, for different types of pairs of users and different types of encounter distance threshold settings. On the high level that encounter distance threshold changes from 1 meter to 4 meters, we observe the similar trends in each cumulative average encounter duration for each type of user pairs that send add-as-friend request.

Before the add-as-friend request is sent, the average encounter duration is very small and rises very slowly, while for the time just before and just after the add-as-friend request is sent, the duration rises sharply to a considerable large value, then after the request is sent the value rises smoothly. For the user pairs that do not send friend requests, we observe that the cumulative average duration has a small increase mainly in the first two days in the conference, and in the last two days of conference, the value remains stable. This means that for user pairs that do not send friend requests, they mainly completed their encounters during the first half of the conference.

We discover that the social selection on physical proximity in friendship formation is weak. As shown in Figure 2, before the manual add-as-friend request is sent, the cumulative duration of encounters is very small and almost does not rise (the green line and blue line). This indicates that social selection on encounter duration has very little effect on a user adding another as a friend. Because we believe that if the social selection on physical proximity works in friend formation, then the cumulative average duration of encounters before sending the add-as-friend request should be large. Even for the add-as-friend request sent from friend recommendation (the red line and

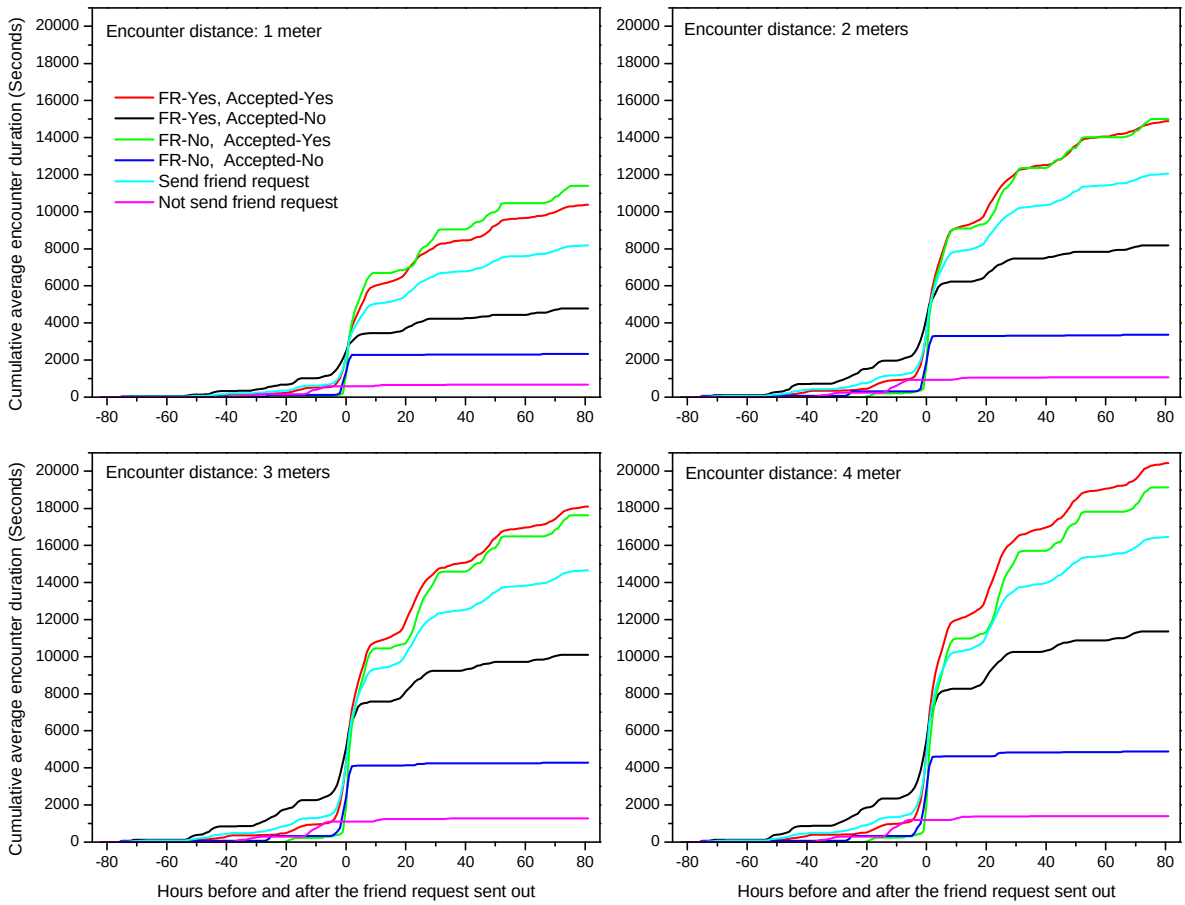

Figure 2. Cumulative encounter duration averaged per encounter over time for different pairs of users.

black line), before sending, the cumulative encounter duration increases at a slow speed. But the slow increase is due to the fact that the friend recommendation system takes physical encounter as an important one of the information sources utilized in calculating the recommendation list. Thus, the duration of encounters is not enough to affect users to accept the friend recommendation and send the friend request, contrary to our hypothesis (1). The reason why our hypothesis is not validated by encounter duration may be that in an academic conference, the objective is to know more researchers with similar research interests and keep connected with them, therefore the physical proximity becomes irrelevant for the friendship formation. Therefore, results in Figure 2 show that the role of social selection on physical proximity measured by cumulative average encounter duration is very weak in a conference environment.

The social influence from friends on physical proximity is clearly strong. In Figure 2 after the add-as-friend request is sent out, for accepted friend requests from manual and friend recommendation (the red line and green line), the cumulative average encounter duration increases rapidly with time. For the unaccepted friend requests from friend recommendation (the black line), the duration of encounters increases, but is at a much slower rate. For unaccepted manual friend requests, the duration of encounters does not increase and remains stable. It clearly shows that the cumulative average encounter duration of user pairs that the add-as-friend request is accepted, is about one and a half times to that of user pairs with unaccepted friend requests from friend recommendation and about two to four times to that of user pairs with unaccepted friend requests from manual sending. Once the friend request is accepted, users are more likely to encounter each other with longer duration. This phenomenon is especially obvious for the user pairs that send add-as-friend requests from the friend recommendation system and accept the request, as the encounter distance threshold increases from 2 meters to 4 meters, except the case where the encounter distance threshold is set to be 1 meter. Therefore, the role of social influence from being friends on physical proximity measured by cumulative average encounter duration is very strong, similar to the influence from friends in online environments such as joining a community in LiveJournal [1], editing a Wikipedia article [6] and attending a DBLP conference [1].

In addition, for the unaccepted add-as-friend requests, the cumulative average encounter duration of the user pairs with requests from friend recommendation, is considerably about two times larger than the value of the user pairs with requests sent out manually as time progresses. This indicates that, although there exists a weak role of social selection on physical proximity in friendship formation, the friend recommendation system that utilizes physical proximity information in NF&C, significantly helps to increase the possibility to find the people you should meet in a conference for attendees, whether or not the add-as-friend request from friend recommendation is eventually accepted.

Results in Encounter Frequency

Changes of average number of encounters per user pair as times increases, for different types of user pairs and different encounter distance threshold settings, are also considered. When changing the encounter distance threshold setting from 1 meter to 4 meters, the results present similar trends. Therefore, only the result for the case when the encounter distance threshold is 4 meters is shown in Figure 3.

Before the manual add-as-friend request is sent, there are just a few encounters on average per user pairs (the green line and blue line). This indicates that social selection on physical proximity in terms of the average encounter frequency has negligible effect on the friendship formation process to prompt users to manually add others as friends, which is in accordance with the results from the cumulative average encounter duration in Figure 2. Thus, the hypothesis (1) is not supported by the distribution of encounter frequency.

After sending out the add-as-friend request, the average number of encounters clearly increases. User pairs with accepted friend requests have more encounters than user pairs with unaccepted friend requests, for both types of friend requests sent from manual and friend recommendation page, respectively. Therefore, being a friend has obvious social influence on physical proximity in terms of the average encounter frequency, which supported the hypothesis (2).

Furthermore, from the left inner figure, we observe that

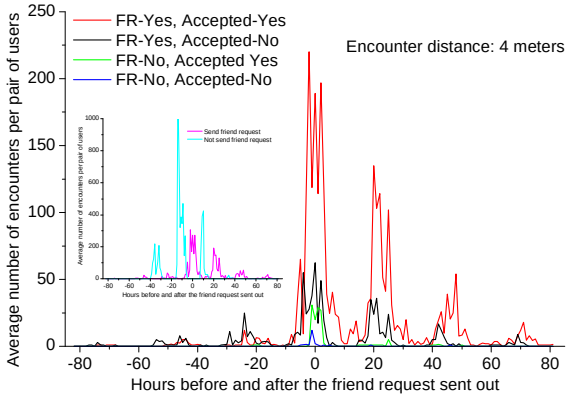

Figure 3. Average number of encounters per pair of users for manual friend requests and friend recommendations.

for user pairs who do not send friend request to each other, they encountered pretty much mainly during the first two days of the conference. Based on Figure 2, we know that user pairs who do not send friend request to each other generally encounter each other very shortly and rarely stop to stay and have a talk. On contrast, user pairs who have sent friend request have fewer encounters but longer duration of each encounter. NF&C helps to establish social links among conference attendees and provides more valuable opportunities for them to talk with each other in a face-to-face manner.

CONCLUSION

We built an indoor location-based mobile social networking system at an academic conference, named Nokia Find & Connect (NF&C), which not only implements personalized conference schedule to provide a kind of conference navigator system in the mobile phone, but more importantly offers diverse channels to establish social links among conference attendees. The social linking is especially helpful in that the linked conference attendees may have more opportunities to talk in a face-to-face manner. NF&C helps to discover potential like-minded researchers in the form of friend recommendations, which consider physical proximity information with the principle of "voting with your footprint" [11], except the similar research interests and favorite papers and sessions.

In this work, we investigated the roles of social selection and social influence in terms of physical proximity in the social friendship formation process. Through defining encounters to measure the physical proximity interactions between people, we analyzed the distribution of cumulative encounter duration and encounter frequency averaged on per user pairs, for different types of user pairs. We made a distinction between user pairs by considering whether they send out friend requests, where the friend request comes from (manual or friend recommendation) and whether the friend request is accepted or not (become friend or not).

We find that social selection on physical proximity has very little effect in the friendship formation process to prompt users to manually add others as friends, in the academic conference environment. However, we find that the social influence on physical proximity in terms of encounter duration and encounter frequency in friend formation is strong. Furthermore, for the user pairs whose friend requests are from friend recommendations, generally there are more physical proximities than that for user pairs whose friend requests are manual, whether the friend request is accepted or not.

The results presented imply that although the social selection role on physical proximity in liking people to become friends is weak (at least in our academic conference environment), the friend recommendations that utilize the physical proximity information to discover potential like-minded individuals, finds the right conference attendees to have more face-to-face talks.

Our work is limited in that the short deployment (four days) in only one conference environment may make the results somewhat biased, even though we obtain a clear physical proximity distribution as presented earlier. Future work includes deploying NF&C at more large conferences and revisiting our results, and considering the relationships between physical proximities and number of friends.

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