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Harnessing Facebook for the Evaluation of Recommender Systems based on Physical Copresence

Alexandre de Spindler and **Stefania Leone** and **Michael Grossniklaus** and **Moira C. Norrie** [1]

Abstract. Various mobile social applications have proposed the use of ad-hoc network connectivity as a means of detecting user encounters and shared social contexts. These applications range from simple opportunistic information sharing to techniques for collaborative filtering in mobile settings. However, it can be difficult and costly to test the underlying assumption that repeated physical copresence can be used as a measure of user similarity. We have therefore developed a framework that allows existing online social platforms such as Facebook to be coupled with simple, standard mobile applications in order to test such hypotheses. The central idea is to map the physical copresence of users to connections in virtual social networks and then exploit the rich support for developing pluggable applications to measure user similarity within these networks.

1 Introduction

Several mobile social applications have proposed the use of ad-hoc network connectivity as a basis for detecting user encounters. Physical copresence provides a means of not only sharing information opportunistically between mobile devices, but also determining shared social contexts which can be an indicator of some kind of similarity between users. Hence, the communication layer can be used to perform some of the filtering of information normally associated with recommender systems.

Some of these applications focus on copresence at specific events in order to exchange information closely related to these events, while others use repeated copresence in public spaces such as railway stations to build user communities and share general information such as jokes or images. We have taken the idea one step further and adapted collaborative filtering to mobile settings by using physical copresence as the basis for measuring user similarity [3].

One of the major challenges in such applications is to validate the underlying assumption that physical copresence can be used as a measure of user similarity. While it might seem obvious that copresence at an event such as a music concert can be taken as an indicator of similar tastes in music, questions arise as to whether this could be extended to other categories such as books and films. Also should we consider only events such as concerts as a basis for filtering recommendations, or could we extend it to other types of locations such as bars, restaurants, work places, public spaces and even transport systems?

Unfortunately, it is very complex to test such assumptions in real world settings. Since recommendations are based on chance encounters, a meaningful experiment would either require the set of locations or events to be restricted artificially or the recruitment of a vast number of participants. Our goal was to investigate ways in which existing social networking sites such as Facebook could support such experiments by using data collected on physical copresence to create connections in virtual networks. The rich support for developing pluggable applications offered by sites such as Facebook could then be used to measure user similarity within these networks. Similarities can be measured in terms of ratings of specific items such as films and travel destinations to less specific personality properties such as attitudes and priorities in life.

To support such experimentation, we have developed a framework that bridges physical and virtual social networks by allowing users to easily connect to other users encountered in the real world through Facebook. The framework consists of two main components. The first allows the physical copresence of participants to be tracked in a transparent and unobtrusive manner. The second component is a general copresence Facebook application that we developed to enable users to view and connect to other users who they encountered in the real world. Researchers investigating the use of copresence in recommender systems can then develop their own Facebook applications to test specific hypotheses about different forms of user similarity.

In this paper, we present our framework and discuss how it could be used as an experimental platform for recommender systems that use physical copresence as a basis for filtering information. We begin in Section 2 with a discussion of related work and background information. In Section 3, we introduce a sample scenario that exemplifies how users interact with our infrastructure. Section 4 discusses the design of the framework and gives detailed information about the implementation of the various components involved. Section 5 then describes how the framework could be used to test specific ways in which copresence can be used as a measure for user similarity. Concluding remarks are given in Section 6.

2 Related Work

Several projects have investigated ways of detecting physical copresence in mobile environments and the analysis of copresence data as well as the usefulness of physical copresence for community detection or information sharing. Different goals of analysing the data collected have been pursued, ranging from identifying contact patterns as a basis for designing new data forwarding algorithms [17] to the identification of users [18], community detection [11] and serendipitous matchmaking systems for the benefit of the users [5]. We outline a few of these projects below to indicate the range of applications that rely on copresence data.

Freyne et al. [8] propose a system for message delivery in a mobile environment. Collocation is one possible trigger for delivery and

[1] ETH Zurich, Switzerland, email: despindler@inf.ethz.ch

therefore the system features proximity detection. However, the copresence data is not used to identify relationships among users and therefore the data is removed from the system as soon as it serves its triggering purpose.

Serendipity [6] is a project conducted at MIT where Bluetooth-enabled mobile phones were handed out to 100 students who were asked to carry them around for 9 months. Apart from logging usage patterns of phone applications, the phone was set to scan its Bluetooth environment every 5 minutes and record any other Bluetooth-enabled devices discovered. A number of similar studies followed, all pursuing the goal of collecting collocation data in order to recognise contact patterns [1, 14].

The notion of a *familiar stranger* denoting unknown people one frequently meets has been picked up by projects trying to recognise the familiarity of people based on copresence data [16]. Furthermore, such data has been used to provide users with an awareness of the familiarity of people currently in their vicinity, i.e. to recognise a user's social situation [15].

Lawrence et al. [12] developed AIDE, a system which recognises so called copresence communities, groups that are co-located on a regular basis. As an example application, AIDE uses these communities to disseminate information which is supposed to be relevant to all of its members. There have been no attempts to measure the degree of common interests within a copresence community.

The TRACE [2] project adopted a wizard-of-oz style approach to try and study the relationship between copresence and user similarity. Visitors attending a particular event such as a karaoke evening were handed out business cards indicating a web site address where they would later be able to view photos and other information about the event. Users of the web site could also open discussions with other visitors to the web site and, in this way, the developers of TRACE were able to connect users who had been copresent and monitor their interactions. Through this simple experiment, they were able to show that there was some evidence supporting the assumption that copresence can be an indicator of user similarity. However, the study was relatively small scale and one issue was the fact that users who interacted via the event-related web site would often shift their communication to other channels such as regular email at which point the researchers lost track of their communication.

In our own previous research, we have adapted collaborative filtering (CF) to mobile settings by assuming that the degree of copresence between users is a measure of similarity [3]. Our algorithm uses connectivity in mobile ad-hoc networks and opportunistic information sharing to exchange ratings and recommendations among users. The approach avoids the need for a central server and heavy computation of user similarity measures. We have also shown that the algorithm is computationally equivalent to traditional user-based CF algorithms. However, the quality of the recommendations is dependent on the underlying assumption that user copresence is a good measure of user similarity.

Our initial efforts to test this assumption were based on questionnaires designed to assess the similarity of people interviewed at different locations of the Edinburgh festivals [4]. Each year in the month of August, several festivals and large events take place in Edinburgh, including the Fringe, a book festival, a film festival and a military tattoo. The festivals therefore cover several categories of events such as music, drama, dance, comedy, film screenings, book readings and interviews with artists and authors. We wanted to assess whether copresence at particular venues would not only be a good indicator of similarity of tastes with respect to the category of events held at that venue, but also whether it could be extended to other categories.

Although the results obtained support the hypothesis that people who attend the same events tend to share similar tastes and interests, such questionnaires tend to be basic and lack generality. Since visitors were interviewed as they entered or left a venue, the number of questions had to be kept small. Further, due to the nature of a questionnaire-based interview, the kind of possible similarities is determined beforehand during the design of the questionnaire and cannot be further explored interactively after evaluating initial responses. Finally, such studies were unable to track visitors attending multiple events, and it was therefore not possible to investigate if and how the degree of similarity depended on the number of encounters.

Apart from studies based on questionnaires, such a hypotheses could also be tested by deploying an application to the general public or developing a simulation of the algorithm. However both of these approaches also have severe drawbacks. Developing and deploying such an application may require a high investment and will also be high risk if there is no prior evidence backing the underlying assumptions that copresence is a good indicator of user similarity. It is also difficult within academia to carry out large-scale experiments due to the costs involved. Effective simulation models require the integration of a human behaviour model and not only a model of the system operation. Although such models exist, it is difficult to find appropriate ones where behaviour can be characterised in terms of taste and interest and which are computationally not too intensive.

Given the rise in interest in social networking sites such as Facebook, we decided to investigate ways in which existing online social platforms could be used to test such hypotheses without having to implement and deploy full-scale mobile applications to a large number of users. The main idea is to relate physical copresence of users to connections in virtual social networks. Currently, social platforms such as Facebook offer a rich development environment for pluggable applications. As a result, applications that allow specific forms of user similarities within a network to be measured may be easily developed and deployed. Similarities can be assessed in terms of preferences related to specific categories of items such as films, music or travel destinations or less specific personality properties such as attitudes and priorities in life.

The mapping between real-world and virtual social networks is not a completely novel idea. As part of the Cityware project[2], a Facebook application has been developed to notify users about other Facebook users met in the real world. However, the system is not built on copresence detected soley by the mobile devices carried by users but rather relies on the presence of desktop computers featuring Bluetooth connectivity. These nodes perform the scanning of the physical environment and send the copresence data to a central server. As a result, the system would require the installation of many such nodes in order to work on a larger scale. Our aim therefore was to develop a physical-virtual copresence framework in which the mobile devices perform the scanning themselves in order to detect copresence.

3 Scenario

Before describing our framework in detail, we first use a simple scenario to explain the general operation of the system and the user's view of the application. To participate in our framework, users must install our application to gather collocation events on their mobile device and register with our Facebook copresence application.

Before going to work in the morning, a user might start the application on their mobile device. If, for example, it is a Bluetooth-

[2] http://www.cityware.org.uk

enabled mobile phone, it then would periodically scan the user's environment for other Bluetooth-enabled devices. When the application discovers other Bluetooth-enabled devices in the vicinity, it stores the identifiers of these devices locally, together with the current time and, if available, a representation of the current location.

The user may keep the application running throughout the day so that it records copresence events on the way to work, at work, during lunch and in the evening when they meet friends at a bar, restaurant or movie theatre. All the copresence events gathered throughout the day are stored persistently and can, therefore, be uploaded to a desktop or laptop computer when the user arrives back home in the evening. From this machine, the data is sent to a central server that manages copresence data from all users. This server also maintains a registry that maps device identifiers to Facebook user identifiers.

When the user later logs into the Facebook web site, they will be presented with an overview of all Facebook users that their mobile device was able to discover during the day by means of the collected copresence data and the registry mapping. Using our Facebook copresence application, they can browse their profiles and connect to the other users as well as keeping track of where and when they encountered somebody. Copresence events can also be displayed on a geographical map in a similar way to points of interests in geographical information systems. A web-based interface displays all locations where a particular user was encountered as well as all users met within a particular region in space and time.

Once users have established links to other users through the copresence application, other Facebook applications can exploit these copresence networks to measure user similarity. For example, a researcher who wants to test the hypothesis that users who go to the same bars at the same time like the same films, could develop their own likeness application for films that uses the copresence data to check whether there is a correlation between encounters in specific locations that are known bars with film preferences.

4 Physical-Virtual Copresence Framework

Having presented a scenario from the user's perspective, we now describe our framework. The framework consists of the three main components shown in Figure 1.

A mobile component is used for gathering collocation data. It consists of an application implemented with Java ME[3], a widespread development platform and runtime environment for mobile applications. The application runs on mobile devices and periodically scans its physical environment for other mobile devices. When a device is discovered, its unique identifier is stored along with the time of the discovery and the location of the scanning device, if that information is available. Note that devices do not need to have the scanning application installed in order to be discoverable. Each detection of a mobile device constitutes a so-called copresence event. The set of copresence events is later exported to a file and uploaded to a central database that processes and manages copresence events from all users of the framework.

Various technologies can be used for automated physical copresense detection, such as Bluetooth [6, 1], wireless hotspot subscriptions [9, 13] or radio frequency [10]. For our copresence framework, we also adopted the approach of using the scanning range of a Bluetooth transceiver to detect physical copresence. Nowadays, most mobile phones have the required hardware already built in and are easily configured to periodically scan their environment as users carry them around. Also, the issue of assigning unique identifiers to mobile users is easily resolved by relying on the MAC address of the Bluetooth receiver. Due to the personal nature of mobile devices, in most cases there exists a one-to-one relationship between the users and their device. Finally, the scanning of a device's Bluetooth environment is simple to implement and, therefore, we do not provide more details here.

To detect the location, we are currently using GPS, but are also experimenting with other location technologies such as GSM cell tracking and wireless hotspots recognition. An issue that is frequently raised when using GSM cell identifiers for determining a location is the fact that the geographic position of GSM cell antennae is not readily available. There seems to be a growing interest for position data of GSM cells as well as wireless hotspots such as used by the Google maps application for the iPhone. Therefore, the number of available resources supporting this kind of location technique can be expected to increase. Our application is designed to cope with the fact that the location tracking module may change in the future. Currently, the simplest way to track positions from a developer's point of view is to use a built-in GPS receiver as it already exists in some mobile phones. The GPS receiver may also be an external device connected to the mobile phone using Bluetooth.

A central server is the heart of the system and maintains the data gathered by the users as well as a registry mapping device identifiers to virtual social network user identifiers. Users must register their mobile device with their social platform identifier. This is a requirement for other users to be able to recognise a physically encountered person as the corresponding social platform user. This server application is implemented using Java and db4o[4] to persistently store the mapping of social network identifiers to physical device identifiers as well as all copresence events. Note that the registry mapping device identifiers to virtual social network user identifiers is also available to the mobile device which can therefore inform its owner about the physical copresence of social platform contacts.

The third component is a Facebook application which notifies Facebook users about other users they have met in the real world whenever they log into the web site. Based on these notifications, users can manage their physical encounters within the virtual social network as we will describe next. This facebook application is implemented using state-of-the-art web technologies such as Java Servlet technology, XSLT and the Facebook REST [7] API[5] for accessing social platform data.

On the one hand, this application can be used to browse a list of physically encountered users as shown in Figure 2. The user may connect to any of those users, i.e. request to build a virtual relationship, or browse their profiles if they are already connected. These connections form the basis for comparing their taste and interests, either using profile data or custom Facebook applications as will be described in the next section. On the other hand, collocation events can be displayed on a geographical map allowing the users to keep track of where and when particular users were encountered. The map can be set to display all users met as depicted in Figure 3, all locations where a particular user was met or all users met within a given region in space or time.

5 Use of the Framework

Our framework allows collocation data to be collected by users and this data to be stored on a central server. We now go on to describe

[3] http://java.sun.com/javame

[4] http://www.db4o.com

[5] http://developers.facebook.com/documentation.php

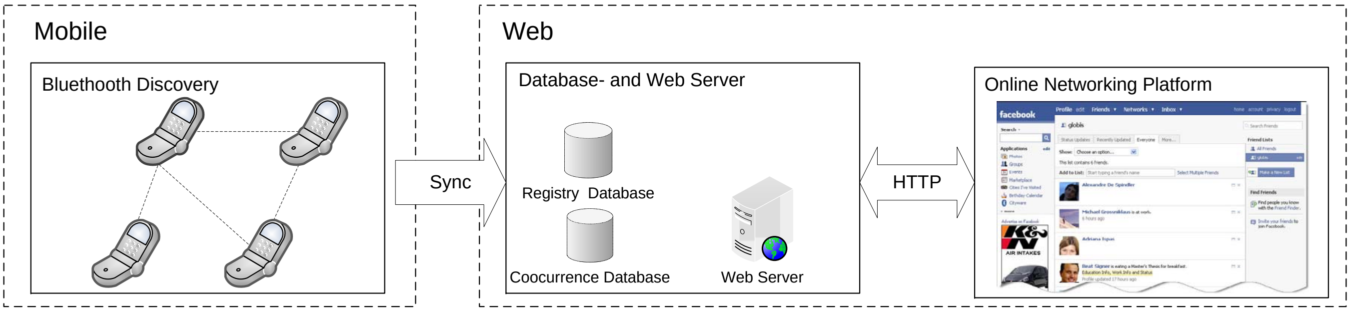

Figure 1. Framework Architecture

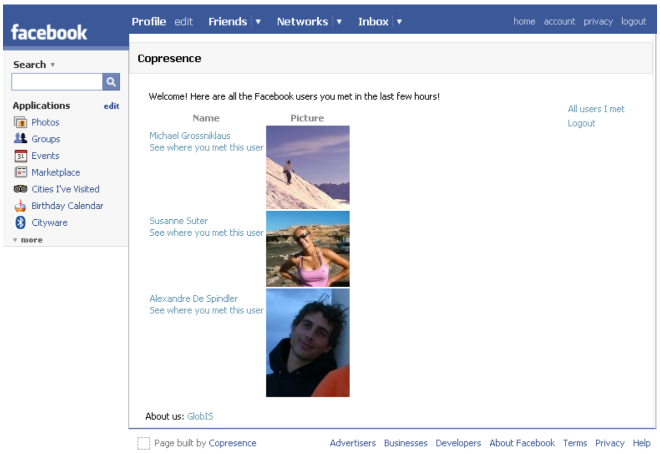

Figure 2. Overview of users met

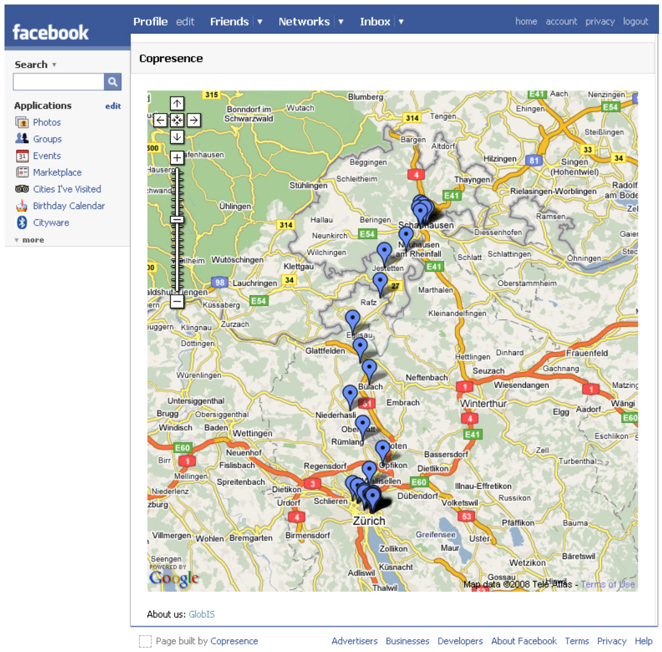

Figure 3. Map showing locations where users were met

how this data can be used to investigate the relationship between physical copresence and user similarity. For any user, we can build a graph representing their social network of real-world encounters. In this graph, users are represented by nodes which are connected by an edge if they have been in each other's vicinity. The edges are weighted with a value indicating the number of times that the users have been copresent.

In order to validate a hypothesis about user similarity measured by means of copresence, a relationship between the values of the edge weights and the actual similarity of the connected users must be shown to be significant. Having the Facebook identifiers of these users gives us the possibility of using that platform to validate such hypotheses. Since all collocation data gathered by our infrastructure is stored persistently, approaches to assess user similarities can be designed and applied at any time.

Additionally, our system allows sequences of user encounters to be analysed. For example, a user might be first met on a bus to a train station. Then the user could also be present on the train to another city. In that other city another user might be met repeatedly on the way from the train station to the office. If such repeated encounters on a user path are of relevance to a particular mobile social software, our system can be used to test its proper functioning.

The first step of any analysis within our framework consists in deciding on user characteristics determining the similarity. Depending on the application domain of a particular recommender system, such characteristics range from standard demographic data such as age, gender and education to domain-specific user taste and interests. An important part of this step is consideration about how users provide their data. The assessment of user characteristics is nothing new to Facebook and applications measuring user similarities are very popular. *Flixster* is a Facebook application with which users rate a predefined set of movies in order to compare their taste with that of their friends. *Likeness* is an application allowing users to be compared based on a wide variety of characteristics. Users are presented ten statements about a topic of their choice, such as top things to do on a day off or ten reasons to quit a job. They are asked to rank these statements according to their personal preferences and the resulting sequence is used to compare them with those friends that have ranked the same statements.

As can be seen from these two examples, it is important that users can give their answers with as little effort as possible. For example, it is much easier for a user to rate ten movie items individually as opposed to putting the items in a descending order of preference. However, if users are asked to rate items using pre-defined rating values, the given values must cover the whole range of potential answers. If a movie is to be rated using the rating values "I liked" and "I disliked", a user cannot choose a suitable value in the case that the movie has not been watched. Furthermore, a negative opinion may be the reason why it has not been watched and it is unclear whether users would choose "I disliked" in this case.

Even though the Facebook platform already offers a wide variety of applications that measure user similarity, the data generated by these applications is not publicly available and hence cannot be used by other applications and frameworks such as ours. Therefore, a second step consists of developing a Facebook application for measuring user similarity based on the characteristics chosen in the first step. The idea is that users for whom collocation data is available install this application. The application can then gather data, either by accessing the users profile or by letting the user interact with it. The data gathered is then sent to the central server where it is stored along with the copresence data and available for analysis.

Our experience has shown that the complexity of developing a Facebook application is well within the skills of an experienced application developer. The developer's work consists of three tasks. First, a web application providing the means to assess the user properties determining the similarity must be developed. Facebook does not host any of the applications that are developed by external developers. Thus, the second task consists of deploying the web application on a hosted web server. Finally, the application has to be registered with the Facebook platform. The registration mainly consists of specifying the location of the web server and application. As a result, the application will appear as part of the Facebook platform to the user.

As an example, asume we want to test whether there is a correlation between copresence and movie preferences. Therefore, we could design a questionnaire as shown in Figure 4. The questionnaire contains a list of movies about which users state their opinion. In the simplest case, such a questionnaire may be implemented as a regular HTML page using text and form elements. As usual with HTML forms, a URL must be provided which points to a server-side component handling the submission of the response data. In this example, handling the response simply consists of making the data persistent so that it can be analysed at evaluation time. This behaviour may be implemented either in Java or with any web scripting language.

In order to set up such an experiment, a web server is required where the questionnaire as well as the response handling component is made accessible. We have been working with Apache Tomcat[6], an application server implementing Java Servlet and JavaServer Pages technologies. Using Java Servlet technology, the processing of response data as outlined in this simple example can be programmed using few simple lines of code. However, the resulting Servlet may be extended to also access the user's Facebook profile and store the additional data along with the user response. As mentioned before, Facebook offers a REST-based API that allows the Facebook platform to be accessed via HTTP GET and POST requests. This API also provides the means to notify the users through a Facebook built-in news feed, to write messages and invite them to use a particular application.

[6] http://tomcat.apache.org/

Once the characteristics used to measure similarity have been defined and a corresponding Facebook application has been deployed, actual user data must be gathered. Therefore, the recruitment of users is an important aspect of conducting an experiment. Apart from the incentives such as mapping real-world encounters to social network connections, displaying the location of these encounters and notifying users about the physical proximity of social network contacts, it is also important to ensure a high frequency of physical encounters. One possibility of addressing this issue is to leverage the concept of regional networks already present in Facebook. These networks could be used in order to recruit users from a restricted geographical region, effectively increasing the chance of these users being copresent at some time.

Finally, once the data required to prove or disprove the hypothesis has been gathered, it must be examined for possible correlations between collocation and user similarity. This can be done by applying standard statistical tests such as chi square (χ^2) or mean-value analysis. As our methodology to prove the existence or lack of correlation between datasets is based on straightforward statistical analysis, it is of little interest and lies outside the scope of this paper.

6 Conclusions

A frequent problem associated with mobile social software is the fact that underlying assumptions may be difficult to test. For example, a collaborative filtering approach based on opportunistic information sharing in mobile ad-hoc networks assumes that the number of times users are co-located correlates with their similarity. Previous projects have used a range of methods such as questionnaires, wizard-of-oz style experiments and the deployment of applications to try and validate such hypotheses but each can be severely restricted in terms of the amount of data collected due to practical considerations.

We have shown how on-line social networking systems such as Facebook can be coupled with simple, standard mobile applications to provide a testbed for a variety of mobile social applications by mapping physical copresence onto connections in virtual social networks. Applications can then be developed using the support of the social networking systems to analyse, for example, the relationship between physical copresence of users and their similarity in terms of interest and taste. The simple application development environment offered by sites such as Facebook allows these applications to be easily designed and deployed.

Clearly, it is important to attract users to such applications, especially since it requires them to register their mobile phones. We believe that this can be done by offering additional functionality such as a geographical map showing where user encounters took place or the possibility of notifying users through their mobile device in the event of other Facebook users being currently in their vicinity.

Altogether, we believe that the association of virtual and real world social networks provides an important incentive for people to participate in registering with our framework. As a consequence, it should be possible to attract a sufficient number of users in order to conduct an experiment for validating assumptions underlying a wide variety of mobile social applications.

We have finished developing the framework presented in this paper and have integrated it in Facebook. We are currently experimenting with selected users collecting data, uploading it to the server and using the Facebook application. The next stage consists of releasing it to the public and developing further applications allowing user simi-

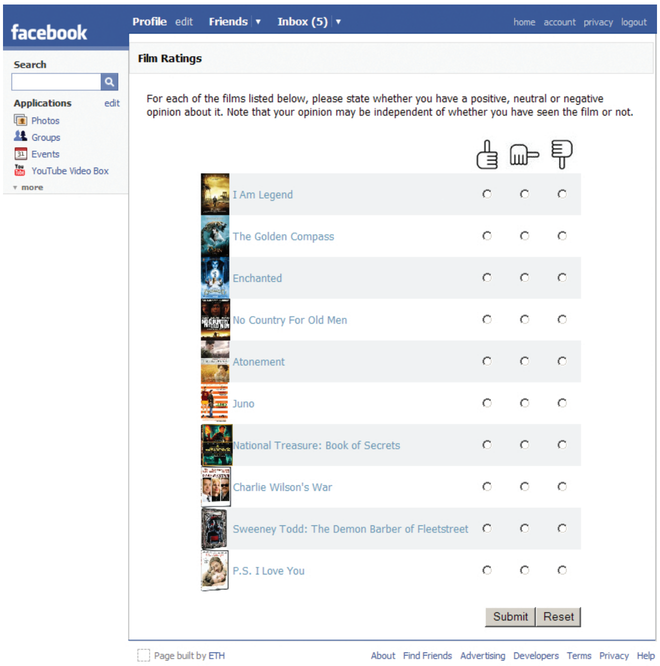

Figure 4. Example user similarity assessment

larities to be measured and put into relation with the collocation data collected.

REFERENCES

[1] A. Chaintreau, P. Hui, C. Diot, R. Gass, and J. Scott. Impact of Human Mobility on Opportunistic Forwarding Algorithms. *IEEE Transactions on Mobile Computing*, 6(6):606–620, 2007.

[2] S. Counts and J. Geraci. Incorporating physical co-presence at events into digital social networking. In *CHI '05: CHI '05 extended abstracts on Human factors in computing systems*, pages 1308–1311, New York, NY, USA, 2005. ACM.

[3] A. de Spindler, M. C. Norrie, and M. Grossniklaus. Collaborative filtering based on opportunistic information sharing in mobile ad-hoc networks. In *On the Move to Meaningful Internet Systems 2007: CoopIS, DOA, ODBASE, GADA, and IS*, pages 408–416, Berlin / Heidelberg, Germany, 2007. Springer.

[4] A. de Spindler, M. C. Norrie, and M. Grossniklaus. Recommendation based on Opportunistic Information Sharing between Tourists. *Information Technology & Tourism*, (to appear).

[5] N. Eagle and A. Pentland. Social Serendipity: Proximity Sensing and Cueing. Technical Report 580, MIT Media Laboratory, 2004.

[6] N. Eagle and A. Pentland. Social Serendipity: Mobilizing Social Software. *IEEE Pervasive Computing*, 4(2):28–34, 2005.

[7] R. T. Fielding and R. N. Taylor. Principled design of the modern Web architecture. *ACM Trans. Interet Technol.*, 2(2):115–150, 2002.

[8] J. Freyne, E. Varga, D. Byrne, A. F. Smeaton, B. Smyth, and G. J. F. Jones. Realising Context-Sensitive Mobile Messaging. In *OTM Workshops (1)*, pages 407–416, 2007.

[9] T. Henderson, D. Kotz, and I. Abyzov. The changing usage of a mature campus-wide wireless network. In *MobiCom '04: Proceedings of the 10th annual international conference on Mobile computing and networking*, pages 187–201, New York, NY, USA, 2004. ACM.

[10] L. E. Holmquist, J. Falk, and J. Wigstrm. Supporting group collaboration with interpersonal awareness devices. *Personal and Ubiquitous Computing*, 3:13–21, 1999.

[11] P. Hui, E. Yoneki, S. Y. Chan, and J. Crowcroft. Distributed community detection in delay tolerant networks. In *MobiArch '07: Proceedings of first ACM/IEEE international workshop on Mobility in the evolving internet architecture*, pages 1–8, New York, NY, USA, 2007. ACM.

[12] J. Lawrence, T. R. Payne, and D. D. Roure. Co-Presence Communities: Using Pervasive Computing to Support Weak Social Networks. In *WETICE '06: Proceedings of the 15th IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises*, pages 149–156, Washington, DC, USA, 2006. IEEE Computer Society.

[13] M. McNett and G. M. Voelker. Access and mobility of wireless pda users, 2005.

[14] A. Natarajan, M. Motani, and V. Srinivasan. Understanding Urban Interactions from Bluetooth Phone Contact Traces. pages 115–124, 2007.

[15] T. Nicolai, E. Yoneki, N. Behrens, and H. Kenn. Exploring Social Context with the Wireless Rope. In *OTM Workshops (1)*, pages 874–883, 2006.

[16] E. Paulos and E. Goodman. The familiar stranger: anxiety, comfort, and play in public places. In *CHI '04: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 223–230, New York, NY, USA, 2004. ACM.

[17] L. Pelusi, A. Passarella, and M. Conti. Opportunistic Networking: Data Forwarding in Disconnected Mobile Ad Hoc Networks. *Communications Magazine, IEEE*, 44(11):134–141, 2006.

[18] J. Perkio, V. Tuulos, M. Hermersdorf, H. Nyholm, J. Salminen, and H. Tirri. Utilizing Rich Bluetooth Environments for Identity Prediction and Exploring Social Networks as Techniques for Ubiquitous Computing. In *WI '06: Proceedings of the 2006 IEEE/WIC/ACM International Conference on Web Intelligence*, pages 137–144, Washington, DC, USA, 2006. IEEE Computer Society.