Exploring Social Context with the Wireless Rope

Tom Nicolai[1], Eiko Yoneki[2], Nils Behrens[1], and Holger Kenn[1]

[1] TZI Wearable Computing Lab, Universität Bremen, Germany
{nicolai, psi, kenn}@tzi.de
[2] University of Cambridge, UK
eiko.yoneki@cl.cam.ac.uk

Abstract. The Wireless Rope is a framework to study the notion of social context and the detection of social situations by Bluetooth proximity detection with consumer devices and its effects on group dynamics. Users can interact through a GUI with members of an existing group or form a new group. Connection information is collected by stationary tracking devices and a connection map of all participants can be obtained via the web. Besides interaction with familiar persons, the Wireless Rope also includes strange persons to provide a rich representation of the surrounding social situation. This paper seeks to substantiate the notion of *social context* by an exploratory analysis of interpersonal proximity data collected during a computer conference. Two feature functions are presented that indicate typical situations in this setting.

1 Introduction

As the field of wireless and locative technologies matures, a more enduring relationship between the physical and cultural elements and its digital topographies will become interesting topics to explore. Their interaction, influence, disruption, expansion and integration with the social and material practices of our public spaces will be getting more focus. Is public space a crowd of individuals? How can the crowd inspire the individual through collaboration, competition, confrontation? How change, effect, or experience could only be achieved by a mass movement, a cooperative crowd? How can we stage a series of new happenings? In [1], Haggle project takes an experiment of human mobility, where mobility gives rise to local connection opportunities when access infrastructure is not available. Our project Wireless Rope aims to take a further look from a social perspective.[1]

Context awareness in general is recognized as an important factor for the success of ubiquitous computing applications and devices. The relevance of social context in particular was also noted, including the identities and roles of nearby persons (e.g. co-worker or manager) as well as the social situation [2].

[1] http://wrp.auriga.wearlab.de

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Several works picked up the concept of sensing identities and used this information to annotate meeting recordings with a list of attendants [3] or to facilitate information exchange [4].

However, less is known about the recognition of the broader social situation on the basis of proximity data. This paper undertakes an initial exploration in the detection of such situations. The focus is on social contexts that do not presume knowledge about the identities and roles of individuals. For the approach presented here, it is not necessary to recognize the particular identities of individuals in the proximity. Instead it is interesting, e.g. if the person is with the others, or just passing them by, and if they are encountered regularly or not. This paper introduces two feature functions of proximity data to recognize several situations during a visit to a computer conference. Situations like arrival and departure, as well as coffee breaks and lunch are identifyable by this method.

With a robust classification of social contexts, an application would be able to detect meaningful episodes for a user while moving in different social circles and circumstances. Knowledge about these episodes could in turn be used to automatically adapt input and output modalities of a device (e.g. silent mode for mobile phones), to trigger actions (e.g. checking the bus schedule), or to guide the creation of an automatic diary according to episodes.

The paper is organized as follows: after a review of related work, the concept of proximity detection is elaborated. In section 4, the definition of the familiar stranger is given and its relevance to the classification of social situations is explained. The next section introduces the various components of the Wireless Rope system that was used to carry out the experiment described in section 6. The analysis of data and its discussion follows. The paper concludes with section 9.

2 Related Work

Social context has many different sides. At a very coarse level, it is related to the milieu a person lives in. Kurvinen and Oulasvirta examine the concept from a social science perspective [5]. They conclude, that the recognition of "turns" in activities gives valuable clues for an interpretation of social context. They also state that sensor data can only be interpreted for this purpose in the light of a well-defined domain.

Bluetooth proximity detection was already used in a number of other projects. Most notably, Eagle and Pentland used it to measure the social network of students and staff on a university campus in an extended experiment with one hundred students over the course of nine months [6]. Hui et al. carried out a similar study during a conference with the goal to identify prospects for ad-hoc networking scenarios [1]. Paulos and Goodman on the other hand use proximity detection to measure variables that might indicate the comfort in public urban places [12].

Proximity detection can also be realized by a number of other technologies. GPS can be used to capture the absolute position of two persons. A proximity service with knowledge of both positions can then calculate the exact distance [7]. Infrared systems were already used in smart badges to detect people facing each other at conferences [8]. The Hummingbird system uses radio frequency to determine an approximate proximity in the range of 100m radius [9].

3 Proximity Detection with Bluetooth

The Wireless Rope uses Bluetooth for proximity detection. This technology is widely available and a lot of people carry a Bluetooth enabled mobile phone with them. Thus, it is possible to detect a certain amount of peoples' phones without handing a special device to each of them, which makes Bluetooth appealing for experiments involving a large quantity of persons.

The range of Bluetooth varies between 10m and 100m, depending on the device class. In mobile phones, the range is usually 10m. A part of the Bluetooth protocol stack is the *device inquiry*. It enables a device to discover other devices in the proximity—usually to establish a connection for data transfer. The discovery process requires active participation of the peer device. It may automatically answer an inquiry request or not, which can be configured by the user with the Bluetooth visibility option. If it answers, it discloses its device address and device class among others. The address uniquely identifies a Bluetooth device and can be used to recognize a formerly discovered device. The device class distinguishes mobile phones from computers and others and gives vague information about the further capabilities of a device.

The device inquiry does not give details about the distance to the device, except that it is in the communication range (i.e. 10m for most mobile phones). The measurement of the distance within the range is only possible indirectly by taking the bit error rate into account [10]. Unfortunately, additional software is necessary on the side of the discovered device, and a connection must be established prior to the measurement, which involves interaction by the user of the discovered device. Thus, the Wireless Rope uses the plain device inquiry mechanism to detect the proximity of other devices. It uses the device class to distinguish mobile phones from other devices to identify the proximity to other persons. The assumption here is, that the presence of a mobile phone indicates the presence of its owner. Mobile phones are very personal objects and are seldom left behind.

4 Familiar Strangers

To carry out a categorization of different social situations, some knowledge about the social structure of our modern lifes is required. For the analysis presented here, the distinction between familiar and unfamiliar persons is important in particular.

Beyond this bipartite view, a third kind of social relationship emerged at the transition between familiar and strange persons with the urbanization of society: the familiar stranger. The sociologist Milgram did initial experiments regarding this concept [11]. His definition of a familiar stranger is that it is person who is encountered repeatedly, but never interacted with. Typically, familiar strangers are encountered on the bus during ones daily way to work or while visiting the same recreational facilities. Paulos and Goodman presented a concept to recognize these persons with a device [12]. They state that such a device could be used to indicate the comfort a person feels in specific urban places.

Following this concept, we use a simple algorithm to distinguish strange persons from familiar strangers on the basis of proximity data. For the purpose of this paper, a familiar stranger must have been met more than five times. Different meetings are separated by periods of at least five minutes of absence. No further distinction between familiar strangers and familiar persons is considered here, although Eagle and Pentland remark that it could even be possible to identify friends on the basis of Bluetooth proximity data [6].

5 The Wireless Rope

To experiment with the notion of social context, we implemented a couple of components incorporating proximity detection. The Wireless Rope is a program for Java phones that collects information of surrounding devices using Bluetooth. It enables a group to actually feel the boundaries of the group. Like a real rope tying together mountaineers, the Wireless Rope gives the urban exploration group immediate feedback (tactile or audio) when a member gets lost or approaches. Thus everybody can fully engage in the interaction with the environment, and cognitive resources for keeping track of the group are freed.

Besides the direct interaction with familiar persons, the program also includes strangers and familiar strangers and recognizes them when they are met

Fig. 1. Sightings on phone display

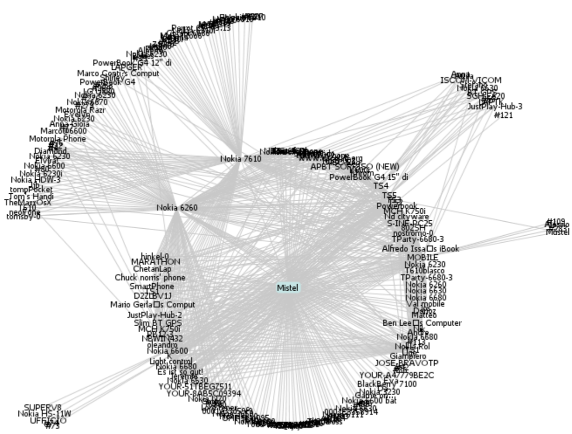

Fig. 2. Connection map on website

repeatedly. A glance at the program screen tells different parameters of the surrounding social situation: How many familiar and how many strange persons are in the proximity? How long have these persons been in proximity? Is there somebody with me for some time whom i have not noticed?

As an additional service, the collected information kept in all Wireless Rope programs may be gathered at a central server via special Track Stations. Users can look at the connection map created by gathered information from phones via the web (Fig. 2). The following subsections give details about the various components of the Wireless Rope.

5.1 Wireless Rope Program on Java Bluetooth Phones

The Wireless Rope program can be installed on mobile phones with Bluetooth that support the Java MIDP 2.0 and JSR-82 (Bluetooth) APIs. It performs periodic Bluetooth device inquiries to collect sightings of surrounding Bluetooth devices. Devices are classified into one of four categories and visualized as circles in different colors on the display:

Stranger (gray): All new sightings are classified as strangers.

Familiar Stranger (blue): Strangers which are sighted repeatedly by the proximity sensor are automatically advanced to the familiar stranger category.

Familiar (yellow): If the user recognizes a familiar person on the display, he can manually add him to the familiar category.

Contact (green): During an interaction with a person, both might agree to add themselves to their contacts (bidirectional link). Besides being notified of their proximity, contacts can use the Track Stations to exchange additional data.

While a device is in proximity the corresponding circle slowly moves from the top of the screen to the bottom. A time scale on the display lets the user interpret the positions of the circles. Proximity data are kept in the device until the information can be transmitted to a nearby Track Station.

5.2 Bluetooth Devices Without Wireless Rope

All Bluetooth devices that run in visible mode (respond to inquiries) are automatically included in the Wireless Rope and their sightings are collected. Users are notified of their existence and they are visualized on the display. The only difference is that these devices can not be added to the "Contact" category, because it involves a bidirectional agreement that is only possible with the Wireless Rope program.

5.3 Track Stations

Track Stations might be installed as additional infrastructure at highly frequented or otherwise meanigful locations, e.g. in conference rooms, train stations or bars. They consist of small Bluetooth enabled PCs in a box. The Track

Stations automatically record the passing-by of users by Bluetooth device inquiries and can transmit relevant digital tracks to contacts at a later time. They can notify trusted contacts of the last time they were seen by the station. By connecting these devices to the Internet, users can also check at which station a contact was seen the last time. By correlating the list of familiar strangers with the list of persons that often visit a station a user may see how much a place is “his kind of place.” Paulos and Goodman call this value “turf” [12]. Thus the Track Stations augment the reach of the Wireless Rope at important places. Periodically, these devices collect all log data from the mobile phones and aggregate them in a database for visualization and further analysis.

5.4 Reference Points

For roughly localizing the Wireless Rope users in space and to recognize a formerly visited place, reference points are used. Any stationary Bluetooth device can be used for this purpose. The Bluetooth device class is used to determine whether a device is stationary or not. The Bluetooth address then identifies a place.

5.5 Connection Map

The information collected by the Track Stations is visualized in realtime on a website. This connection map is anonymized for non-registered users. Registered users can explore their own neighbourhood including contacts, regularly met familiar strangers and randomly encountered strangers. The connection map is a tool for personal social network analysis, e.g. to identify common contacts and distinct cliques.

6 Experiment

The Wireless Rope was used to carry out an experiment to gather real-world proximity data for an exploratory analysis. The program was installed an a Nokia 6630 mobile phone to perform periodic Bluetooth device inquiries every 30 seconds.

The Ubicomp conference 2005 in Tokyo together with the workshop “Metapolis and Urban Life” was selected as a social event for the experiment for its varied program schedule, and because it was expected that a large proportion of the conference attendees had a detectable Bluetooth device with them. One of the attendants was carrying a prepared device during the entire time of the conference to collect the data. Additionally, he took photographs with the same device to document his activities. The program schedule of the conference provides detailed information about the planned timing of activities.

Since a significant amount of the encountered peoples’ phones was configured to answer these inquiries, it was possible to detect other phones and thus the related owners in a proximity of approximately ten meters. The data was recorded in the phone memory and later transferred to a computer for analysis.

The experiment ran over six days. On day one and two, the workshop took place. Part of the first day was an exploration of the city in the afternoon. Day three to five were spent on the main conference. The last day was spent with recreational activities in the city.

7 Data Analysis

The Wireless Rope provided the data used for the later analysis. Each device inquiry returned a set of unique device identifiers and additional information about the class of the devices. This data was recorded along with timestamps. The device class was used to filter out non-personal devices, like laptops and network equipment. In the next step, a set of quantitative features was extracted from the sets of device identifiers by a sliding time window of five minutes.

The features are chosen to be independent of the percentage of people that can be identified by the device inquiries. The proportion might change from situation to situation, with the particular mentalities of the people, cultural differences, and the general Bluetooth penetration in a country among others. Some groups of people are more extrovert than others and enable their Bluetooth visibility on purpose. Others are not aware about the consequences and might have it enabled randomly. Without independence from these factor, a comparison of data from different situations is difficult.

Let F_t be the set of all detected familiar persons in the time interval $[t, t+1]$, and S_t the set of strangers respectively. For this experiment, only familiar and unfamiliar persons are distinguished. The familiar strangers are treated as being familiar.

The number of arriving familiar devices is $f_t^+ = |F_t| - |F_t \cap F_{t-1}|$ and $f_t^- = |F_{t-1}| - |F_t \cap F_{t-1}|$ is the number of leaving familiar devices. s_t^+ and s_t^- are defined correspondingly. The analyzed features indicate the dynamic in the group of familiars and strangers. They show how much an individual moves in accordance with the surrounding people:

1. $DynFam(t) = \frac{(f_t^+ + f_t^-) - ||F_t| - |F_{t-1}||}{|F_t|}$
2. $DynStra(t) = \frac{(s_t^+ + s_t^-) - ||S_t| - |S_{t-1}||}{|S_t|}$

8 Results and Discussion

The data set comprises 52411 Bluetooth sightings and 1661 meetings in total. Figure 3 and 4 show the histograms of individual Bluetooth sightings and derived meetings, respectively. There were approximately 650 registered conference visitors. 69 devices were classified as familiar and a total of 290 as strangers for the whole data set including conference and city encounters.

Figure 5 shows the features DynFam and DynStra for the six days of the experiment. The peaks indicate the different social activities the test subject was engaged in. The conference activity shows up clearly in the data. Arrival is

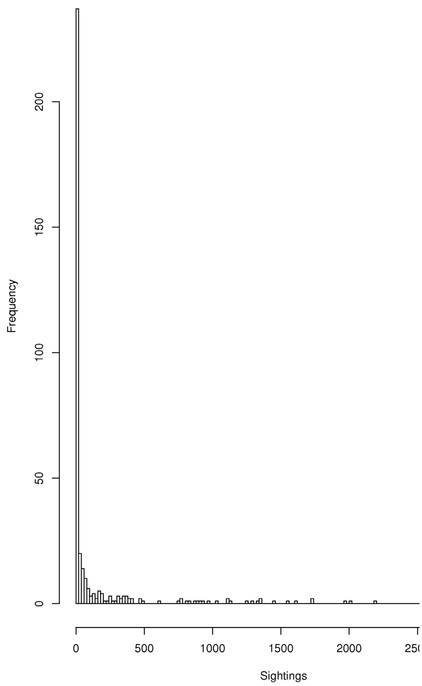

Fig. 3. Histogram of sightings

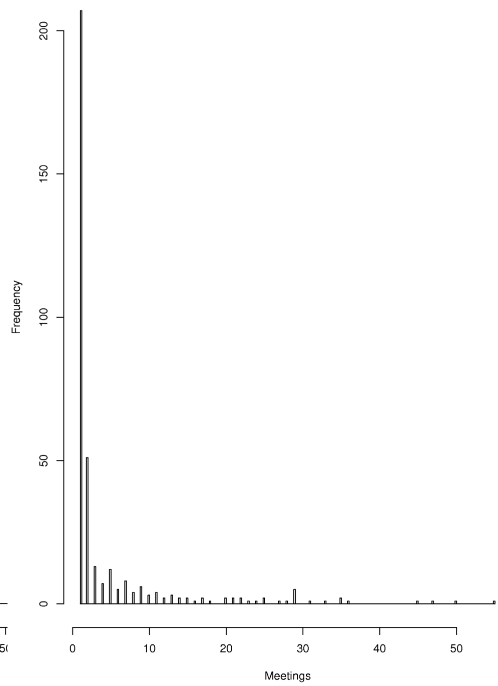

Fig. 4. Histogram of meetings

indicated by a peak in DynStra that is triggered during the movement through the crowded city. Coffee breaks, lunch and visits to the exhibition are indicated by peaks in DynFam. The workshop during day one and two is not detected, since the group behavior was rather homogeneous and did not exhibit the measured dynamic. The city exploration as part of the workshop on the other hand is clearly indicated. The arrival to the workshop did not require movement through crowds.

The peaks vary in width and height. The height relates to the frequency of the changing of people in the surrounding and the width to the duration of the changing. With the knowledge of the larger context—the conference visit in this case—it is possible to assign meanings to the individual peaks.

There were a couple of problems encountered with this experiment. First, Bluetooth is generally unpopular in Japan. Anyhow, most times there was enough reception in the city for this analysis. Only the movement in the night was not detected, although there were strangers on the streets. Inaccuracies in Bluetooth device inquiry were also discovered, but seem to have no significant negative effect (compare [6]). Moreover, the processing could not have been carried out like this during the measurement. The reason is, that the familiarity was calculated over the whole conference time before the features were calculated. Thus, effects of the process of getting familiar are not addressed here.

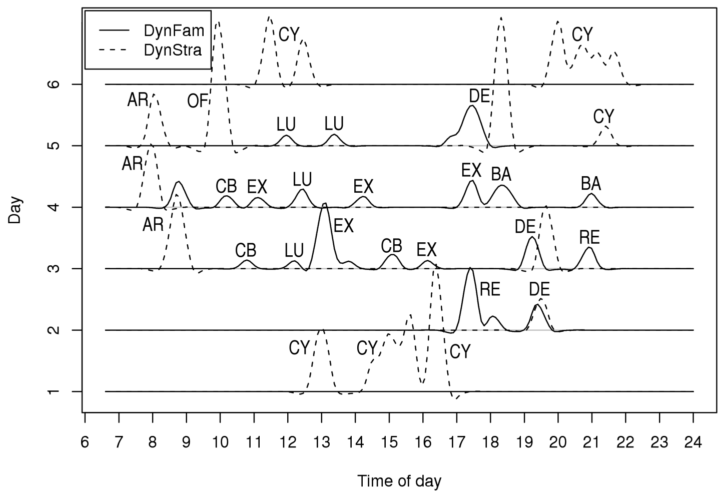

Fig. 5. Feature data of six days in Tokyo (smoothed by splines). Day 1 and 2: Workshop; day 3, 4, 5: Conference; day 6: day off. The peaks indicate social events or situations the test subject attended. CY: Moving through the city, RE: Conference reception, DE: Departure from conference, AR: Arrival at conference, CB: Coffee break, LU: Lunch, EX: Exhibition (posters and demos), BA: Banquet, OF: Off the conference.

9 Conclusion and Future Work

The Wireless Rope system was presented as a framework to experiment with proximity data in a variety of situations. It runs on modern mobile phones and collects proximity data by Bluetooth device inquiries. The analysis of data from a computer conference suggests, that the presented features are suited to indicate situations with a high dynamic in the movement of surrounding people on the basis of data collected by Bluetooth device inquiries. While movement in the city could also be detected by cheap location tracking technologies [13], the detection of movement within a building would require an expensive additional infrastructure. Even if other methods were in place, the classification of familiars and strangers in the proximity adds valuable information.

The conference was a well suited setting, since there was contact with a lot of different persons. Social relations are not very differentiated in this situation, since most persons are strangers at the beginning. The familiarity classifier indicates mainly, if someone is a regular conference attendee or not. In daily routine, a detailed discrimination of social roles, like family, friends and working colleagues would help to identify meaningful situations and episodes. As an alternative to the personal inquiry device, stationary devices could be used to measure the quality of a conference, e.g. to measure if sessions start on time, how popular individual sessions are, or how masses of people move through the conference space.

To further study this topic, it is necessary to determine the significance of these findings by comparing them to other persons, places, and scenarios. More features need to be developed and tested to account for other situations. Further, this method could be used in combination with other context sensors, like location. Correlation with a calendar could also yield interesting results. A learning algorithm could probably be used to determine the usual daily routine of a person and automatically detect meaningful deviations.

References

1. Hui, P., Chaintreau, A., Scott, J., Gass, R., Crowcroft, J., Diot, C.: Pocket switched networks and human mobility in conference environments. In: Proc. SIGCOMM 2005 Workshop on Delay Tolerant Networking, Philadelphia, USA, ACM Press (2005)
2. Schilit, B.N., Adams, N.I., Want, R.: Context-aware computing applications. In: Proc. Workshop on Mobile Computing Systems and Applications, Santa Cruz, USA, IEEE Computer Society (1994) 85–90
3. Kern, N., Schiele, B., Junker, H., Lukowicz, P., Tröster, G.: Wearable sensing to annotate meeting recordings. Personal and Ubiquitous Computing **7** (2003) 263–274
4. Kortuem, G., Segall, Z.: Wearable communities: Augmenting social networks with wearable computers. IEEE Pervasive Computing **2** (2003) 71–78
5. Kurvinen, E., Oulasvirta, A.: Towards socially aware pervasive computing: A turntaking approach. In: Proc. International Conference on Pervasive Computing and Communications (PerCom), Orlando, Florida, IEEE Computer Society (2004) 346–351
6. Eagle, N., Pentland, A.: Reality mining: Sensing complex social systems. Personal and Ubiquitous Computing **10** (2006) 255–268
7. Olofsson, S., Carlsson, V., Sjölander, J.: The friend locator: Supporting visitors at large-scale events. Personal and Ubiquitous Computing **10** (2006) 84–89
8. Gips, J., Pentland, A.: Mapping human networks. In: Proc. International Conference on Pervasive Computing and Communications (PerCom), Pisa, Italy, IEEE Computer Society (2006) 159–168
9. Holmquist, L.E., Falk, J., Wigström, J.: Supporting group collaboration with interpersonal awareness devices. Personal Technologies **3** (1999) 13–21
10. Madhavapeddy, A., Tse, A.: A study of bluetooth propagation using accurate indoor location mapping. In: Proc. Ubiquitous Computing (UbiComp), Tokyo, Japan, Springer Verlag (2005) 105–122
11. Milgram, S.: The Individual in a Social World: Essays and Experiments. Addison-Wesley (1977)
12. Paulos, E., Goodman, E.: The familiar stranger: Anxiety, comfort and play in public places. In: Proc. SIGCHI Conference on Human Factors in Computing Systems, Vienna, Austria, ACM Press (2004) 223–230
13. Hightower, J., Consolvo, S., LaMarca, A., Smith, I., Hughes, J.: Learning and recognizing the places we go. In: Proc. Ubiquitous Computing (UbiComp), Tokyo, Japan, Springer Verlag (2005) 105–122