

APPLICATIONS FOR SOCIAL SITUATION MODELS

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ABSTRACT

We motivate why models of social networks on small time and space scales and especially social situations are valuable for new useful social networking services that are context aware and socially aware. A model for social situations and pragmatic approaches for instantiating such models with the help of mobile devices is introduced. Two example applications are discussed: Social Life-logging and a communication service with social situations as recipients. Social Life-logging aims at the recording and later retrieval of social situations, which represent valuable granularity elements that simplify retrieval and improve usefulness in comparison or in addition to known multimedia-based life-logging concepts. Social situations as recipients for communication acts support an interesting new mode of communication.

KEYWORDS

Reality Mining, Social Signals, Social Computing, Mobile Computing, Context Aware Computing

1. INTRODUCTION

Social Networking (SN) platforms such as Facebook [Facebook10] evolved from community platforms (providing a bundle of communication-, information- and awareness-services [Groh05]) by adding explicit models of social networks and corresponding services such as friend recommender services. **Social Networking**, in general, can be defined as a collaborative or social computing **paradigm**, that makes use of an explicit social network model, (selectively) opens parts of the participating user's information spaces (in most cases profile pages) to other users from the social network, and offers useful communication-, information-, and awareness-services that can operate on these open parts.

The concept of **Mobile Social Networking** can be seen as a mobile interaction extension or broadening of this paradigm by **detecting and modeling the user's individual and social context** via mobile (or wearable) devices and by using these context models and selectively opening them (as part of the individual information space) to other users from the network for new services or variants of existing services with increased usefulness, especially in mobile interaction scenarios.

The **general social context** of a person in relation to a time interval t and/or a space region r encompasses characteristics of dyadic social relations, social interactions or more complex social situations that took / take place within t or r or $t \times r$ or spanned / span over t or r or $t \times r$. In a more narrow sense that we will use here, the **social context** of a person can be defined as encompassing characteristics of all social relations, social interactions and social situations which are directly related to or confined to small time-intervals and space-regions around the present time or present location of a person. Examples include higher abstraction level social context elements such as characteristics of other persons present in the current situation, strengths and semantics of social relations among these persons and lower abstraction level social contexts such as discourse patterns, social signals such as gestures and facial expressions during communication etc. Detecting and modeling social relationships on small space- and time-scales (that is the transformation of lower abstraction level social context elements (especially social signals) into higher abstraction level social contexts) is the realm of the emerging field of **Social Signal Processing** [Vinciarelli09], [Pentland09a], [Pentland09b].

A usual definition of the **individual context** of a person (see [Dey01]) is in most cases related to that person's current time and current place and encompasses all individual parameters of the person and characteristics of the physical environment of that person relevant for the current interactions of the person

with the current physical environment. Examples include current location, states of an IT-application that is currently used or a personal physical disability relevant to the current interaction scenario.

In some cases or situations, individual and social context are closely related and may be deduced from one another. E.g. the fact whether a person currently feels depressed or suffers from long term clinical depression can be regarded as part of the individual context (e.g. relevant for a mobile SN service such as a (collaborative) recommender service avoiding certain items), but current research investigates how depression may also be deduced from social signals (as part of social context) for example facial expressions during social interactions (see e.g. [Torre10]).

2. SOCIAL SITUATIONS: MODELS AND DETECTION

General Model The variety of possible social situations that a group of individuals may be engaged in is clearly very large. Social Sciences investigate, model and describe a multitude of aspects of such situations but often take a mid- and/or long term scientific perspective involving aspects of many such situations, which are related to each other.

In order to establish socially context sensitive Mobile Social Networking services, a simple model for individual social situations is necessary which allows to model key aspects of such situations by means of essential information which not only clearly define such a situation but also allow for the unique distinction of the former at a suitably general level. The level of modeling must be general enough to allow for every aspect of the model to be accessible for measurement via sensors in mobile devices and subsequent analysis via Social Signal Processing as well as to capture a common basis of model aspects that all social situations share. All the same it must be definite enough to allow for identification of social situations and for useful applications in socially sensitive services. Thus, such a model must prove itself on the application level in Mobile Social Networking.

Hence, we define our model as a **four-tuple** (T, S, P, C) consisting of a time span, a subset of 3D-space, a set of participants, and content-tags that freely describe semantic aspects (purpose, topic, etc.) of the situation. The temporal and spatial components are necessarily subsumed by an arbitrary four-dimensional entity whose projections on the time and/or spatial axes result in the respective T and S components. The spatial projections thus comprise three-dimensional volumes, polygons, lines as well as points. Application of this model allows for the use of basic algebraic and other analytical operations to be able to find possibly sought unions, intersections, complements or Cartesian products.

As an example consider a birthday party (>> possible content tags) inside an apartment (>> spatial frame) on a Saturday evening (>> time frame) involving a set of 30 persons. This situation may entail several other, more fine-grained situations (such as e.g. the formalization of "Barbara, Georg and Alex chatting for an hour at the kitchen table") and may overlap with other situations with respect to one or more tuple-elements. It is plausible to assume that the proposed general model conveys all essential information yet does not carry additional redundant or otherwise dispensable data.

Model Detection Apart from the modeling aspect of social situations, obviously, the most important factor is the detection of the former which, again, can be achieved in a variety of ways either manually or automatically. With respect to our work, we are mostly interested in a (semi-)automated approach which is mainly based on the use of numerous mobile agents. The critical factor in our work is the development and evaluation of decentralized information retrieval and processing that, in particular, happens independently from any (available) external infrastructure such as Wireless LAN, GPS, mobile phone cells, etc., while at the same time, as far as possible, being decoupled from manual user input and thus consequently from coherent possibly erroneous information (intentional or unintentional) as well. It should be noted that as mobile agents allow for both instant and deferred data processing, their use enables a vast extension to existing and new social networking services, be they location- or, preferably, even situation-aware. As an example for infrastructure-independent data sources, amongst others, audio- and video recordings, still images, SMS, shared audio or other data, calendars as well as acceleration- and gyroscopic sensors can well serve the aforementioned requirements and deliver continuous rich data for the automatic detection of social situations.

A particularly interesting aspect within this realm is the clustering, classification and interpretation of data sources for which only very limited training data are available, e.g. restricted to a single user, a group of users, or even none of them. Whereas the timely and spatial components of our proposed model can be automatically detected rather easily, the latter two components, namely the participating individuals as well as especially the associated tags and/or content, constitute a way more difficult aspect, in particular with respect to our favored decentralized approach and the rather limited computational power of mobile agents.

3. COMMUNICATION SERVICES

Models of social situations can be used for communication services. One such service could use social situations as **recipients of communication acts** (e.g. simple text-messages). An exemplary use case could be a user being involved in a social situation (e.g. a party) where she does not have all contact data of all participants. Some of the contact data could have been gathered via personal networking before or during the social situation, yet other contacts might not (e.g. because exchange was prevented due to privacy settings or the relevant other participants of the social situation did not take part in decentralized mobile social networking at all). If the user later wants to send a message to all participants of the past situation (e.g. because she liked the party and wants to invite roughly the same set of people to her own party), knowing at least some of the participants of the social situation can help in sending a message to the situation as a whole.

Concept We assume that the mobile social networking agents, apart from models of social situations, maintain a **longer term, more general view on the personal network** (preferably with weighted, typified and directed edges). We furthermore assume that apart from the agreeable view on the social situation that the participating agents share and establish as a common view, each agent has a **private view on social situations** that might differ from the views of the other participants because of private information that its user does not want to share or that other users involved in its private view do not want to share. Especially the set of persons involved in the situation might differ in some aspects.

Assuming that the situation encompassed n other persons (besides the user), $m < n$ of those persons are known to the user or, more precisely, have existing contact records in the user's mobile social networking agent (however acquired). The algorithm for sending a message to a social situation needs to determine **communication pathways to the remaining $n-m$ users** with the help of the longer term social network and with the help of other social situations that may have been detected. The message's meta data encompasses the original sender and the four-tuple modeling the social situation that the receiver and the sender have shared.

First, the m known other agents are asked to send the message to as many of the $m-n$ unknown participants as possible. An appropriate message identification ensures that duplicate messages can be identified on behalf of the target agent. Sending the message follows the same algorithm recursively. We limit the number of intermediary hops to one, meaning that the path-length from the original sender to the original receiver is limited to two. If more than one intermediary would be used, the fragile social tie initiated by and possibly limited to the social situation in question would not be enough to ensure that the communication path would be comprehensible for the receiver.

If the m known agents fail or deny delivering the message, the algorithm tries to use intermediates from time-overlapping social situations with sufficient overlap in the set of persons or super-situations to deliver the message to the participants of the original situation. If that also fails, similar situations from the past (in decreasing chronological order) are tried. The similarity thresholds (especially with respect to the set of persons) are rather strict. In both cases the message's meta data must contain the other social situation that is heuristically used to deliver the message to the original situation in order to make the communication path comprehensible for the receiver.

If that also fails, the set of first degree friends not involved in the original situation and not tried before is used. All persons in all cases are tried in the order of decreasing social relation weight.

All these measures are intended to ensure that the "natural" course of human communication (which, especially in the sensitive case of communicating with a person for the first time, is governed by the opposing forces of fear of rejection and hope for affiliation [Schüler05]) using intermediaries is as closely mimicked as possible while keeping the rules and models as simple as possible. The four-tuple model of

social situations ensures that enough data is available for the receiver to comprehend the communication path.

Evaluation

We used MIT’s Reality Mining dataset [Pentland09b] to evaluate the algorithm. It contains time and place of mutual Bluetooth encounters of the mobile devices of 100 MIT students over the course of time of nearly 17 months as well as such with “other” devices. Encounters with a total of about other 21000 devices (which, in our simulation, were all assumed to be human agents) were recorded. Aside from the social situations heuristically derived from these encounters (we viewed every set of devices with mutual encounters over at least one time-frame as a social situation), in order to fulfill our assumptions, we needed a long term social network between all devices. For the edges *between* “other” devices (in lack of any such data) we created a realistic weighted social network small world graph among these agents (devices)

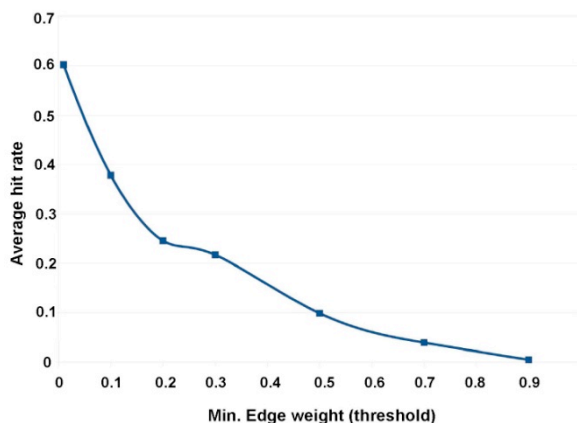


Figure 1 Varying the minimum edge weight threshold

because we did not have data about encounters *among* the other devices. We used the Watts/Strogatz-based algorithm in [Stavrou01] with $P=0.3$ and $k=8$. The weights for edges involving at least one participating agent were computed via relative frequency and relative duration of encounters, assuming (in the absence of any scientific data on this subject) a 1:2 ratio with respect to amalgamating these two aspects in computing the edge-weight. This left us with a weighted, undirected and untyped social network of roughly 21000 nodes (participants and “other”). We then determined the hit ratio of sending a message to an unknown node using the algorithm described above while considering only nodes connected to the sender with an edge weight

exceeding some threshold. Figure 1 shows the results.

Obviously, the success of the algorithm substantially varies with the chosen threshold. For the algorithm, this implies that weakly related intermediaries might also have to be taken into account if only one intermediary were allowed at most.

4. SOCIAL LIFE-LOGGING

The original concept of **life-logging** can be defined as the ongoing (audiovisual) **recording of everyday activities** of a person (mostly with mobile devices). Ideas for these extreme forms of a diary date back to Bush’s vision from 1945 [Bush45]. The total “multimedia” content that a human sensorially acquires during the course of her life can be estimated as equivalent to a few hundred Terabytes of data, regarding the audiovisual resolution of human sensory organs and a typical human lifespan. On from the mid-1990s, rapid developments in the fields of data storage and wearable computing allowed for the vision of life-logging to become realistic. Still, one of the main obstacles in (multimedia) social life-logging is not the recording of the data but the efficient retrieval from the resulting large amounts of streamed data.

One key insight in overcoming these limitations is that the human brain is substantially geared towards events and situations, and to large parts works **episodically** [Byrne08]. Furthermore, since humans are essentially social beings, a large share of events and situations that occur have a strong **social** context or are determined by their social nature. Since a large portion of social situations, as described before, has a clearly defined extension in space, time, participating persons and semantics, these findings naturally lead to the concept of **Social Life-Logging (SLL)**. In SLL, the granularity of life-logging is defined by social situations which are (semi-)automatically detected and recorded. The level of recording depends on the model of social situations and can range from simple explicit symbolic storage of the social situation model data (who, where, when, what) to complete additional multimedia coverage of the situation. Using social situations as key-elements allows for clear life-log-data-semantics for services operating on these data such as retrieval of social situations while still covering a large share of the intended usage aspects of conventional life-logging.

Related Work Life-logging has been seriously considered scientifically **since the early 1990s**. Here, we will distinguish between systems aiming at continuous recording and those aiming at sporadic recordings.

Examples of systems with **continuous recording** encompass several approaches. **Forget-me-not** [Lamming94] was an early approach to life-logging at Xerox research using the ParcTab devices exchanging data with others via infrared transmission. Lamming also emphasizes the episodic nature of autobiographic memory. Hence the system contained simple heuristics to derive episodic interactions (similarly to our concept of social situations) with other devices (people), and displayed them in a simple fashion. Other approaches relying on wearable computing for the capturing of life-logging data were made at MIT's Wearable Computing Lab (see e.g. [Rhodes96]). The corresponding systems were, for example, intended as "**Memory Prostheses**" supporting everyday activities, and made proactive recommendations if information items were possibly useful for a current context, or gave identification hints on other people (identified through Personal Area Networking or primitive face recognition) via augmented reality etc. Pentland's **Reality Mining** project is a recent approach that also uses mobile devices in order to continuously capture large bodies of individual and social context data (e.g. via mutual Bluetooth encounters of devices), for example for the identification of activity-patterns (e.g. "Eigenbehaviours") [Pentland09a, Eagle06]. [Aizawa04] present a laptop-based life-logging system with a multitude of input channels including time, location, audio and video, and even such exotic data as electric brain signals as well as data from interaction with software applications. Intelligent retrieval concepts for the life-logging data based on captured and modeled contexts using speech processing and face recognition are presented. [Byrne08] use a continuous capture of images by a **SenseCam** life-logging system (see [Hodges06]) which also delivers GPS location information, etc. so as to develop intelligent episodic life-log retrieval methods based on the axes time, space and persons, with an episodic grouping into so-called events. Another approach which aims at segmentation of life-log-data is [Doherty07]. Other classes of systems restrict life-logging to a narrow class of input data (such as WiFi-based location information [Rekimoto07]).

Again other systems aim at **sporadically recording** only those data which are meaningful for the user (using some metric). Among these sporadic recording life-logging systems, Pentland's **InSense** [Blum06] uses social signal-sources such as location- and acceleration-sensors as well as microphones in conjunction with subsequent analysis of social signals (vocal prosody, posture, etc.) to detect a user's situation or context. In a training phase, the user manually labels activities (e.g. content and interestingness). With the help of a stochastic learning approach, a model of interesting contexts is learned which is then used to classify current contexts as sufficiently interesting, thus triggering the recording process. [Healey98] previously used physiological sensors (such as skin resistance) to detect individual arousal as an indicator of interestingness. Microsoft's **MyLifeBits** [Gemmell02] is a system for organizing life-log elements like images, etc. by employing many visualizations, retrieval techniques and annotation possibilities and, for example, allows for time-based or "story"-based search, the latter of which finds groups of related data-items. **Microblogging**-Systems such as Twitter [Twitter10] can also be seen as partly following the life-logging spirit with a manual selection of events that are commented through Tweets, with the feature that these "log-elements" are published on the Web and thus (together with the Social Networking features present in Twitter) have a special flavor of socialized life-logging.

Concept Our concept is **distinguished** from some of the concepts described in the previous section in that not a continuous or sporadic stream (or single elements) of audio, video or other life-log-data is captured and stored for later retrieval (where this retrieval is supported by individual context data), yet that **only social situations** as a form of social context are detected, modeled and stored for intelligent later retrieval. Furthermore, our model's social situations are generally not detected and modeled from only a single user's point of view but under a **Mobile Social Networking paradigm** by using and **exchanging** data and models among agents. Particularly each agent may collect the **points of view** of other participants regarding the social situation (their model of the situation) in order to assemble, communicate and negotiate a joint (common) view (model) which increases reliability and confidence of the (common) model. Due to the episodic and social nature of the human brain, social situations are **excellent units for retrieval** and **excellent memory aids**. In contrast to memory prosthesis applications aiming at the individual point of view of life-logging, we employ a social memory prosthesis on the basis of agreeable social situations. In that way

the need for extensive (e.g. interest based) error-prone filtering of individual contexts is attenuated because it is reasonable to assume that there are far less agreeable social situations than individual situations. Social situations provide content and natural structuring elements for the life-log that other types of content (e.g. multimedia contents) can easily be attached to, which circumvents several problems of classic life-logging.

Nevertheless, our concept has **similarities** with some of the aforementioned approaches. E.g. akin to Forget-me-not, only the context (in this case the social context) is part of the life-log. We also face **similar problems** such as how to support intelligent searching, browsing and visualizations on the space of social situations.

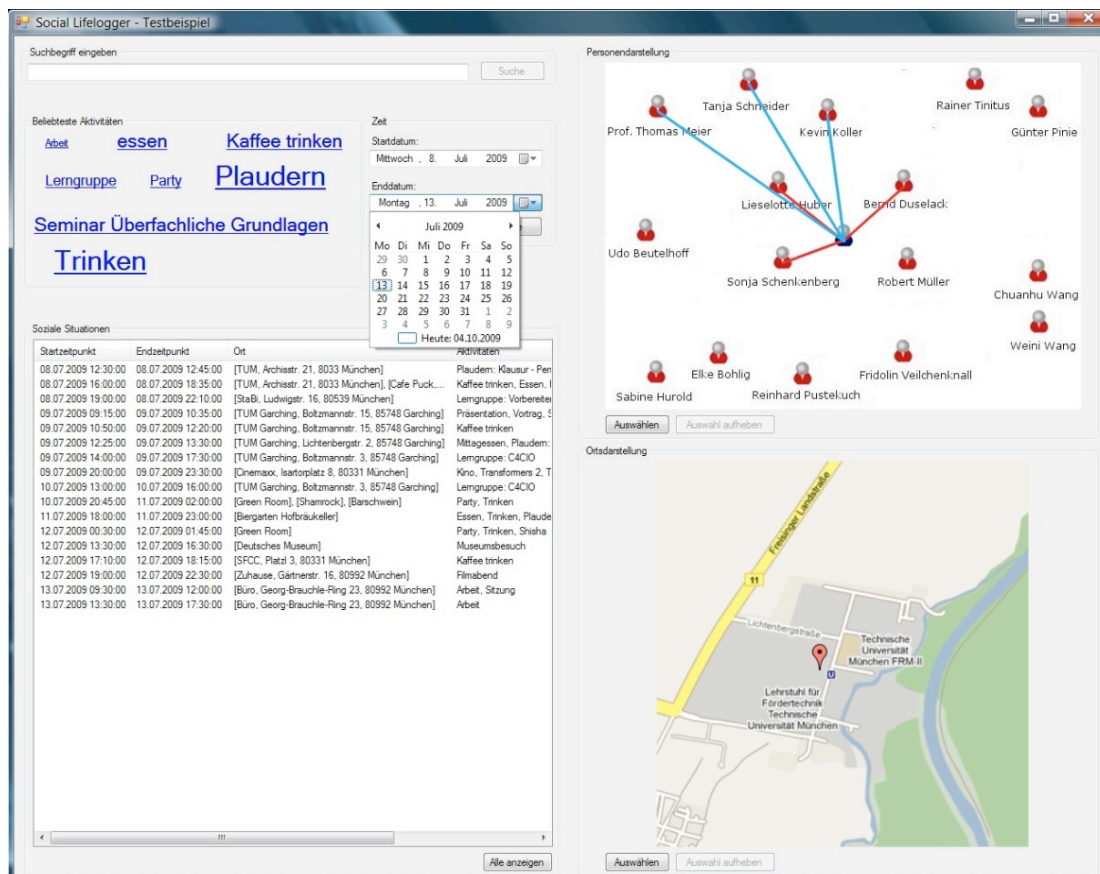


Figure 2 Evaluation-Version of the Social-Lifelogging-Application

As has been discussed in a previous section, our model of **social situations** encompasses a **time-duration**, a **spatial** reference (e.g. a polygon), a set of **persons** participating in the situation, and tags that define the activity or **content** reference of the social situation. For each of these model elements we will now discuss how these elements are visualized and retrieved in our concept.

The **visualization** of time is done with a conventional two-dimensional calendar based view of the beginning and the end of the social situation. This is a pragmatic visualization that most of the users are used to. The same reasoning leads to a two-dimensional map as a visualization for the spatial reference of the application. For the visualization of persons we relied on a first degree star shaped social network with weighted edges as a basis where the edge-weights are visualized via line thickness similar to other approaches like [Byrne08]. We distinguish several basic types of edges (such as friends or co-workers). This view provides a familiar reference frame for the user. Only edges to persons involved in the social situation (“instantiated” edges) are shown. In order to compensate for the missing edge visualization for non-situation-participating first-degree-related persons, the weight of the relation is also depicted via the distance to the central user. Persons involved in the social situation which are not first degree are shown via dashed edges that abstract from the exact network paths. In these cases, the distance from the center is a metaphor for the path length. Colors depict the type of edges to situation participants. Tags specifying the activities are

depicted via a tag-cloud where the current situation's activity is highlighted and more frequent activities are shown using a bigger font. If the number of first grade related persons in the social network becomes too large, persons should be grouped by the number of common situations as far as possible and a fish-eye type of focusing should be applied.

For the four situation elements, we provide **text-based as well as graphical retrieval interfaces**. So, for example, time intervals can be selected from a calendar and spatial references can be selected from a map via a selection-rectangle. Furthermore, the user can directly select single social situations from a list view (with several distinct ordering options) which shows spatial references (that are determined from the GPS trace of the situation via reverse geo-coding), time intervals and activities in text form. Once the situation has been selected, it is then depicted in the map-, social network- and activity views, allowing for easy further data retrieval. In this way, the desired situations can be found with very few easy "concentric" retrieval steps. In order to search for situations involving a specific set of users, a selection rectangle can also be used in the social network view. In future implementations of the system it will be possible to use either a strict filtering rectangle or a soft filtering rectangle which allows for a certain degree of mismatches w.r.t. to the set of involved persons. In the tag cloud, searching is also possible by (multi-)clicking on the respective tags.

Evaluation In order to evaluate the concept we implemented an extended mock-up version of the concept with the key UI concepts described in the previous chapter plus the interaction, omitting most of the model and controller implementations. We conducted a qualitative **user study** with five participants. Over the course of one week, the participants had to manually note down every social interaction (according to our four-tuple model) in which they were involved in. For each participant, an extensive dataset was created, featuring the necessary visualizations for the system components which allowed to interact with the system for the participants.

After four weeks, the participants were asked for a user study test and detailed interview. In a first step, the concepts of the system were uniformly introduced to the participants with the help of an artificial dataset. After that, they had to solve several tasks (retrieving social situations w.r.t. the four axes, etc.) by interacting with the system on their own dataset. The interview was partitioned into four sections: The first section aimed at determining how much of each of the social situations was remembered and how the application could help remembering missing details. The second and third part contained questions investigating the perceived quality of the functionality (searching + visualizing social situations), while the fourth part investigated the application in a whole. The questions aimed at determining in how far the proposed model for social situations was sufficient for the intended use, whether the concept was helpful for remembering social situations, whether the users regarded the purposes and possibilities of the concept as useful and whether the methods for the visualization and the retrieval of social situations were helpful and suitable. With respect to determining the degree of remembering the persons of a certain situation, some persons were deliberately left out. Three of the participants did not recognize the manipulation and the other two could only determine one out of six missing persons on average. Similar results for the other model-axes also showed that the participants did not very well remember all aspects of a social situation but that they were able to recall the situation with the help of the application which speaks in favor of the general purpose of the application. With respect to text-based vs. graphical search, all participants agreed that text-based search (as realized in the application) was essential and was judged as sufficient while the graphical tools were perceived as a good supplement. Minor improvements such as suitable auto-completion mechanisms for the text-based search were suggested. Searching w.r.t. time was perceived as essential also in a social life-logging system, and three users rated the familiar calendar-based view and searching as suitable and user-friendly for the intended application while two of the participants would prefer a time-line based view / retrieval mechanism in the fashion of Apple's TimeMachine. The map view of the spatial reference of social situations as well as the social network view depicting the persons in a social situation together with the graphical selection principle for searching in these two cases was judged as very good by all participants. With respect to the activity visualization, the participants stated that more frequent activities may not necessarily be more important and thus suggested the option of a manual importance ranking for activities. One user suggested that the manual importance ranking should be provided for whole situations, allowing for a specially highlighted view in the list view and allowing for a simple machine learning-based importance predictor / classifier for unlabeled situations. The quality of the search results using the various searching possibilities were judged as very good by all participants and the modeling of social situations as four-tuple as sufficient and expressive.

5. CONCLUSION

We have shown how models of social situations may be applied in useful mobile social networking services. Aside from future research on heuristically discovering social situations with the help of mobile devices, we will also conduct user studies and further simulations with respect to the social and algorithmic relevance of the parameters of the algorithm for using social situations as recipients of communication acts. The social life-logging concept will also be developed further by incorporating new UI and retrieval concepts.

REFERENCES

- [Aizawa04] Aizawa, K.; Kawasaki, S.; Tancharoen, D.; Yamasaki T. *Efficient retrieval of life log based on context and content*. In: ACM Multimedia Workshop on Continuous Archival of Personal Experience (2004) S. 22-31.
- [Blum06] Blum, S.; Pentland, A.; Tröster, G.: *InSense: Interest-Based Life Logging*. In: IEEE MultiMedia, Vol. 13 (2006), Nr. 4, S. 40-48.
- [Bush45] Bush, V.: *As We May Think*. In: The Atlantic Monthly (July 1945).
- [Byrne08] Byrne, D.; Lee, H.; Jones, G. J. F.; Smeaton, A. F.: *Guidelines for the presentation and visualisation of lifelog content*. In: iHCI 2008 - Irish Human Computer Interaction Conference 2008, Cork 2008.
- [Dey01] Dey, A. *Understanding and Using Context*. Personal Ubiquitous Comput. 5, 1 (Jan. 2001), 4-7.
- [Doherty07] Doherty, A.R.; Smeaton, A.F, Lee, K.; Ellis, D: *Multimodal Segmentation of Lifelog Data*. In: In Proc. of RIAO 2007, Pittsburgh 2007.
- [Eagle06] Eagle, N.; Pentland, A. *Reality Mining: Sensing Complex Social Systems*. In: Personal and Ubiquitous Computing, Vol. 10 (2006), Nr. 4, p 255-268.
- [Facebook10] www.facebook.com (URL, Jan. 2010)
- [Gemmell02] Gemmell, J.; Bell, G.; Lueder, R.; Drucker, S.; and Wong, C.: *MyLifeBits: Fulfilling the Memex Vision*. In: ACM Multimedia '02 (2002), S. 235-238.
- [Groh05] Georg Groh. *Ad-Hoc-Groups in Mobile Communities - Detection, Modeling and Applications*. PhD-Thesis, TU-München, Germany, 2005.
- [Healey98] Healey, J.; Picard, R. W. : *StartleCam: A Cybernetic Wearable Camera*. In: Proceedings of ISWC (1998), S. 42-49.
- [Hodges06] Hodges, S.; Williams, L.; Berry, E.; Izadi, S.; Srinivasan, J.; Butler, A.; Smyth, G.; Kapur, N.; Wood, K. *SenseCam: a Retrospective Memory Aid*. In Dourish and A. Friday (Eds.): Ubicomp 2006. Hrsg.: LNCS 4206, Springer-Verlag Berlin Heidelberg 2006, p. 177 – 193.
- [Lamming94] Lamming, M.; Flynn, M. *Forget-me-not: Intimate Computing in Support of Human Memory*. In: Proceedings of FRIEND21 Symposium on Next Generation Human Interfaces, Meguro Gajoen 1994.
- [Pentland09a] A. Pentland N. Eagle. *Eigenbehaviors: Identifying structure in routine*. Behavioral Ecology and Sociobiology 63:7, 2009.
- [Pentland09b] A. Pentland N. Eagle and D. Lazer. *Inferring social network structure using mobile phone data*. Proceedings of the National Academy of Sciences (PNAS) Vol 106(36), pp.15274-15278, 2009.
- [Rekimoto07] Rekimoto, J.; Miyaki, T.; Ishizawa, T. : *LifeTag: A WiFi-based Location Life-Logging Device*. In: ACM Symposium on User Interface and Software Technology (UIST2007).
- [Rhodes96] Bradley Rhodes and Thad Starner: *The Remembrance Agent: A continuously running automated information retrieval system*, (PAAM '96), London, UK, April 1996, pp. 487-495.
- [Schüler05] Julia Schüler. *Ein hierarchisches Modell der Anschlussmotivation - nung-auf-Anschluss und Furcht-vor-Zurückweisung und die Selbstregulation durch Zielsetzung*. PhD-thesis, Universität Wuppertal, 2005.
- [Stavrou01] Angelos Stavrou. *Small World Graph Generation Program*. Columbia University, 2001. <http://www.cs.gmu.edu/~astavrou/software/smallworld/GraphS.java>, (URL Nov 2009)
- Date of access: 2009-09-15.
- [Torre10] F. de la Torre Frade, J.Cohn et al. *Depression Assessment Project*, Robotics Institute, Carnegie Mellon University, 2010 http://www-old.ri.cmu.edu/projects/project_633.html (URL, Jan. 2010)
- [Twitter10] www.twitter.com (URL, Jan 2010)
- [Vinciarelli09] Alessandro Vinciarelli, Maja Pantic, and Herve Bourlard. *Social signal processing: Survey of an emerging domain*. Image and Vision Computing, 27(12):1743 – 1759, 2009.