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Contextual Social Networking

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Habilitationsschrift

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Kurz-Zusammenfassung

Der zentrale Gegenstand der vorliegenden Arbeit ist die vielschichtige Frage, wie Kontexte detektiert und abgeleitet werden können, die dazu dienen können, neuartige kontextbewusste Social Networking Dienste zu schaffen und bestehende Dienste in ihrem Nutzwert zu verbessern. Die (noch nicht abgeschlossene) erfolgreiche Umsetzung dieses Programmes führt auf ein Konzept, das man als Contextual Social Networking bezeichnen kann. In einem grundlegenden ersten Teil werden die eng zusammenhängenden Gebiete Contextual Social Networking, Mobile Social Networking und Decentralized Social Networking mit verschiedenen Methoden und unter Fokussierung auf verschiedene Detail-Aspekte näher beleuchtet und in Zusammenhang gesetzt. Ein zweiter Teil behandelt die Frage, wie soziale Kurzzeit- und Langzeit-Kontexte als für das Social Networking besonders interessante Formen von Kontext gemessen und abgeleitet werden können. Ein Fokus liegt hierbei auf NLP Methoden zur Charakterisierung sozialer Beziehungen als einer typischen Form von sozialem Langzeit-Kontext. Ein weiterer Schwerpunkt liegt auf Methoden aus dem Mobile Social Signal Processing zur Ableitung sinnvoller sozialer Kurzzeit-Kontexte auf der Basis von Interaktionsgeometrien und Audio-Daten. Es wird ferner untersucht, wie persönliche soziale Agenten Kontext-Elemente verschiedener Abstraktionsgrade miteinander kombinieren können. Der dritte Teil behandelt neuartige und verbesserte Konzepte für kontextbewusste Social Networking Dienste. Es werden spezielle Formen von Awareness Diensten, neue Formen von sozialem Information Retrieval, Konzepte für kontextbewusstes Privacy Management und Dienste und Plattformen zur Unterstützung von Open Innovation und Kreativität untersucht und vorgestellt.

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Abstract

The thesis centers around the multi-faceted research question of how contexts may be detected and derived that can be used for new context aware Social Networking services and for improving the usefulness of existing Social Networking services, giving rise to the notion of Contextual Social Networking. In a first foundational part, we characterize the closely related fields of Contextual-, Mobile-, and Decentralized Social Networking using different methods and focusing on different detailed aspects. A second part focuses on the question of how short-term and long-term social contexts as especially interesting forms of context for Social Networking may be derived. We focus on NLP based methods for the characterization of social relations as a typical form of long-term social contexts and on Mobile Social Signal Processing methods for deriving short-term social contexts on the basis of geometry of interaction and audio. We furthermore investigate, how personal social agents may combine such social context elements on various levels of abstraction. The third part discusses new and improved context aware Social Networking service concepts. We investigate special forms of awareness services, new forms of social information retrieval, social recommender systems, context aware privacy concepts and services and platforms supporting Open Innovation and creative processes.

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Contents

Introduction

In his visionary articles from 1991 [Weiser, 1991] and 1993 [Weiser, 1993], Mark Weiser set up a program for the next generation of computer systems. He demanded and predicted that according to his paradigm of **Ubiquitous Computing**, computer systems as such should and will gradually move out of focus of the users as the services they offer will be ubiquitously available and the multi-modality and quality of the UI and its **context awareness** will render them more and more invisible. Users should and will be able to access the information they require in a certain situation when they require it and where they require it. Many computing paradigms heavily overlapping with Ubiquitous Computing such as **Mobile Computing** and Wearable Computing continuously contributed to this vision.

A second highly influential paradigm became manifest on the Web in recent years: **Social Computing**. This paradigm refers to users directly or indirectly socially interacting via generating and consuming large amounts of content of all types of formats. The set of all services supporting this interaction may be referred to as **Social Media**. Concepts like 'Wisdom of the crowd' or 'Crowdsourcing', describing certain forms of collective intelligence and its dedicated usage through mobilization of large amounts of users for certain forms of distributed collaborative problem solving were hyped in this context.

One important paradigm in Social Computing is **Social Networking**, where users aim at collaboratively maintaining and expanding their social networks with the help of Social Networking platforms, providing suitable services supporting users in these tasks. These services include awareness services, services for direct communication and information services. A characteristic property of Social Networking is the explication of social relations, which is used in most of these services to a certain degree. These explications may be perceived as special forms of contextual information.

Both paradigms (Social Networking and context-awareness / Mobile Computing) flow together in the new field of **Contextual (Mobile) Social Networking**, where the large number of sensors available in the personal mobile device and the deep embedding of computing resources and services into all day (social) lives of users allows gathering many new and interesting forms of contexts that may be used to further enhance and improve Social Networking and generate new forms of Social Networking services. This new field has substantial overlap with other relevant active fields such as Reality Mining and Social Signal Processing.

This thesis thus centers around the multi-faceted **research question** of how interesting forms of **context** (with a special focus on **social contexts**) may be **mea-**

sured and **induced** e.g. with the help of sensors in mobile devices and appropriate inference techniques (e.g. from Social Signal Processing) and how these context elements can be **applied** in new services and for improving existing services in Social Networking. This includes e.g. short term social contexts, modeling current states of interaction as well as long term social contexts, e.g. represented by the explicated long term social relations of Social Networking.

The general research question will be split up further into smaller problems and the thesis aims at contributing to the solution of these problems with a multitude of research methodologies ranging from empirical models involved in investigating possibilities for the derivation of meaningful and semantically rich social contexts to design science approaches for the investigation of limits and chances for their application in certain Social Networking service classes.

How to Read This Text

This thesis is a cumulative Habilitation-thesis with **additional connective texts**. These additional texts serve **two purposes**: first of all they provide **context** for the original papers included. This context contributes to **readability** and **illustrates the larger scale relations** between the papers in order to clarify their contribution to the topic of the respective chapter and to the larger topic of Contextual Social Networking. The second role of the additional texts is to **present results of additional research that have not yet been published**. The level of detail of these presentations is chosen as corresponding to an overview article, omitting details that do not contribute to understanding but nevertheless presenting the research questions, methods and results of these additional studies in a thorough and scientifically sound way. The extension of the connective texts varies between the respective chapters, depending on the function of the chapter or section, on the nature and length of the original papers related to the chapter or section and on the degree to which the papers cover the topic of the chapter or section.

Related work is not presented in a systematic way for all topics discussed in the connective texts, because due to the vast number of fields related to Contextual Social Networking, such an effort would exceed the scope of these texts. However, the original papers will contain related work sections for the specific questions dealt with in the respective works.

The **scientific methodologies** used for the various topics and problems related to Contextual Social Networking are also discussed in the respective original papers and are not elaborated on in depth in the connective texts. Typical methodologies used encompass Design Science approaches, empirical approaches using various data-sets and numerical simulation.

Each chapter **contains a number of original research papers** published in refereed journals, conferences, and books or as technical reports. These papers are added at the end of each chapter. At the beginning of each chapter, a chapter abstract summarizes the content of the chapter, lists own publications related to the chapter's topic and also lists supervised theses related to the chapter.

Own publications are cited with a special symbol ∗ and **supervised theses**

are cited with a special symbol ●. Own publications that are **included** in full text at the end of the chapter are cited with a further special symbol ▶. In the electronic PDF version, the ▶ symbol acts as a direct **link** to the respective original **full text** of the paper. After the end of the chapter's additional text, a further PDF **link** allows the reader to **skip** all the full texts of papers related to that chapter and go directly to the beginning of the **next chapter**. Sections or subsections whose main function is to introduce one or more own publications are marked with a '*' symbol. They are often short and intended to be perceived as a unit together with the respective publications.

References to parts, chapters, sections, figures and other **structural units** are printed in **red** (in the electronic version and colored printed version) and also contain direct PDF **links** to the respective units in the electronic version. **Citations** are printed in a **purple** color (in the electronic version and colored printed version) and link to the respective entry of the bibliography (in the electronic version). **Important terms** of a textual unit are printed in **bold** font to contribute to a better overview of the content of longer text passages. Abbreviations are also used to contribute to a better readability and explained repeatedly. A list of abbreviations is included as a reference at the end of the thesis.

In the text, **male and female forms** for human beings are used alternately. If the male form is used, females are explicitly understood to be included. If the female form is used, males are explicitly understood to be included as well.

The appendix contains a **list of (co-)authored publications** of the author (including those publications that have otherwise not been mentioned in the thesis) and a list of **thesis projects supervised** by the author as a reference. Furthermore, it also contains a cordial word of thanks to my many co-authors and co-workers without whom few of the studies in this thesis would have been possible.

Content

Part I is devoted to illustrate the basic scenarios which the problems and ideas discussed in this thesis are related to and situated in.

chapter 1 is devoted to the **definition** of **Social Networking** in general and **Contextual Social Networking** in particular. The first part of this chapter aims at briefly characterizing concepts related to the Social Networking paradigm such as Social Networking **service** or **platform** and embeds these paradigms into the greater area of **Social Media**. We then briefly review the concepts of **context** and **context awareness** in order to characterize the types of context elements relevant for our case and so arrive at a characterization of **Contextual Social Networking**. After a short general discussion of challenges and opportunities for future research, pointing to questions taken up in subsequent chapters in more detail, an **early study** on acquiring and using simple **group contexts** for community support is presented giving a first idea of precursor concepts to Contextual Social Networking.

chapter 2 discusses **Mobile Social Networking**, which is very closely related to Contextual Social Networking because it allows acquiring a whole range of interesting context elements (especially social contexts) because of the suitability for the adoption of respective sensors and the deep, unobtrusive embedding into user's all day lives, delivering 'Honest Signals', a term coined by Alex Pentland of MIT. We illustrate the field Mobile Social Networking from **two perspectives**. First we investigate the structure of the (heterogeneous) **scientific field** Mobile Social Networking with the help of a **scientometric study** analyzing structures and properties of networks of publications, authors, institutions, conferences and other scientific entities in the field and its relations to contributing, neighboring and constituting fields. The second perspective analyzes **existing approaches, services, and platforms** of Mobile Social Networking on the Web to also cover the 'practical side' of this paradigm.

chapter 3 is devoted to **Decentralized Social Networking** (DSN) as a scenario which integrates well with Contextual Social Networking for several reasons discussed at the end of the first chapter. Besides a short discussion on main **architectural elements** of DSN scenarios, we will focus on concepts for **distributed group management** which is an interesting problem for certain variants of DSN and has gained attention due to the group-centric concepts of new centralized SN platforms such as Google+: how do groups and / or sub-communities present themselves, manage membership, and manage their associated information space(s) in a distributed and democratic way, forming a special flavor of social context? In close connection with that we will also discuss a study investigating the **role and structure of groups** in existing conventional SN platforms.

Part II will then discuss methods and concepts related to the **acquisition of contexts** that can be used in Contextual Social Networking (CSN). A special emphasis is put on long-term and short-term **social contexts**, which are especially interesting study objects in view of new context-aware service variants.

chapter 4 discusses methods for **conceptualizations and other characterizations of social relations** as a key form of long-term social context that are semantically richer than the simple concepts of 'friendship' currently used in SN platforms such as Facebook. Several studies investigating **folksonomies** and **polytopic** ('vector-space-like') types of characterizations of social relations are discussed. A study investigating **tagging based conceptualizations** for social relations and a follow up study researching socio-psychological phenomena in connection with tagging relationships identified several serious **difficulties** in relation to using folksonomies for the purpose of providing richer semantics for social relations. Thus a special focus of this chapter is on **Natural Language Processing (NLP) based methods** of analyzing communication content in view of the acquisition of alternative semantically rich models for social relations. We investigated possibilities for describing social relations along several axes: three studies investigated class-based and continuous assessments of a relation's valence (and / or intensity) via **sentiment analysis** using email corpora. Two other studies investigated NLP based methods for assessing intensity and valence of relations using editorial content instead of communication content.

The next two chapters then switch the view to methods for the **acquisition of short-term social contexts** via pragmatic Mobile Social Signal Processing. Short-term social contexts characterize elements of the social aspects of a situation a user is in. This encompasses questions asking for the general social nature of a situation, the set of persons nearby, the set of persons that are currently interacting with the user or even for the emotional state of the users nearby or the emotional state of the interaction with particular users.

chapter 5 begins with a very brief introductory look onto the fields of **Social Signal Processing** and **Reality Mining**. We then introduce **Social Situations** as a simple model for short term social contexts, basically modeling sets of currently interacting persons and the spatio-temporal boundaries of these interaction situations. Basic scenarios for detecting Social Situations using mobile device sensors are discussed. We first focus on the **geometry of interaction** (mainly body angles and interpersonal distances) as basic signal- or data sources for detecting evidences for or against the existence of Social Situations. An empirical **study** is presented that investigates and evaluates methods for Social Situation detection on the basis of interaction geometries using a social interaction data-set.

chapter 6 then discusses two further interesting issues: first we discusses **audio** as an interesting source for social signals allowing to detect and characterize social interaction and Social Situations in particular. A special focus is on **turn taking patterns** which exhibit characteristically different coordination properties within social encounters (Social Situations) as compared to turn taking patterns of e.g. pairs of persons in different spatially close Social Situations. An **HMM based approach** for the detection of social interaction on the basis of turn taking patterns is introduced. In order to compute turn taking patterns, techniques for **privacy preserving speaker diarization** have to be investigated and developed that perform well in noisy social environments and situations where not all candidate participants deliver a audio-measurement of their own or no appropriate speaker training data for all persons is available. A previously unpublished pragmatic approach is presented in more detail which performs well on two different datasets and which allows direct inference of probabilities for social interaction.
A second important issue of this chapter are methods for the **exchange and combination of context-elements of various sensor sources and of various levels of abstraction** between devices of different users, e.g. accounting for aspects such as subjectivity which cause the problem go beyond simple sensor fusion for Social Signal Processing. An approach based on Subjective Logic is presented that allows the exchange and combination of data in view of detecting and characterizing Social Situations of users which are assumed to be associated and represented in a hypothetical decentralized social networking scenario by intelligent **personal social agents** (partly) running on their mobile devices. The data which can be exchanged and combined range from raw measurements, and intermediate results of analysis, e.g. opinions on the nature and probability of the social interaction, to higher level results, such as Social Situations that the respective users are or are not involved in. Evaluation results confirm that the combination of audio (using methods discussed in the first part of the chapter) and interaction geometry yield better results than both data sources alone.

Part III mainly focuses on new **context aware Social Networking services**.

chapter 7 mainly focuses on **Awareness** services. Visualization techniques for social contexts such as **dynamic social network visualization** and their connection to Awareness services are discussed. Approaches for **Social Life-Logging**

services, communication services involving Social Situations and Matchmaking services are also presented. The chapter concludes with a discussion on the role of social contexts for **activity prediction** which, in turn, may represent an interesting service element for Social Networking.

chapter 8's main topic is **privacy management** for Social Networking using social contexts. First, we will discuss techniques for the **inference of missing profile elements** using, among other techniques, clique based methods which thus make use of a form of long-term social context. Although the corresponding publication focuses on large scale data-mining and not on attacks on the privacy of individuals in particular, this part deals with contrasting methods to those immediately aiming at privacy protection. Privacy management and its relation to the general problem of controlling information flows and its relation to information markets are topics of the second part of the chapter. After introducing several **studies on privacy-management and contextual privacy management in Social Networking**, we discuss a study linking a **new concept for social context sensitive privacy management, control of information flows and information markets** in Social Networking.

chapter 9 discusses foundations and options for an **alternative, agent-based information retrieval system** for decentralized Social Networking and Mobile Social Networking that makes use of long-term social and spatio-temporal contexts in oder to satisfy conscious as well as unconscious information needs. After a brief discussion on information services in SN and MSN, foundations and options for such an approach based on principles of **human information retrieval** and an **possible architecture using spatio-temporal embedding** as a key element and connecting element for several other types of context are shortly discussed. We discuss elements of a study providing an implementation of key elements and its functional evaluation with the help of a large Wikipedia dataset. The last section discusses current and future work activities evaluating the basic heuristic foundations of the aforementioned alternative, agent-based IR approach using a large **Twitter dataset**.

chapter 10's focus are **Social Recommender Systems**. In a first part, the term Social Recommender Systems and the concepts and variants behind the term and general ways to incorporate social context into recommender systems are discussed. A second section is devoted to **Social Filtering** which makes use of social context in a variant of Collaborative Filtering. We then discuss the use of social context for **person recommenders**. The next section is devoted to **team recommender systems**, where social context is also used to a certain extent but where the main focus is on recommending teams as a social entity. Thus team recommender systems strictly spoken may be subsumed under social recommender systems but may only partly be subsumed under services using social context. A final part deals with social context in recommender systems for **personal information management** (PIM).

chapter 11 discusses where and how social context may be used to generate or improve services in connection with IT support for **Open Innovation** processes. The first deals with with **contextual awareness services** and service elements for Social Networking based **Open Innovation platforms**. Examples are visualizations of multi-modal networks of innovators, organizations, and innovation artifacts and service elements for reputation modeling in OI communities. The second part deals with **contextual IT support for creativity**, which is an important element in early stages of OI processes. Examples are measurement and usage of short term social contexts around co-located collaborative UI environments such as multi-touch tables. A special use case presented is **collaborative music composition**.

We conclude with a **short summary and critical assessment** of the results and the field of Contextual Social Networking as a whole.

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Part I

Foundations

Chapter 1

Contextual Social Networking

This chapter aims at defining the idea of Social Networking in general and Contextual Social Networking in particular. In the first part, concepts linked to Social Networking (SN), such as SN service, social network, or social network platform are defined and scientific disciplines related to Social Networking are identified. A second part discusses the role of context in Social Networking and coarsely describes various classes of context that subsequent chapters aim to discuss in more depth. Also, basic classes of SN services will be presented that these contexts may be used in that will be discussed in more depth in the last part of the thesis. After a short general discussion of challenges and opportunities for future research, pointing to questions taken up in subsequent chapters in more detail, an early study on acquiring and using simple group contexts for community support is presented giving a first idea of precursor concepts to Contextual Social Networking.
Own publications related to this chapter: ∗[Groh, 2007]▶, ∗[Groh and Schlichter, 2005].
Supervised theses related to this chapter: •[Boening, 2010], •[Pötzl, 2012].

1.1 Social Networking

The terms Social Networking, Social Media, Communityware, Web 2.0 and other related terms have been in widespread use in recent years. Common key and common denominator to the concepts behind these terms is an **increased level of computer-supported or -mediated social interaction** of users from the **broad public** (non-IT-specialists) accompanied by an increased **generation and exchange of massive amounts of content**. This increase can be measured in comparison to the situation prevalent in the early Web (sometimes referred to as Web 1.0) where content was predominantly produced by a small number of IT affine specialists and often only passively consumed by the larger audience as in traditional forms of media such as TV or the printed press. While the early Web in principle provided the same basic conceptual possibilities for generating and exchanging content and for supporting social interaction, in Web 2.0 an increasing number of Social Media services and platforms were created that are especially tailored to supporting these activities. They substantially lower the associated technological barriers, allowing the users to switch from consumers to prosumers.

We will now present these **concepts** in more depth, mostly by providing suitable working **definitions** for them as a basis for the discussion in later chapters. We will omit defining related basic concepts that (although not one-hundred per cent precisely or indisputably defined themselves) may be assumed to be sufficiently well known and sufficiently well founded (such as 'the Web' ('WWW', 'Web 1.0') or 'the Internet').

1.1.1 Web 2.0 and Social Media

Taking a rather **non-technical perspective**, Web 2.0 may simply be loosely defined as denoting the extension of Web 1.0 in terms of instances of Social Media services and platforms supporting (direct and indirect) **social interaction** via the **generation and exchange of large amounts of content** by a **broad** (compared to the number and nature of Internet users), non-IT-specialist set of users. As such the concept of Web 2.0 relies on the definition of Social Media which we will discuss below and which is (as the other elements of the definition) not fully precise. As mentioned above, basic Web 1.0 may be seen as already providing all the basic prerequisites and characteristics of collaboration, social interaction and distributed content generation and exchange (cp. [Berners-Lee and Laningham, 2006]). So Web 2.0 may just be used as synonym for the gradual paradigm change in Web usage towards a participatory web. On this non-technical level, systematic studies using a quantitative empirical or qualitative sociological or even historical criticism methodology would be necessary to render the definition more precise and investigate the implications of this paradigm change. One important implication is reflected by the ongoing debate on quality of user-generated content. While e.g. some studies suggest the quality of science related articles in Wikipedia to be of comparable quality to established encyclopedias [Giles, 2005], there is still much scepticism concerning the quality of user-generated content in Social Media and Web 2.0 (see e.g. [Flintoff, 2007]). As an explanatory theory, some studies suggest social influence as a factor working against 'wisdom of the crowds' effects [Lorenz et al., 2011]. Other studies propose algorithmic measures for the quality of user-generated content ([Hu et al., 2007], [Wöhner and Peters, 2009], or [Hasan Dalip et al., 2009]) in order to be able to separate the wheat from the chaff in Social Media content.

Taking a slightly **more technical perspective**, Web 2.0 has been defined by one of the initiators of the term in [O'Reilley, 2007] as a paradigm switch of replacing certain types of conventional monolithic software by a collection or network of web-based services that

- utilize and implement 'the Web as a platform',
- 'harnesses collective intelligence' of a broad user base (which points to Social Media),
- emphasize the importance of content / data (made accessible, relatable and extensible via web-based services),
- that are continuously updated (replacing the traditional software life cycle) and integrate users as co-developers,

- use lightweight programming models,
- collectively implement 'software above the level of a single device',
- and provide a 'rich user experience'.

The author explains each of these intuitive points in more depth using appropriate examples. Since these elements may not be synchronously imposed or implemented in a coordinated fashion, but will rather continuously be realized and adopted, Web 2.0 again should rather be perceived as a coarse paradigm involving elements of system architecture, software engineering and corresponding business models.

In each of the above characterizations of Web 2.0, **Social Media** and **Social Media services** implicitly or explicitly play an important role. The OASIS Reference model for service oriented architecture 1.0 [MacKenzie et al., 2006] defines **service** in the context of **Service-Oriented-Architectures**, which the second of the above views may be regarded to be implementing, as "a mechanism to enable access to one or more capabilities, where the access is provided using a prescribed interface and is exercised consistent with constraints and policies as specified by the service description". We may define **Social Media services** as web-based services (in this sense) targeted to and implementing direct support of a broad, non-IT-specialist user base for direct and indirect social interaction via creating and exchanging (communicating) content mentioned above (see also [Kaplan and Haenlein, 2010]). Examples of Social Media services are Wikipedia [wik, 2012d], Twitter [twi, 2012], or CiteULike [cit, 2012]. A functionally coherent bundle of Social Media services may be called a **Social Media platform**. An example for a Social Media platform is Facebook [fac, 2012b], which includes a number of services (for messaging, photo-sharing, social network management etc.). The distinction between a Social Media service and a Social Media platform is often not totally sharp: For example, Foursquare [fou, 2012] can be seen as a location-based awareness service but contains also service elements for related social network management and thus considering it as a Social Media platform can also be justified. Social Media services may be instances of one or more **Social Media service classes** such as Wiki, Blog, or discussion board. **Social Media** as an encompassing term then refers to the union of all such **Social Media service classes**. Social Media services can technically be implemented / be instances of **Social Media service software**. For example Wikipedia as well as Diplopedia [dip, 2012] are instances of / are technically implemented using the generic Social Media service software MediaWiki [med, 2012] for realizing Wikis. All such software will be collectively referred to as **Social Software**. Software that implements functionally coherent bundles of Social Media services (e.g. Elgg [elg, 2012] for Social Networking) may be denoted as **Social Media software platforms** or also shortly as **Social Media platforms**. In this and later chapters it will become clear from the context which of the two definitions of Social Media platform will be referred to.

Since **collaboration** may be considered a special form of social interaction involving user-generated content, all web-based or at least optionally web-based **CSCW** tools such as Revision Control Software (e.g. SVN [svn, 2012]), services such as Google Docs [goo, 2012a] or collaboration platforms (e.g. Creativity Support Systems or whole Open Innovation platforms see chapter 11) can also be regarded as

Social Media or Social Software, respectively. Although this is a consistent view, most listings of Social Media services or platforms (e.g. [wik, 2012a]) do not contain dedicated CSCW tools such as Revision Control Software. Social Media is seen by some authors as involving user-generated content that is “created outside of professional routines and practices” [OECD, 2009, p.18] [Kaplan and Haenlein, 2010]. The growing popularity of Social Software in enterprise contexts [Koch and Richter, 2009] and the use of Social Software in fields such as Open Innovation (see chapter 11) blurring the boundaries between ‘**professional**’ and ‘**non-professional**’ may justify to not conceptually exclude professional uses of Social Software. This yields services and platforms that may still be justifiably classified as Social Media, although non-professional use is still the most typical case for Social Media.

According to [OECD, 2009, p.18] and [Kaplan and Haenlein, 2010], user-generated content in the context of Social Media should “show a certain amount of **creative effort**” and should be **published to a larger audience** (cp. openness discussed below). This would effectively exclude Social Media-like services and platforms used by small closed circle communities (see subsection 1.1.6) and would also exclude direct communication support by classic e-mail or chats. Although 1:1 chats, e-mail and other messaging services are justifiably not perceived as typical Social Media, we will still not exclude them from the conceptual definition of Social Media, because the point of view taken in this thesis is predominantly an informatics and engineering perspective aiming at increasing utility for users and not so much a descriptive sociological perspective. Messaging is an important service in Social Networking that is strongly interwoven with other SN services and should thus not be excluded from the definition of Social Media either. Furthermore, 1:n messaging may e.g. be hard to conceptually distinguish from certain forms of microblogging.

Social Media possess some further **general properties**. Typically, Social Media are (at least in their basic versions) open to large non-IT-specialist audiences and do not charge money. This openness includes admissibility as well as sufficiently low barriers in terms of technological proficiency in order to participate. This does, however, not exclude e.g. limiting access via user accounts or privacy settings. Furthermore, compared to traditional media, Social Media content is subject to constant change, which is a natural consequence of the participatory nature of Social Media. Furthermore, Social Media is different in terms of dynamics. Not only may Social Media react faster to events, but they can also be more interactive, e.g. enabling backchanneling [Sutton et al., 2008] and may give rise to emergent social effects such as triggering initiatives in cases of disasters. This could be observed in the Southern California wildfire in 2007 [Sutton et al., 2008] or the 2011 Fukushima nuclear accident where several initiatives to collaboratively collect radiation measurements and make them available via Social Media were started (e.g. via the sensor aggregation site Parachube [par, 2012]). These emergent dynamics of Social Media may also have political consequences, which is reflected by the 2011 Arab Spring phenomenon [DeLong-Bas, 2012].

1.1.2 Technical Aspects

Basic **general enabler technologies for Social Media** are the set of technologies for building general Rich Internet Applications (RIAs) or Web-applications (see e.g. [Shklar and Rosen, 2009]):

- basic Web protocols and technologies such as HTTP [htt, 2012a] or HTTPS [htt, 2012b],
- declarative representation of structure, actual content, and format of content: HTML5 [htm, 2012], XML [xml, 2012a] (and its related languages such as XSLT [xsl, 2012], XML Schema [xml, 2012b], etc.) or elements of specific XML languages such as GML [OGC, 2011a]), CSS [css, 2012], DOM [dom, 2012], Unicode [uni, 2012],
- technologies supporting semantically rich meta-data for content (OWL [OWL, 2012], RDF [RDF, 2012], SPARQL [spa, 2012], etc.),
- client-side technologies such as Flash [fla, 2012], Java-Script [jav, 2012], JSON [jso, 2012], Silverlight [sil, 2012], or AJAX [aja, 2012] (together with their complementing server-side counterparts)
- general server-side technologies such as programming languages like PHP [php, 2012a], or open source database systems like MySQL [mys, 2012],
- occasionally, more specific server-side frameworks for RIAs or Web-applications that are mostly based on the MVC pattern (see [Gamma, 1995]) and that may partly supplement each other such as the Java-based Servlets [ser, 2012], JSP [jsp, 2012], or Spring [spr, 2012], .NET-based counterparts such as ASP [asp, 2012], or Rails together with Ruby (Ruby on Rails) [rub, 2012].

More heavyweight server-side Web-application frameworks such as full Java EE (Enterprise Edition) [jee, 2012] or formal Web-service protocols such as SOAP [soa, 2012] or UDDI [udd, 2012] are seldom used for Social Media.

Furthermore, **specialized enabler technologies** for Social Media include technologies supporting the fine granular syndication and mash-up of content from different providers / different Social Media services such as RSS [rss, 2012] or Atom [ato, 2012] or ontologies and frameworks from the field of Social Semantic Web such as SIOC or FOAF (see subsection 3.1.3). Social Software implementing Social Media service classes includes Elgg [elg, 2012] for Social Networking platforms and Community Support platforms (see subsection 1.1.4 and subsection 1.1.6), mediaWiki [med, 2012] for Wikis, PHPBB [php, 2012b] for discussion boards, and WordPress [wor, 2012] for Blogs. Additionally, certain Social Media services may function as 'meta' Social Media, hosting several distinct Social Media services of the same class such as Wikia [wik, 2012b], a Wiki-Farm hosting multiple Wikis. Many other Social Media services and platforms are based on proprietary implementations using the basic enabler technologies mentioned above (e.g. GoogleDocs, Google+ [goo, 2012b] or Facebook).

1.1.3 Social Media Classes

Various **Social Media service and platform classes** may be distinguished: [Kaplan and Haenlein, 2010] designate six classes of Social Media, corresponding to combinations of two axes (self-presentation / self-disclosure: {low, high}, and social presence / media richness: {low, medium, high}): Blogs (high, low), Social networking sites (e.g. Facebook) (high, medium), Virtual social worlds (e.g. Second Life) (high, high), Collaborative projects (e.g. Wikipedia) (low, low), Content communities (e.g. YouTube) (low, medium), and Virtual game worlds (e.g. World of Warcraft) (low, high). [Kietzmann et al., 2012] distinguish seven intuitive facets of Social Media depicted in Figure 1.1 that may be used to characterize individual services and platforms.

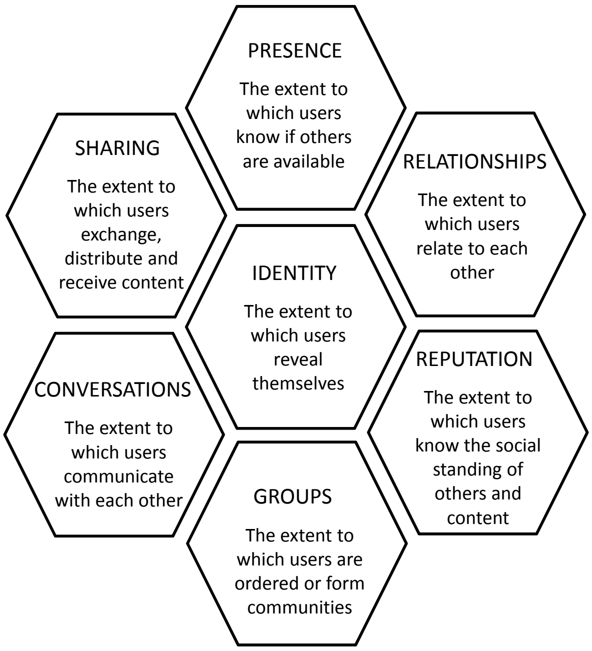


Figure 1.1: Facets of Social Media (source: [Kietzmann et al., 2012])

In order to coarsely distinguish the various forms of communication / social interaction supported by Social Media, some non-technical, nominal classification axes can be introduced (see also ∗[Groh and Schlichter, 2005]):

- **Cardinality** of persons involved in a typical communication act (sender : receiver): {1:1, 1:n, m:n}; (n:1 is typically not realized in Social Media).
- **Directedness** of the communication act: {direct, indirect}: is the communication act directed to a specific dedicated receiver or list of receivers or to an open set of receivers, possibly formally or informally constrained e.g. via certain properties.
- **Anonymity**: {non-anonymous, anonymous}: the identity of the sender(s) is or is not known to the receiver(s).

- **Threadedness**: {threaded, non-threaded}: do 'reply-type' relations exist between communication acts?
- **Content**: {textual (natural language, code, etc.), graphical (photos, drawings, charts etc.), video (movies, audio+video of a human speaker, game elements etc.), audio (music, spoken language, etc.), contextual (locations, social relations, user-item-relations etc.), and others}; this simple two-layer taxonomy ignores theoretical aspects (exclusiveness of the concepts, multiple super-classes etc.) and technical aspects (such as variable forms of encoding (e.g. for text), or MIME-types) and focuses on the user perception of typical forms of content.
- **Transmission**: {stream, discrete transfer}; again, this distinction focuses on user perception. On a lower technical level, more fine grained or more accurate distinctions may be made.
- **User Interface / Device / Usage Pattern**: {mobile, laptop, desktop}; Mobile refers to smart-phones and comparable devices used in a truly mobile way (e.g. while walking), laptop refers to laptops, netbooks, tablets, etc., used in a stationary way with changing usage environments, desktop refers to computers that are used in a stationary way with fixed usage environments.
- **Goals** of the communication / social interaction: higher level of abstraction: informing or being informed, create or gain awareness, collaborate, chat, etc.; lower level of abstraction: find a partner, maintain + expand social network, generate + manage ideas, exchange movies or music, entertain or be entertained, explicate and organize knowledge, etc. This set of coarse goals may overlap in various ways (e.g. gaining awareness may be perceived as a form of being informed and may occur in partner finding as well as in collaboration, collaboration may involve maintaining a social network (e.g. in case of Open Innovation)), and goals may occur together.
- **Commercialization**: {commercial, non-commercial}: refers to whether the communication acts pursue a commercial goal. While the individual communication act may be non-commercial, the service as such may be commercial (e.g. charge money for its use).

Social Media services and platforms will **typically** support communication that is 1:n, undirected and non-commercial.

Using these classification axes, possible **Social Media classes** of different levels of abstraction can be distinguished, matching our definition of Social Media discussed above. Other lists of Social Media classes which may exhibit substantial overlap include e.g. [wik, 2012a]. For every class, one or more example Social Media service or platform instances are mentioned (many taken from the examples listed in [wik, 2012a]. In general, many important and interesting such Social Media classes may be formed that overlap in such a way that the resulting system of classes will not necessarily form a taxonomy. This is also not the case for the classes mentioned below.

Classes with an emphasis on communication types

- **Blogs** (services). Examples: Blogspot [blo, 2012] (Blog hosting platform); the official Google blog (an instance) [goo, 2012c]. Social Software example: WordPress [wor, 2012]. Overlaps with: Microblogs. Superclass: information services. Supported typical communication form: 1:n; indirect; non-anonymous; non-threaded; textual (+ photos); desktop or laptop; discrete transfer; non-commercial; typical goals: self-presentation, informing, awareness.

- **Microblogs** (services). Examples: Twitter [twi, 2012]. Overlaps with: direct communication services. Superclass: information services. Emphasis on short blog items and mobile use. Supported typical communication form: 1:n; indirect (and also direct); non-anonymous; non-threaded; short textual; mobile; discrete transfer; non-commercial; typical goals: self-presentation, informing, awareness.

- **Wikis** (service). Example: Wikipedia [wik, 2012d]. Social Software example: Wikia [wik, 2012b]. Supported typical communication form: m:n; indirect; anonymous; non-threaded; textual; desktop; discrete transfer; non-commercial; typical goals: Knowledge management (codification, structuring, etc.).

- **Discussion Boards / Forums** (services). Example: Sherdog [she, 2012]. Superclass: information services. Social Software example: PHPBB [php, 2012b]. Supported typical communication form: 1:n; indirect; non-anonymous; threaded; textual; desktop + laptop; discrete transfer; non-commercial; typical goals: Exchange opinions and facts, give advice.

- **Messaging** services. Examples: Skype [sky, 2012], e-mail, SMS. Superclass: direct communication services. Overlaps with: Microblogging. Supported typical communication form: 1:n and 1:1; directed; non-anonymous; threaded; textual (+ attachments); mobile; desktop, or laptop; discrete transfer; non-commercial; typical goals: informing, chatting, etc. Usually not considered to be social media but matching our definition of Social Media (see discussion above).

- **IP-telephony** services: Examples: Skype [sky, 2012]. Superclass: direct communication services. Supported typical communication form: 1:n, m:n, and 1:1; directed; non-anonymous; non-threaded; audio + video; desktop or laptop; streaming; non-commercial; typical goals: informing, chatting, etc. Usually not considered to be social media but matching our definition of Social Media (see discussion above).

- **Chat** service. Superclass: direct communication services. Supported typical communication form: m:n and 1:1; mostly directed; non-anonymous; non-threaded; textual; desktop or laptop; ≈ streaming; non-commercial; typical goals: informing, chatting, etc. Usually not considered to be social media but matching our definition of Social Media (see discussion above).

- **Social Games** platforms. Examples: Farmville [far, 2012], World of Warcraft [wow, 2012]. Superclass or heavily overlapping class: Virtual Worlds.

Supported typical communication form: 1:1, m:n; directed; non-anonymous; non-threaded; via game elements emulating human social interaction; desktop or laptop; ≈ streaming, non-commercial (apart from Goldfarmers [Ahmad et al., 2009]); typical goals: entertainment

- **Virtual Worlds** (platforms) Examples: Second Life [far, 2012]. Supported typical communication form: as in Social Games.

Collaboration oriented classes

- **Revision Control** services. Example social software: SVN [svn, 2012]. Superclass: Information service. Overlaps with: content oriented classes, especially document management. Play an important role in collaborative software development (e.g. Open-Source). Supported typical communication form: 1:n; un-directed; non-anonymous; threaded; code; desktop or laptop; discrete transfer; non-commercial; typical goals: collaborative document management (mostly concurrent editing and versioning).
- **Content Management** platforms. Examples for social software: WordPress [wor, 2012], Joomla [joo, 2012]. Superclass: Information service. Overlaps with: Blogs, Wikis, content oriented classes. Supported typical communication form: 1:n; un-directed; non-anonymous; non-threaded; textual + graphical; desktop or laptop; discrete transfer; non-commercial; typical goals: collaborative content management
- **Open Innovation** platforms (see also chapter 11). Example: Open-I platform (see [ope, 2011]. Overlaps with: Social Networking platforms. Supported typical communication forms: 1:n, 1:1 and m:n; directed and un-directed; non-anonymous; threaded; textual + graphical; desktop or laptop; discrete transfer; commercial and non-commercial; typical goals: develop and incubate ideas and project proposals.
- **Collaborative Creativity** services and platforms. Example: IdeaStream [Forster, 2010]. Supported typical communication form: m:n; un-directed; anonymous and non-anonymous; ≈threaded and non-threaded; textual + graphical; desktop or laptop; discrete transfer; commercial and non-commercial; typical goals: develop and rate ideas.
- **Knowledge Codification** services such as Wikipedia (see below) may be listed here as well, because users interact and collaborate towards establishing a useful knowledge base.

Social Networking and related classes

(see subsection 1.1.4, chapter 2 and later chapters)

- **Social Networking** platforms (see subsection 1.1.4). Example: Facebook [fac, 2012b]. Example social software: Elgg [elg, 2012]. Supported typical communication forms: 1:n, 1:1, and m:n; directed and un-directed; non-anonymous;

threaded and non-threaded; textual, contextual, and photos; desktop or laptop; discrete transfer; non-commercial; goals: maintain and expand social network (including self-presentation).

- **Mobile Social Networking** platforms (see chapter 2). Comparable to Social Networking platforms with an emphasis on mobile usage, contextual content elements and context awareness of services (see section 1.2 and Part III). Super-class: Social Networking platforms.

- **Location-Based Social Networking** platforms / services. Example: Foursquare [fou, 2012]. Emphasis on location as contextual content element. Overlaps strongly with / is subclass of: Mobile Social Networking platforms.

- **Professional Social Networking** platforms. Examples: Xing [xin, 2012], LinkedIn [lin, 2012]. Offers a comparable spectrum of services to other general SN platforms (messaging, profile management, social network management, awareness etc.). Super-class: Social Networking platforms. Most of the content is textual. Goals: Establish or maintain professional contacts, self-presentation of professional identity, skills, etc.

- **Company Community / Social Networking** platforms. Examples: IBM's SocialBlue [soc, 2012] (formerly called Beehive). Similar to Social Networking and Community platforms, targeted to members of large companies. Goals of communication: maintain and expand social network within the company (including self-presentation), expert-finding (see e.g. ∗[Nauerz and Groh, 2008]), yellow pages function. Companies may also use Blogs and Wikis as instruments of knowledge management or project management [Koch and Richter, 2009]. Overlaps with: Social Networking and Community platforms. Slightly overlaps with: Open Innovation platforms.

- **Partner Finding** platforms. Example: Friendscout24 [fri, 2012]. Comparable spectrum of services to SN platforms, with less focus on social network management. Overlaps with: Social Networking platforms. Most important communication form: 1:1; directed; non-anonymous; non-threaded; textual + photo; discrete transfer; non-commercial; goal: finding a partner (e.g. messaging, chat); also 1:n; indirect (profile related services and service elements).

- **Community** platforms (see subsection 1.1.6). Comparable to Social Networking platforms, supporting smaller and more specialized groups of users (in terms of interests or location). Examples: Gothic.net [got, 2012], Yelp [yel, 2012] meta-community platform. Overlaps with: Social Networking platforms, Open Innovation platforms

Goal oriented classes

Besides collaboration, Social Media may support other more or less specific goals as well. Goals and content are naturally closely connected, so each of the classes listed here might, in principle, as well be listed under 'classes with an emphasis on content'. Both meta-classes thus heavily overlap. However, the classes listed here may be viewed as being specifically geared towards supporting distinct goals of users or user groups or specific more abstract goals, whereas 'classes with an emphasis on content' are geared towards handling specific types of content (e.g. photos, slides etc.) or specific types of handling of content (e.g. searching, aggregating).

- **Altruistic** community platforms. Examples: Utopia [uto, 2012]: a community platform to support sustainable consumption, Causes [cau, 2012]: a meta-community platform for communities focusing on social issues, IndieGoGo [ind, 2012]: a crowd funding platform. The spectrum of services and the communication forms are comparable to other community platforms. Superclass: Community platforms. Overlaps with: Social Networking platforms, Political community platforms.

- **Political** community platforms. Example: Occupy movement platforms, e.g. Occupy Wallstreet [occ, 2012], Wikileaks [wik, 2012c]. Overlaps with: Altruistic community platforms. Wikileaks may not be a typical Social Media service since it is not as open for uncontrolled user-generated content. It relies on a broad spectrum of whistleblowers and implements a special form of 1:n, anonymous, indirect, textual form of communication with the goal to function as a control instance for organizations, governments and companies via leaking classified information documenting unethical behavior.

- **Knowledge Codification** services such as Wikipedia (see below) may be listed here as well, because the collaborative establishment of a broad knowledge base may be viewed as a distinct abstract goal.

Classes with an emphasis on content

- **Events** services / platforms (see also subsection 9.1.1). Example: Eventful [eve, 2012] (users can upload, comment, demand, state planned attendance for events). Most important communication forms: 1:n, n:m; indirect; anonymous and non-anonymous; non-threaded; contextual (spatiotemporal), textual + photo; mobile, desktop, or laptop; discrete transfer; non-commercial; goals: awareness, information in view of events. Superclass: Awareness services. Slightly overlaps with: Microblogging. Overlaps with: News services.

- **News** (services) (see also subsection 9.1.1). Example: Digg [dig, 2012] (users can submit and rate news articles). Overlaps with: Events services. Superclass: Information services. Most important communication forms: 1:n, n:m; indirect; anonymous and non-anonymous; non-threaded; textual, contextual (user-item-relations); desktop or laptop; discrete transfer; non-commercial; goals: awareness, information.

- **Social Search** services (see also chapter 9). Examples: 'Google Search, plus Your World' [plu, 2012]. Incorporate social context into search. Most important communication form: n:m; indirect; anonymous; non-threaded; contextual (social context (social relations), ratings); desktop or laptop; discrete transfer; non-commercial; goals: provide new useful modes for web search. Overlaps with: News services (via including collaborative ratings into search results), Information services, Recommender services.

- **Question Answering** services. Examples: Ask [ask, 2012]. Overlaps with: community platforms such as health advisory platforms (example: Net Doctor UK [net, 2012a]). Superclass: Information services. Overlaps heavily with: Discussion Board services. Typical communication forms: 1:n; indirect; non-anonymous; threaded; textual; desktop or laptop; discrete transfer; non-commercial; goals: altruistic motives (answerers and contributors).

- **Information Aggregation** platforms. Example: Netvibes [net, 2012b]. Use content syndication protocols to aggregate content and services into a personalizable dashboard portal. Typical communication form of the aggregation service as such: m:n; indirect; anonymous; non-threaded; many forms of content; discrete transfer + streaming; goals: organize, personalize, filter information and services, provide single point of access. Other large portals such as Yahoo [yah, 2012] offering a multitude of Social Media services, services proving editorial content, web search etc., may also be perceived as Information Aggregation platforms.

- **Knowledge Codification** services. Example: Wikipedia [wik, 2012d], Example social software: Web-Protege [Tudorache et al., 2008] for collaborative ontology development. Heavily overlaps with: Wikis. Overlaps slightly with: Document Management. Most important communication form: n:m; indirect; anonymous; non-threaded; textual and formal formats for knowledge representation (e.g. Semantic Web [Antoniou and Van Harmelen, 2004]); desktop or laptop; discrete transfer; non-commercial; goals: codify knowledge (e.g. in the form of encyclopedias or ontologies). May also be listed under ‘Goal oriented classes’ and ‘Collaboration oriented classes’.

- **Document Management** services. Example: Google Docs [goo, 2012a]. Sharing and editing documents. Overlaps with: Information services, Content Sharing. May also be listed under ‘Collaboration oriented classes’. Most important communication forms: 1:n, n:m; indirect; non-anonymous; non-threaded; textual; desktop or laptop; discrete transfer; non-commercial; goals: distributed document management.

- **Content Sharing** services. Content (own or other) is shared ‘as is’ (no editing as in Wikis). Subclasses: File, Video, Photo, Presentation Sharing, Social Bookmarking, Blogs. Superclass: Information services. Typical form of communication: 1:n; indirect; anonymous and non-anonymous; non-threaded; diverse range of content types; desktop or laptop; discrete transfer and streaming; non-commercial; goals: diverse.

- **File Sharing** services. Examples / Example social software: BitTorrent [bit, 2012] Peer-to-Peer file sharing protocol and abstract distributed service.
- **Video Sharing** services. Example: Youtube [you, 2012]. Superclass: Content sharing.
- **Photo Sharing** services. Example: Flickr [fli, 2012]. Superclass: Content sharing.
- **Presentation Sharing** services: Slideshare [sli, 2012]. Superclass: Content sharing.
- **Social Bookmarking** services: CiteULike [cit, 2012]. Superclass: Content sharing. Overlaps with: Rating services.

- **Rating** services. Subclass: Product reviews services. Heavily overlaps with: Recommender services. Overlaps with: Events and News services. Typical form of communication: 1:n; indirect; anonymous and non-anonymous; non-threaded; textual, contextual (user-item-relations); mobile, desktop, or laptop; discrete transfer; non-commercial; goals: inform others about the quality of products or services.
- **Recommender** services (see chapter 10). Example: Amazon product recommendations [ama, 2012], Recommender service on Last.fm internet radio [las, 2012] (see also •[Thar, 2008]). Large class of Social Media services with many subclasses (see ∗[Groh et al., 2011a]▶). Heavily overlaps with: Rating services. Typical form of communication: m:n; indirect; anonymous; non-threaded; contextual (user-item-ratings + recommendations); mobile, desktop, or laptop; discrete transfer; non-commercial; goals: get recommendations for entities on the basis of content, ratings etc.
- **Product Reviews** services. Example: Epinions [epi, 2012]. Superclass: Rating services.

Coarser functional classes of services and service elements

The three classes that will be introduced now (see also ∗[Groh and Schlichter, 2005]) will be used in Part III and subsection 1.1.4. They represent a coarse partitioning of Social Media services with respect to function, especially concerning Community Support Systems and Social Networking. Social Media support social interaction via content generation and exchange. In the discussion above we thus implicitly identified all such social interaction with communication in the most general sense (cp. the Speech Act view taken in ∗[Groh and Birnkammerer, 2011]▶). Two of the classes below mainly differentiate between direct communication and indirect communication. The services predominantly involving indirect communication will be denoted as ‘Information services’, which is the typical form of general Social Media as discussed above. The three classes may not be fully disjoint, although we may classify each service or service element into its predominant class.

- Awareness services (see section 7.2 and subsection 9.1.1) inform users about events or states which are directly linked with other users that fulfill certain criteria (e.g. participate in the same Social Networking platform or fulfill certain social or other contexts), both proactively and on request. Thus their primary form of content is contextual information. Typical form of communication: 1:n and m:n; indirect; non-anonymous; non-threaded; contextual (e.g. locations, social relations, online-status etc.); mobile, desktop, or laptop; discrete transfer; non-commercial; goals: awareness. Example subclass: Location-Based Awareness services (see also chapter 2).

- Direct Communication services (see also subsection 9.1.1) support direct communication of all forms. Examples: Messaging, certain forms of Microblogging, chat, IP-telephony, certain interaction forms in social games.

- Information services (see also subsection 9.1.1). Information services support indirect communication (if not already classified as Awareness service) and comprise the majority of the finer grained Social Media classes discussed above.

1.1.4 Social Networking

As indicated above, **Social Networking** (SN) is a Web 2.0 **paradigm** associated with and supported by special Social Media platforms that we will denote as **Social Networking platforms**. The paradigm is characterized by users socially interacting with the **main goal of maintaining and expanding their social network** via an instance of a Social Networking platform that provides a coherent bundle of Social Media services (denoted as **Social Networking services**). SN services may be partitioned into indirect communication / information services including Blog-like services, personal news, photo-sharing, recommender systems, etc. (compare subsection 9.1.1), direct communication services (messaging, chatting, etc.), and awareness services (compare section 7.2 and subsection 9.1.1). A key characteristic of Social Networking is the **explication of social relations** (such as friendship, or group relations) resulting in a possibly multi-modal social network. Services involving the management and visualization of this network may conceptually be subsumed under the class of awareness services in SN. In most cases, SN also incorporates the explication of person-item-relations such as ratings (e.g. the Facebook ‘like’), or authorship relations. Each user may be associated with his personal information space (e.g. via the authorship relation to his items). A central element of this space is the **personal profile**, a publicly accessible sub-space that is used as a personal reference, e.g. introducing a person, or used as a reference point for SN services (e.g. for awareness services providing personal news such as the Facebook ‘Wall’). Thus the main forms of communication in SN will typically be geared towards 1:n and 1:1 communication cardinality (m:n can also be the case), and will include directed and un-directed forms, and will be predominantly non-anonymous. Communication can be threaded and non-threaded and its content will predominantly be textual, but also contextual (for the awareness services), and will also include complementing forms of content such as photos. All forms of UI / usage scenarios will typically be used and most communication will be discrete transfer and non-commercial.

While the main focus of the paradigm is on the general management, maintenance and expansion of personal relations and the related communication and awareness it may also **involve collaborative elements**. The explication and publishing of social relations, generating a commonly usable social network beyond the star-shaped personal network of 'friends', may already be perceived as a collaborative element. On the other hand other e.g. playful collaboration elements may also be perceived as indirectly contributing to the main goals of SN (e.g. collecting and publishing events interesting for certain groups). Vice versa, Social Media instances (such as Wikipedia) and Social Media platforms (general Wiki platforms, Open Innovation platforms or creativity support systems (cp. section 11.1)) that are more focused on explicit collaboration towards a common, more serious goal, may also be associated with Social Networking elements (e.g. a social network of contributors).

The **distinction** between general Social Media and Social Networking services is **not very sharp**, since a large share of the Social Media services and platforms discussed above may, in principle, also be used in SN platforms, as long as they directly or indirectly support the main goals of maintenance and expansion of the personal social network or simply provide added value to a SN platform. It may also be the case, as indicated above, that SN elements such as the explication of the user's social network may be used in other Social Media platforms (e.g. geared towards exchanging certain forms of content).

In essence, as will be discussed below and throughout this thesis, the explication of social structures as a key element of SN can be seen as a form of social context that many Social Media services could profit from.

1.1.5 Social Networking Services

Typical SN services and service elements which will be discussed in more detail in Part III encompass the following classes:

- Services for managing the social network such as services for managing the personal (first-order) contacts (edges) (e.g. adding friends via request + confirmation handshakes, removing friends etc.) or awareness services operating on the resulting network: browsing, visualizing the network, be alerted of changes, searching etc. (class: awareness).
- Services for privacy management: managing privacy settings etc. (class: awareness).
- Direct communication: messaging, chat.
- Group management: create and manage group membership, manage group information space (publish events or other content). (classes: awareness, information services).

- Profile management: add, edit or delete text, photos etc. (classes: awareness, information services).
- Information services: personal microblogs or bulletin boards (e.g. the Facebook Wall), adding comments on all kinds of content, searching for content.
- Content related awareness services: standardized comments (e.g. Facebook 'like').
- Awareness services with respect to other contexts such as location (as in Foursquare [fou, 2012]), online-status, etc.
- Further services that complement the service spectrum such as games (e.g. Farmville [far, 2012]) or collaboration services (such as creativity support services (see chapter 11)) that are often neither classified as awareness, direct communication, or information services.

These services may technically be implemented as part of the platform or (via APIs) be provided by third party service providers.

1.1.6 SN vs. Community Computing

Comparing the paradigm **Social Networking** (and the technical and algorithmic approaches from SN services, platforms and general SN support systems) to the earlier paradigm of **Community Computing** (and the technical and algorithmic approaches involved in **community support services and platforms**) (see ∗[Groh and Schlichter, 2005], [Koch, 2003b], [Koch, 2003a]), certain distinctions and commonalities may be stated. Community support systems (CSS) may be perceived as precursors of SN platforms. The emphasis on explication of social relations and their importance and central role is less distinct in concepts for IT-based Community support than in SN, although Buddylists and other forms of social relation explications were also present in CSS. Furthermore, communities targeted by CSS are in most cases substantially smaller, may be more specialized, and thus may be more easily classified into certain classes than the set of users of SN platforms such as Facebook (cp. Communities of Interest [Koch, 2003a], [Carotenuto et al., 1999], Communities of Practice [Lesser and Storck, 2001] / professional communities [Koch and Richter, 2009] or Open Innovation communities (see chapter 11)). In addition, the presence of a distinct common pursuit and the aspect of collaboration are often more emphasized in communities than in SN (cp. ∗[Groh and Schlichter, 2005]). Thus, community support platforms may be equipped with respective specialized services (e.g. compare services for creativity support in OI platforms (see chapter 11)). However, many services for community support are very similar to respective services in SN platforms. We may thus regard Community Computing as a variant of Social Networking.

1.1.7 Related Scientific Disciplines

There are manifold **scientific disciplines** related to and contributing to general Social Networking (SN) and to Contextual, Mobile, and Decentralized Social Networking (jointly abbreviated as *SN). Besides the various disciplines of computer science and informatics contributing to providing the technical basis for (*)SN platforms, such as Network, Service-Oriented, or Web Architectures, Peer-to-Peer Computing (see chapter 3) or Mobile Computing (see chapter 2), many other fields contribute to algorithms, techniques and concepts of SN on higher levels of abstraction. These include Context-Aware Computing (see section 1.2) and Social Signal Processing, as well as its large number of related or encompassing disciplines such as Machine Learning or the many fields related to sensors, sensor-data preprocessing etc. (see Part II). Since most of the content in SN is encoded as natural language text, Natural Language Processing also plays an important role (see chapter 4). Furthermore, fields like Social Semantic Web (see chapter 3) show the relation of Social Networking to symbolic AI and Knowledge Management. Decentralized SN implements a link to Multi-Agent systems and general Distributed Systems (see chapter 3). Privacy and Security (see chapter 8) as cross-sectional disciplines are also of great importance in relation to Social Networking which lives by a carefully chosen balance of selectively opening certain parts of personal information spaces and protecting others (to and from certain audiences). Principles of SN may also be applied to professional social interaction, thus a connection to CSCW and information systems also exists (see e.g. [Koch and Richter, 2009] and chapter 11). Since a characteristic element of SN is the explication of social relations, the resulting large social networks relate SN to the dynamic field of Network Analysis (see [Newman, 2010], [Brandes and Erlebach, 2005]. Furthermore, Social Networking becomes increasingly linked to the emerging scientific field of Computer Games, not only documented by the fact that social network games become an increasingly important business model in the spectrum of business models associated with SN, but also because the spectrum of social interaction in games substantially grows in terms of complexity and number of facets. On the other hand, non-professionally oriented computer supported social interaction as in SN and general social media may also be perceived as bearing game-like characteristics (see •[Pötzl, 2012]). Clearly, Social Networking can be considered as a sub-field of the emerging discipline Social Computing, which encompasses all research related to computer analysis and support of human social interaction.

Apart from computer science and informatics, many other disciplines are closely related to Social Networking. This encompasses many aspects and sub-disciplines of sociology, social psychology, psychology or cultural anthropology. The advent of Social Networking has in fact opened up new opportunities for quantitative research in these disciplines [Lazer et al., 2009], and many existing qualitative theories from these disciplines may influence algorithmic approaches in SN (e.g. see section 5.2) while SN may be used as a ground for quantitatively checking these theories.

1.2 Context-Aware Computing and Contextual Social Networking

In the discussion above the concept of '**context**' already played a role in certain places. One category of content of Social Media services was designated as 'contextual', and explicated social relations as occurring in Social Networking were designated as a form of social context. In this section, we will first briefly recapitulate the existing notion of context and context awareness in Informatics and Computer Science. We will then discuss forms of context that play a role in relation to Social Media services and Social Networking services in particular and will discuss forms of context awareness for these services which will lead to the term Contextual Social Networking.

1.2.1 Context-Aware Computing

The term context and the concept of context-aware applications came into focus in Informatics and Computer Science in the early 1990s and was first used in [Schilit and Theimer, 1994] (see [Dey, 2001] [Baldauf et al., 2007]). Context then referred to "[...] where you are, who you are with, and what resources are nearby. Context encompasses more than just the user's location [...]" [Schilit et al., 1994]. Ben Schilit, Roy Want, Gregory Abowd, Thad Starner and others at MIT Media Lab, Georgia Tech and other institutions were key contributors in this new field, which emerged from the fields of Mobile, Wearable, and Ubiquitous Computing. A whole range of new context-aware applications ranging from tourist guides to more exotic applications such as the Forget-Me-Not social awareness service [Lamming and W., 1992] running on the then innovative ParcTab mobile device [Want et al., 1995] (see e.g. [Groh, 1999] for an overview) explicitly or implicitly attempted to include context information such as location or co-presence information.

Since the mid 1990s more research on context and context awareness has been conducted (see e.g. [Abowd et al., 1999], [Chen and Kotz, 2000], [Dey, 2001], [Groh, 2005, p.18ff.], [Baldauf et al., 2007], [Dey, 2009], [Eigner, 2010, p.33ff.]). However, as Dey pointed out in 2001 [Dey, 2001], these increased research efforts did not lead to a fully clear understanding and definition of context and context awareness, a situation which has not changed substantially since then (see [Baldauf et al., 2007] [Eigner, 2010, p.33ff.]). A **definition of context** subsuming the many definitions given until then was given by Dey in 2001 which, according to its numerous and recent citations, may still be considered as a working consensus:

> Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.

Here, situation may be defined as a collection of states of all entities that are relevance-related to the entity in question. In the same short survey he **defines context awareness** in the following way:

> A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task

As Dey points out, this is a consciously general definition, because he considered definitions existing to that date as too specific and not fully fitting established context-aware application concepts.

While several suggestions were made in view of enumerating and classifying candidate elements of context, [Winograd, 2001] points to the **operational relativity of context**: "Context is an operational term: Something is context because of the way it is used in interpretation, not due to its inherent properties." (see also [Eigner, 2010, p.33ff.]). This analysis also points to the important question which of the data that a particular service may use is considered an integral subject of the service and which of the data is considered context. We will discuss these issues in more depth below.

As [Chen and Kotz, 2000] point out, [Schilit et al., 1994] define **three basic classes of candidate context elements** in view of mobile, ubiquitous, and wearable computing:

- "**Computing context**, such as network connectivity, communication costs, and communication bandwidth, and nearby resources such as printers, displays, and workstations.
- **User context**, such as the user's profile, location, people nearby, even the current social situation.
- **Physical context**, such as lighting, noise levels, traffic conditions, and temperature." [Chen and Kotz, 2000]

[Chen and Kotz, 2000] suggest to complement these classes with an additional class "Time context, such as time of a day, week, month, and season of the year". These classes may still be considered valid as a rough classification scheme for possible context elements. Other classification systems differentiate between information about entities (persons, places, or objects (things)) that at a certain point in **time** either refer to its **identity**, its **location**, or its **status** [Dey et al., 2001].

[Chen and Kotz, 2000] also introduce the notions of **active context awareness**, where an application automatically **adapts** to a measured context, and of **passive context awareness** which points to applications that **present** context information to the user. We will discuss the implications of this distinction in more depth below.

Clearly, context to be used in a context-aware application must be **measurable** (directly or indirectly) and the results (context data) must be **representable** in a way that an application can make use of. Thus it is natural to consider **low level context data**, as directly measured by some **sensor**, and **higher level context data** which is the result of e.g. a combination of different sensor measurements and / or of performing various steps of analysis of the raw data, e.g. using machine learning models. The problem of how to derive higher order contexts from lower level context data will be discussed in more depth in Part II and especially in section 6.4 (compare ∗[Groh et al., 2011d]▶, [Hong et al., 2009], [Welbourne et al., 2005], or [Groh, 2005, p.18ff., 55ff.]). Since the derivation of higher level context from lower level context is a complicated process which involves elements of sensor fusion, or even agent communication or algorithms for reaching agreements among agents ∗[Groh et al., 2011d]▶, it is always possible that a derived higher level context (e.g. a social situation (cp. chapter 5)) does not match the 'actual' context as e.g. perceived by human users.

As discussed above, for the **separation between active and passive context awareness** in light of the citation by [Winograd, 2001], the question arises as to which elements of the data that a service has 'at hand' at a given point in time are considered contextual at all and which data elements are considered the actual objects of the service. E.g. an awareness service informing users about the locations of other users may be actively context-aware as well as passively context aware: Passively, because the location-'context' of users is the actual object of the service and actively because the service will use a user's own location and long-term or short-term social context to adapt its output in various ways e.g. with respect to the set of users shown or the center and zoom level of a possible map showing these locations (cp. chapter 7). A possible line of distinction would classify data as contextual if its processing by the service provides added value to its users (in terms of fine-tuning the 'relevance' that Dey speaks of), but if it is not necessary for providing the actual service. However, this distinction just shifts the definition problem towards deciding between what is added value and what is the core service which is often not possible. For example, in the above mentioned application, if the awareness service correctly displays the locations, but does not properly adapt to social context by showing 'irrelevant' users, the service might face low acceptance and might even become unusable.

Another possible criterion for distinguishing context data is **dynamics**. A coarse grained differentiation between context awareness and personalization may be made by defining that context awareness refers to applications that mostly automatically adapt to (or deal with) *highly dynamic* information (which is then defined as context) and that personalization refers to applications that adapt to information that is *less dynamic* (has a significantly lower rate of change) [Groh, 2005, p.55]. The adaptation in case of personalization is often done or triggered by hand by the user but automatic forms are equally prominent (see e.g. [Eirinaki and Vazirgiannis, 2003]).

In view of context-aware SN, we will not emphasize this stance because the distinction between highly dynamic and less dynamic may, just as the distinction between what is 'added value' and what is 'the actual service', be highly dependent on the actual service in question.

1.2.2 Contextual Social Networking

We will now briefly introduce what context and context awareness may mean in relation to Social Networking. Related problems, applications, techniques and algorithms will be discussed in more depth in Part II and Part III. After a short look on examples of related work, we will discuss general classes of context elements for Social Media and especially for Social Networking.

Related work in terms of detecting and using context for Social Media and related services is manifold (see also •[Boening, 2010]): [Kern et al., 2007] attempt to derive several forms of higher level context (activities derived from accelerometer measurements, social settings derived from audio, and the user's interruptability from a combination of sensors) to act as additional retrieval keys for life-logging applications (see also section 7.3). [Adams et al., 2008] aim at deriving higher level social contexts from lower level location and medium level co-location data, measured via GPS and Bluetooth. They propose approaches for the extraction of socially relevant user locations (called Social Spheres) (compare section 7.4), analyze social rhythms as statistical models of behavior induced from temporal sequences of location changes and propose methods for predicting social relations on the basis of all these contexts. They use an 8 person, ≈5 months dataset of GPS locations and Bluetooth encounter data to derive the contexts and use two example applications to show the added value of including the derived contextual information: a personal photo browser (called SocioGraph) and a Blog browsing application (Jive), which both use the social contexts for filtering purposes. Pentland's Eigenbehaviors [Eagle and Pentland, 2009] are another way to extract social behavior and social rhythms from location data and Bluetooth encounters (see subsection 5.1.1). [Raento and Oulasvirta, 2008] derive general design guidelines for context-aware awareness services which they implement in an application called ContextContacts, providing hints in the current activities and states of other users in a user's address book. These contextual data of others encompass their location but also self entered emotional states in textual form. The authors evaluate their approach and thus implicitly their guidelines using a medium sized user-study. A special focus is attributed to the privacy aspects of such awareness services (see also chapter 8). The CenceMe framework proposed in [Miluzzo et al., 2008] also aims at deriving higher level contexts, especially the presence and current activity of users from lower level context (audio data, accelerometer data and GPS data). The framework is especially remarkable because it distributes the sensing and analysis (e.g. via classification) of contexts between mobile device and back end servers and also makes the the derived higher level contexts available to arbitrary SN platforms such as Facebook via a suitable server interface. It thus contributes to the concept of Distributed Social Networking (see chapter 3).

Candidate context elements useful for Social Media and especially Social Networking services may be partitioned into the following **classes** which may slightly overlap. For each element we may coarsely distinguish short-term, medium-term, and long-term variants. The introduction of long-term contexts corresponds to not emphasizing a strong distinction between personalization and context-awareness. All the classes are formulated with a view centered around a particular user. Context elements may range in abstraction level from low level elementary sensor measurements (an acceleration measurement) to high level derived model instances (e.g. emotional states). Furthermore, elements may conceptually be discrete (a temperature measurement at a given time) or continuous (audio data), or may correspond to whole time series of elements (context histories).

Physical Context

This class involves context elements at a user's current location such as lighting conditions, temperature, barometric pressure, or relative humidity and may also involve elements of computing context not dependent on the user herself such as availability of certain types of networks, available bandwidth etc. Low level context elements may be either measured directly by specialized sensors (e.g. a pressure sensor) or low level context data may be delivered by 'general purpose' sensors such as microphones. Contexts of higher levels of abstraction then will have to be derived from the low level context elements or low level context data, e.g. an assessment of the weather situation may be accomplished using temperature and barometric pressure and a suitably trained classifier.

The short-term versions are evaluated with a comparably short time-interval in the order of seconds to minutes (depending on the user's speed), whereas medium-term and long-term variants may be evaluated as average values involving longer time-intervals (and implicitly also larger spatial areas) from hours to even weeks. Many of these context elements may predominantly be available in a mobile usage scenario, which is true for many of the context elements discussed in this section. The reasons for this are twofold: the respective sensors are usually integrated only into mobile devices and in most cases only make sense there, because the situations that a user is in only substantially change in a mobile case. The embedding into the all day life of the user with its interesting situational changes is much deeper in the mobile case, where context-awareness thus is able to unfold its potential (see also chapter 2 subsection 5.1.1). Usage scenarios for the context elements in this class may e.g. encompass social recommender systems that may adapt recommendations according to the weather situation inferred from the low level context elements. This may e.g. be done in case of Collaborative Filtering by damping the ratings that were given in a context that does not match the current context.

Individual Context

This class involves all context elements that are immediately related to the user herself: location, speed, disabilities, or computing context that involves the nature of her device(s), the state of the applications running, the precise state of interaction of the user with device or application. Furthermore, personal physiological parameters (heart rate, etc.) may also be counted as individual context. Higher level derived individual context may e.g. include the emotional state of the user derived from personal physiological parameters (see e.g. [Picard, 2003] [Kim et al., 2004] [Peter et al., 2005]) or audio data (see section 6.1) or characterizations of the individual life rhythms (e.g. [Eagle and Pentland, 2009]).

Again, measurement and useful application of many of these contexts is limited to the mobile usage scenario. However, individual computing context is certainly also interesting for the non-mobile case. As in the case of physical context, medium-term and long-term variants may be won by suitably averaging over longer time-intervals. Applications of individual context encompass various forms of location-based awareness services (cp. chapter 2 chapter 7) or special forms of information retrieval services for the SN case (cp. chapter 9). Furthermore, aside from the Social Networking case, individual context may be used for a wide range of context-aware service elements such as UIs that adapt to a combination of physical context (e.g. lighting) and individual context (e.g. certain forms of visual impairment, current state of interaction with an application, emotional state of the user etc.).

Social Context

Social context is one of the most interesting classes of context for Social Networking in particular. In congruence with the early definitions of context classes by Starner and other, short-term social context refers to characterizing the social nature of the situation a user is currently in. This may encompass the set of persons a user is currently interacting with together and the spatio-temporal reference of this interaction (cp. chapter 5). Furthermore, higher-level short-term social contexts may also encompass the emotional state of others in the situation or an assessment of the emotional quality of the overall social situation as a whole. Short-term social context may involve time intervals ranging from seconds and minutes (e.g. in terms of changing emotional states) to a few hours at most (in terms of longer lasting Social Situations (cp. chapter 5). Medium-term social context refers to time intervals from several hours to several days and encompasses derived characterizations of longer lasting social behaviors, rhythms, cohesions or events such as a visit to a friend in a foreign city, a vacation trip with others, or general interaction patterns with other people. Long-term social context involves time-intervals from weeks to months and years. A key form of long-term social context are social networks. Here, measurement and derivation of these contexts may e.g. involve textual analysis of communication data (see chapter 4). However, in Social Networking basic forms of such long-term social contexts are typically explicitly stated by the users (e.g. Facebook 'friendships'). Higher level long-term social contexts may be won by applying methods of social network analysis to these basic networks, yielding e.g. centrality assessments for users or dense sub-networks as models for groups of all sorts (see e.g. [Brandes and Erlebach, 2005]).

Measurement and employment of short-term social contexts is, again, typically associated with the mobile usage scenario. The low-level sensors involved include microphones for the basic measurement of audio data and accelerometer, compass, GPS, or gyroscopes for the measurement of interaction geometries (see subsection 5.3.1 or simple Bluetooth for detecting nearby devices. Methods for deriving short-term social contexts are discussed in more depth in chapter 5 and chapter 6. Long-term social contexts will typically be derived from data that is available in non-mobile usage scenarios, but may also be derived from short-term social contexts (e.g. concluding on intensity parameters of a social relation via a statistical analysis of the encounters with that person over a certain time period).

Social contexts may (actively or passively) be used in almost all Social Media and Social Networking services due to the inherently social principles governing these services. Part III will elaborate in more depth on possible uses ranging from awareness services, social information retrieval, special forms of privacy control and information markets, recommender systems and services and platforms for Open Innovation.

We may now define **Contextual Social Networking** (or Context-Aware Social Networking, synonymously) as a variant of Social Networking where the aforementioned classes of context with a special emphasis on social context are incorporated into the SN services either in the sense of active context awareness or passive context awareness. In many cases the most significant contribution to the value of a SN service lies in the derivation of higher level social contexts from lower level context data which is not a trivial task as we will see in Part II. Once such higher level social contexts may be determined with high reliability, it is easy to see how this knowledge may provide added value to existing services or may give rise to new services (see Part III).

As mentioned above many interesting low level context elements may predominantly be measured and employed in mobile usage scenarios, which illustrates the close connection and high conceptual overlap between **Contextual Social Networking** (CSN) and **Mobile Social Networking** (MSN). While the techniques proposed to acquire and use contexts in SN services may in principle as well be used in centralized SN settings (e.g. Facebook), **Decentralized Social Networking** (DSN) scenarios (cp. chapter 3) may be perceived as a natural habitat for CSN: the main paradigm of DSN corresponds to giving the user as much control of his data as possible. In view of the highly sensitive nature of most context data this appears as a highly desirable goal. Certain concepts of unifying privacy control and the idea of information markets also appear to be more compatible with a DSN setting (cp. section 8.4). Furthermore, the idea of personal SN agents as proposed in chapter 6 is a concept which is inherently linked to DSN as well. In view of the high complexity of deriving higher level social contexts, a distributed solution may exhibit general advantages in terms of scalability, fault tolerance etc. However, there are also arguments in favor of the pairing of CSN and centralized Social Networking scenarios: the distributed measurement and derivation of social context elements requires a complex set of protocols and algorithms for exchanging context elements on all levels of abstraction, for reaching agreements (cp. section 6.4 and ∗[Groh et al., 2011d]▶) and other tasks. These tasks may be realized more easily in a centralized SN setting which simply collects all relevant data. Furthermore, acquiring social contexts requires a critical mass of users equipped with the necessary sensors and the readiness to participate in this acquisition process. Critical masses and levels of readiness may be stimulated in an easier way with the market penetration and impact of a large centralized SN platform.

1.3 Challenges and Opportunities for Future Research

Challenges and Opportunities for Future Research in relation to the topics of this chapter may be twofold:

As indicated in section 1.1, there is no precise consensus in scientific literature and among Web-practitioners concerning the terms and concepts in relation to Social Media and Social Networking. Further **comprehensive studies on the development and status quo of these phenomena on the Web** may contribute to introducing suitable classification schemata and appropriate definitions for the related concepts. Collaborative Social Media may be an appropriate tool in such studies: e.g. the Wikipedia articles on Social Media and other related phenomena may, although not complying with the requirements for citable scientific sources, reflect the common view of a large number of experienced users of Social Media which may be especially valuable in terms of agreeable notions, comprehensive lists of existing services, and classification schemata. Furthermore, additional **technology assessment studies** should further investigate the impact of Social Media and the growing level of "computerization" of private social life (as in Social Networking) on society beyond the level of individual services or platforms. This may support and guide computer scientists and Web-practitioners in designing useful services for the user and providing the necessary algorithms and theoretical constructs, support governmental and political bodies in suggesting suitable laws, and may contribute to an increased level of awareness on behalf of the users, e.g. in terms of implications of privacy in SN (or the lack thereof). This awareness on behalf of the users may, again, also be target of suitable Social Media services such as recommender systems and collaboratively maintained guidelines on how to 'survive' in this landscape of growing technological complexity continuously penetrating even private social life.

The second line of challenges and opportunities for future research relates to identifying, detecting, and using contexts for Social Media and Social Networking in particular. This is the **topic of this thesis** and later chapters will elaborate in more depth on the spectrum of related challenges and opportunities. Part II will be especially focused on the detection of social contexts on all time-scales and Part III will focus on using contexts for SN services and service elements.

1.4 An Early Study on Context-Aware Community Support Systems *

In an early study ∗[Groh, 2007]►, we investigated first ideas for the acquisition and use of certain forms of context for improving services in communityware. In this regard, communityware may be perceived as early forms of Social Networking platforms, aiming at supporting communities with a lesser emphasis on the explication of social relations than in SN. So called Ad-Hoc-Groups may be perceived as coarse precursors for short-term social contexts proposed in this thesis such as Social Situations (as defined in chapter 5). For the detection of Ad-Hoc-Groups, straightforward metric clustering such as suitably constrained K-Means [Bishop, 2006] approaches were used, using location and velocity as features. From the found Ad-Hoc-Groups, so-called Abstract Groups were computed by analyzing temporal patterns and similarity of the respective sets of users of Ad-Hoc-Group instantiations. Abstract Groups may be viewed as simple precursors of medium-term or long-term social contexts, describing groups in social networks. The methods proposed in the study may, however, be too coarse to capture the interesting relations between short-term social contexts and long-term social contexts (e.g. cp. section 5.4) with sufficient accuracy. Furthermore, (medium-term and long-term) groups were computed via fuzzy clustering of various forms of textual representations of user-interests, using techniques from NLP and external sources of lexical knowledge. We also developed adaptations of relational clustering approaches to compute groups from the structure of threaded communication (such as discussion boards). Several applications were suggested that can make use of the found instantiations of the various group models as context elements, such as variants of Collaborative Filtering, applications for information management and special awareness services. In contrast to social contexts based on explicit self declaration (such as social networks in SN platforms) or based on situational acquisition via Social Signal Processing (such as Social Situations), the long-term group models proposed in this early study will often lead to quasi-groups (groups that are bound by a statistical commonality and only to a lesser extent by true social relations). While these quasi-groups may nevertheless be used for selected applications as suggested by the study, most SN applications such as e.g. privacy-management (see chapter 8) or awareness services may require more well founded social contexts to perform properly. Part II will discuss more sophisticated methods to acquire reliable social contexts.

▷ ▷ ▷ Skip related publications and continue with next chapter ▷ ▷ ▷

Included Publication:

Groh, G. (2007). Groups and Group Instantiations – Detection Modeling and Applications. *Proc. AAAI International Conference on Weblogs and Social Media (ICWSM07), Boulder, Co, USA.*

Chapter 2

Mobile Social Networking

This chapter discusses Mobile Social Networking (MSN) as a scientific field closely related to Contextual Social Networking (CSN) and an important basic scenario for the acquisition of short-term and medium-term social contexts (Part II) and for applications discussed in Part III. We thus employ two perspectives: First we investigate the structure of the (heterogeneous) scientific field Mobile Social Networking with the help of a scientometric study analyzing structures and properties of networks of publications, authors, institutions, conferences and other scientific entities in the field and its relations to contributing, neighboring and constituting fields. We then investigate and classify existing approaches.
Own publications related to this chapter: ∗[Groh and Fuchs, 2011]▸, ∗[Groh and Daubmeier, 2010]▸.
Supervised theses related to this chapter: •[Fuchs, 2009], •[Daubmeier, 2009].

2.1 Network-based Scientometric Characterization of the Field Mobile Social Networking *

As discussed in chapter 1 and as will be discussed in Part II and Part III, **Mobile Social Networking (MSN)** is intimately linked with **context** in and for Social Networking (SN). Compared to SN in a desktop setting, MSN allows acquiring a larger and structurally different array of context elements (e.g. 'honest (social) signals' [Pentland, 2008]) and used, on the hand because mobile usage is more directly embedded into all-day social life of users than SN in a desktop setting, and other hand because of a large variety of sensors that are integrated into modern mobile devices and that may be used for context acquisition. Thus, as has been discussed in chapter 1, the key difference between SN and MSN lies in the **acquisition and usage of these contexts** available in a mobile usage scenario. As such, MSN may be viewed a sub-field of the large and highly diversified fields of **Context-Aware-Computing** (see e.g. [Dey, 2009]) and **Mobile Computing** (see e.g. [Kamal, 2008]). While long-term social contexts (e.g. social networks) are also measurable in the desktop SN scenario, as will be discussed in Part II, it is especially the **short-term social contexts** that are measurable in the mobile domain. Thus MSN has substantial overlap with the fields **Social Signal Processing** and **Reality Mining** (see subsection 5.1.1), and thus trivially with the hierarchy of their encompassing fields (Behavioral Modeling, Data-Mining etc.) and related fields (Machine Learning, Artifical Intelligence etc.). Furthermore, since long term social context and the relation between short-term and long-term social context also plays a role in MSN (e.g. in terms of privacy (see chapter 8)), there will also be a significant overlap with the field of (Dynamic) **Social Network Analysis** and its associated encompassing hierarchy (General Network Analysis, Graph Theory, Discrete Mathematics etc.). Other fields (with a partial overlap to those discussed above) that are especially significant for MSN are **Privacy-Management**, e.g. because of the highly sensitive nature of short-term social contexts involved (see chapter 8), and **Mobile User Interface Design**, where mobile social user interfaces and social user interfaces with a seamless integration of mobile and stationary elements (see section 11.2) may be upcoming new variants.

Furthermore, the highly diverse field of **Decentralized SN**, discussed in chapter 3 may be of future significance for SN and MSN. Here, a personal social agent may control, relate and unify many different, heterogeneous (M)SN services and the personal information space of a user in a (socially) context sensitive way. Heterogeneous (M)SN services as discussed in Part III may encompass direct and indirect communication services, social information retrieval etc. and may be offered by different single providers / companies or may be collaboratively offered via a system of social agents (e.g. see chapter 9). The personal information space may be viewed as encompassing information items (e.g. communication content) and context data (e.g. Social Situations (see chapter 5). In such a scenario the agent's goal may be identified with collaborating to pareto-optimize the (social) utility of the users involved (e.g. by using social contexts to control access to information items (cp. chapter 8)). While Decentralized SN is perfectly possible and also very beneficial in a non-mobile SN setting, the MSN setting with its intimate connection to acquiring and using social contexts and related deep embedding into a user's all-day social life via a 'personal' mobile device may especially profit from the benefits of Decentralized SN and vice versa (compare chapter 3).

In a scientometric **study**, ∗[Groh and Fuchs, 2011]▶, we investigate methods and services based on network analysis for modeling and analyzing scientific fields with the goal to support users new to a field in getting an overview with respect to relevant topics, researchers, journals and other important 'items' and their relations. The **field Mobile Social Networking is investigated in depth** as a use case. An application was designed, providing services for the management and analysis of a personal scientific information space. Using the application we collect a large multimodal network of scientific papers, authors, journals, and conferences as nodes and citation, co-citation, authorship and other relations as edges, specifying a methodology for deciding the relevance to the field MSN. We analyze the network focusing on various modes with the help of graph clustering, network visualization, centrality measures and other techniques. Furthermore, we compare items using tf-idf-based methods for keyword extraction and computing cosine similarities. The results provide a detailed characterization of the field Mobile Social Networking as of late 2009 as well as evidence for the utility of the suggested services.

2.2 Mobile Social Networking Services and Platforms *

In a second study, ∗[Groh and Daubmeier, 2010]▶, we analyze the MSN platforms and services available on the Web as of late 2009. We derive an extensive categorization schema and categorize and discuss the existing structures using this schema. Furthermore, the dynamics of selected aspects is investigated via an empirical study. In contrast to ∗[Groh and Fuchs, 2011]▶ which focuses on the scientific studies and thus on theoretical aspects of MSN, the study ∗[Groh and Daubmeier, 2010]▶ focuses on the practical state of the art of the field.

2.3 Challenges and Opportunities for Future Research

Many aspects discussed in this thesis may be perceived as being closely associated with MSN (such as Mobile Social Signal Processing (MSSP) discussed in Part II or the (M)SN services discussed in Part III), providing a very broad spectrum of future research opportunities themselves (e.g. methods for measuring interaction geometries with mobile sensors, collaborative agent-based MSSP (cp. chapter 6 etc.), appropriate mobile user interfaces for the MSN services, either for single users or social forms of interfaces involving multiple users etc.).

However, the current chapter is mainly intended to provide an overview of related scientific and practical work on MSN. In terms of network-based **scientometric methods** to model the structure and dynamics of scientific fields and topics related to this thesis (such as MSN, Contextual SN (CSN) or Decentralized SN, Social Signal Processing, Social Recommender Systems, Social Information Retrieval etc.) new methods may be investigated that are targeted to be used in respective useful awareness tools. These tools may allow a scientist to gain or maintain an overview of existing and new methods, surveys, papers, relations, actors, conferences and other entities in the respective fields with the help of interactive network visualization and network analysis (clusters, central entities etc.). While numerous studies have been concerned with analyzing static citation-, co-citation and other types of scientometric networks, slightly less studies investigate the **dynamics** of such networks (see e.g. [Radicchi et al., 2012], [Ghosh et al., 2011]) which is especially helpful in view of the mentioned awareness tools for researchers.

▷ ▷ ▷ Skip related publications and continue with next chapter ▷ ▷ ▷

Included Publications:

Groh, G. and Fuchs, C. (2011). Multi-modal Social Networks for Modeling Scientific Fields. *Scientometrics*, 80(2):569–590.

Groh, G. and Daubmeier, P. (2010). State of the Art in Mobile Social Networking on the Web. *TU-München, Faculty for Informatics, Technical Report, TUM-I1014*.

Chapter 3

Architectural Elements of Decentralized Social Networking

This chapter discusses Decentralized Social Networking (DSN) as a scenario which integrates well with Contextual Social Networking. Besides a short discussion on main architectural elements of DSN scenarios, we will focus on concepts for distributed group management which is an interesting problem for certain variants of DSN: how do groups and / or sub-communities present themselves, manage membership, and manage their associated information space(s) in a distributed and democratic way, forming a special flavor of social context? In close connection with that we will also discuss a study investigating the role and structure of groups in existing conventional SN platforms.
Own publications related to this chapter: ∗*[Groh and Rappel, 2009]*▸, ∗*[Elser et al., 2010]*▸.
Supervised theses related to this chapter: •*[Rappel, 2008]*, •*[Seidl, 2008]*.

3.1 Decentralized Social Networking

Decentralized Social Networking (see e.g. [Yeung et al., 2009]) provides an alternative technique to implement SN scenarios which is designated by the absence of a central SN platform (or more precisely a SN platform instance), hosting the SN services and the user's information spaces. A typical example for a centralized SN platform instance is Facebook [fac, 2012b] which conceptually corresponds to a conventional Client-Server-based SN platform, although naturally many intelligent parallelization techniques have to be employed to handle the large data-volumes involved [Rothschild, 2009]. In a decentralized SN setting, **users autonomously manage their information spaces** and interact with a large variety of alternative SN services provided by a heterogeneous set of providers. The heterogeneity introduced by switching from a well structured centralized platform to a decentralized setting requires developing new concepts for certain problems (e.g. by adopting concepts from areas such as Peer-to-Peer Networks [Steinmetz and Wehrle, 2005], Distributed Systems [Tanenbaum and van Steen, 2006], Multi-Agent-Systems [Wooldridge, 2009] or Semantic Web [Antoniou and Van Harmelen, 2004]). However, it also provides many advantages such as contributing to overcoming the 'Walled Garden' problem [Yeung et al., 2009] of not being able to seamlessly integrate accounts and information spaces of different centralized platforms, or contributing to counteracting the disadvantages of a few centralized platform instances dominating the market by allowing new SN services and their providers to enter the market in an easier way, thus supporting innovation and new concepts better tailored to the specific needs of certain user groups. Furthermore it also acts as a more democratic counterbalance to the immense data-power of these centralized instances, e.g. allowing more flexible privacy policies or information markets (see chapter 8).

Elements of DSN are already a reality (as of 2012): even large centralized SN platform instances such as Facebook integrate new services and their providers with the help of open APIs [fac, 2012a], e.g. contributing to the success of Social Network Games [Järvinen, 2009]. Thus the distinction between Centralized SN and Decentralized SN is not exactly sharp. However, in a fully decentralized SN setting, more general semantically rich meta-data formats (e.g. using Social Semantic Web [Breslin et al., 2009b]) will have to replace or supplement simple APIs providing access to uniform data structures controlled and devised by a small number of companies and distributed collaboration between independent entities on all scales may replace or supplement contract governed business relations between a small number of large companies.

3.1.1 Personal Social Agents

In order to autonomously exert control over their information spaces and a portfolio of services (and thus other users via those services) 'acting' on those information spaces, most users will require adequate support. While in centralized SN scenarios the platform instance itself will act as the supporting entity e.g. by controlling access to a user's information space, a decentralized SN setting offering a much larger variety of possibilities may profit from **personal social agents** associated with individual users. The agent application may be closely associated with the user's personal (mobile, continuously running) device equipped with sensors for context acquisition. Those agents manage the personal information spaces of users e.g. by controlling the acquisition, evaluation and analysis of social contexts (see e.g. section 6.4) or by implementing context-aware access control and privacy (see chapter 8) for elements of the personal information space in the social sphere. They also collaboratively provide or contribute to providing Social Networking services for the society of users represented by their personal social agents in a decentralized way, e.g. by using Peer-to-Peer techniques for distributed information management (e.g. for sharing information items). This collaboration may involve agents representing single users or groups of users including abstract entities such as companies or governmental bodies.

While agents are usually assumed to be **autonomous**, **self-interested** (aiming at maximizing the agent's utility) and **intelligent** (in the sense of being able to choose between alternate ways to act on the basis of sensor data or knowledge and/or to be able to learn from experience) [Wooldridge, 2009], the term agent may be used here in a more liberal sense in order to ensure compatibility with the existing landscape of Social Networking. That means that some or all of these defining elements may in the extreme case be also implemented in very simple ways, e.g. via user accounts in larger social media or SN platforms, realizing basic access control and basic information management capabilities. More sophisticated agents may act as wrapper applications for the various SN services e.g. providing a unified user interface. We may also have fully autonomous and intelligent agents, which aim at (collaboratively pareto-)optimizing the social utility functions of the individual entities they represent over the course of time. In contrast to strictly competitive interaction as in Game Theory [Fudenberg and Tirole, 1991] where each agent attempts to maximize his individual utility function, interaction between such personal social agents may require or profit from collaboration and social behavior within the boundaries defined by the associated user (e.g. in terms of privacy). This may mean that such an agent may (within the aforementioned boundaries) accept temporal reduction of his user's utility (e.g. by revealing potentially privacy compromising information items) if this action is likely to increase the utility indirectly or in the future (e.g. by raising the social status of the user) (see subsection 8.4.1 and the ideas on information markets in ∗[Groh and Birnkammerer, 2011, extd. version]▶ and •[Birnkammerer, 2010]). In that sense, personal social agents need to be 'social' in two ways: on the on hand by making use of agent collaboration techniques from the field of Multi-Agent-Systems (cp. [Wooldridge, 2009]) and by applying and implementing models of human social behavior, e.g. when acquiring and analyzing short term social contexts (cp. Part II) or when contributing to useful information retrieval of shared content (cp. chapter 9). A Multi-Agent-System (MAS) of such agents may provide added value (compared to conventional SN platforms) as a technical basis for supporting human social interaction in DSN scenarios.

3.1.2 Peer-to-Peer Social Networking

Peer-to-Peer Social Networking (P2PSN) (see e.g. [Graffi et al., 2010] or [Datta et al., 2010]) is a technical realization of certain key aspects of DSN, where a conventional bundle of SN services such as messaging or services sharing of content is implemented on the basis of existing P2P techniques and protocols. Usually, a stand-alone application providing the UI and controlling the execution of P2P protocols has to be installed by the user, which may be viewed as a simple personal social agent. However, as of 2012, P2PSN concepts do not involve socially intelligent agents yet, nor do they allow efficiently integrating heterogeneous services, platforms and data on a broad scale e.g. with the help of semantically rich meta-data. It has to be remarked that, on the other hand, elements of social networks have also been used to improve P2P techniques (e.g. by enhancing the efficiency of overlay networks for P2P file sharing applications (see e.g. [Fast et al., 2005])) which also shows the connection between human social context and simple personal agents (peers in this case) collaborating (in this by executing an appropriate P2P protocol) to generate added value for the human users.

Depending on the precise definitions involved, **P2PSN and DSN may or may not be regarded as identical**: An SN platform implemented on a stack of P2P protocols with a standardized Peer SN application (as in [Graffi et al., 2010]) may be regarded as being only based on a different technical network architecture than conventional SN platforms but not being conceptually different from the user perspective from other (centralized) SN platforms. It may thus be regarded as just providing another 'Walled Garden' ([Yeung et al., 2009]), e.g. without full autonomous control on behalf of the user and without a substantially enhanced extensibility (e.g. in terms of new services) compared to centralized SN. A DSN scenario with intelligent personal SN agents forming a Multi-Agent-System may allow more flexible forms of interaction between those agents beyond mere P2P protocols and more direct control over personal information spaces, linking typical 'spare-time-oriented' Social Networking as of 2012 with more serious forms of personality management (e.g. with respect to health, profession, education or interaction with governmental bodies). However, since even 'intelligent' agents may need formal protocols (e.g. for communication, deliberation or task-allocation (see [Wooldridge, 2009]), and since elaborate protocols may involve many degrees of freedom to act for the individual peer, the distinction between SN peers and (personal) SN agents is hard to render precise.

3.1.3 Social Semantic Web

A key enabler for Decentralized SN is **Social Semantic Web** [Breslin et al., 2009b] which is based on the principles and standards of Semantic Web [Antoniou and Van Harmelen, 2004] and allows specifying semantically rich meta-data for information items, social relations and other elements of SN, via specialized ontologies / ontology frameworks such as SIOC [Breslin et al., 2009a], FOAF [Brickley and Miller, 2010] and SKOS [Miles et al., 2005] and protocols acting on these meta-data (such as FOAF+SSL for authentication [Story et al., 2009]). SIOC is an ontology that allows the specification of meta-data for information items representing the content of indirect n:m communication (discussion boards, blogs etc.) such as the necessary structural relations between those items (e.g. follow-up relations). SKOS is an ontology framework on the basis of RDF(S) indented for easy specification of straightforward controlled vocabulary (e.g. thesauri). Compared to OWL, SKOS is conceptually simpler and requires less expertise on behalf of the user. Thus it has been suggested as a framework for simple concept hierarchies for inter-operable knowledge and information management in Social Semantic Web [Breslin et al., 2009b], where the intricate expressiveness of OWL geared towards formal reasoning may not be necessary. FOAF and more specialized associated ontologies such as RELATIONSHIP [Davis and Vitiello, 2010] allow the specification of meta-data in view of identities, profiles and social relations. Together with other standards of the Social Semantic Web, formal and semantically rich meta-data may be instantiated that support conceptually implementing a DSN setting (see e.g. [Decker and Frank, 2004]). As with the other elements discussed above (personal social agents and P2PSN), Social Semantic Web may be integrated with existing SN scenarios and may provide benefits for centralized SN scenarios as well, e.g. by contributing to a semantically richer information management (e.g. in terms of searching) for Social Networking (cp. [Breslin and Decker, 2007]).

3.1.4 Comparing DSN and CSN Scenarios

Summarizing the elements discussed above, a DSN scenario may be defined by the following characteristics:

1. The user has direct autonomous control over his SN information space (which includes instantiations of models for contexts involving that user such as his social network). This e.g. includes granting the user respective formal rights (e.g. the copyright for his information items) and the technical means to exert those rights (e.g. formulating privacy settings in view of information items that SN services must respect). A possibility to support the user in terms of exerting this control are personal SN agents.

2. SN services and SN data (the information spaces of the users) are distributed: Instead of few single SN server platform instances with their associated user bases ('Walled garden' situation [Yeung et al., 2009]), multiple parties (agents or simple peers) collaborate in a distributed system to provide the SN services and manage the SN data, involving standardized protocols (e.g. P2P protocols). In terms of these 'parties' the flexibility of this distributed interaction may range from the level of standardized P2P protocols to a MAS of user controlled, intelligent personal SN agents.

3. SN services and the data they operate on are asynchronously extensible by users via declarative, semantically rich meta-data (e.g. using Social Semantic Web) akin to changing from a procedural implementation paradigm to a declarative (e.g. logic) programming paradigm.

DSN scenarios and centralized SN (CSN) may be **compared along various dimensions**, revealing advantages and disadvantages of both approaches:

- **Political dimension**: consortia of user-groups instead of single companies decide about protocols, formats, user rights etc. Advantages: e.g. better adaption to user needs, more fair representation of user interests; disadvantages: e.g. slower decision processes, least common denominator effects of democratic decision processes.

- **Market dimension**: competition among distributed independent service providers instead of single companies designing all SN services. Advantages: e.g. higher innovativeness, better adaption to the needs of special user communities, disadvantages: e.g. lower impact and thus more critical mass problems, fragmentation effects may counter certain general main advantages of SN (having large uniform social networks).

- **Technical dimension**: distributed system instead of single SN platform instance. Advantages: e.g. fault tolerance, disadvantages: e.g. in general higher complexity.

- **Social intelligence dimension**: Acquiring, analyzing and storing sensitive social contexts in a privacy conformal way may be more compliant with the idea of personal SN agents associated with mobile devices than handling these elements in a centralized platform. (Compare chapter 8 and chapter 6))

- **Privacy dimension**: more control of his or her data for each user in DSN. advantages: e.g. adaptability to individual needs, better legal possibilities for content revocation, possibility for information markets (see subsection 8.4.1); disadvantages: content revocation may be technically more difficult in DSN due to massive distribution if protocols do not support it explicitly. (Compare chapter 8).

3.2 Group Management in DSN Scenarios *

Some elements of Social Networking such as the establishment and management of simple forms of (user-)groups appear to be comparatively easy to realize in centralized SN. In most cases, a labeled entity for the group is created by some user and membership relations to that labeled group can be declared by any other user without restrictions. Such simple forms of groups are also not extensively difficult to realize in DSN scenarios, e.g. in P2PSN by using and adapting respective P2P protocols (compare ∗[Elser et al., 2010]▶), but usually require more effort than in CSN, since a central instance to register the group and make its existence known to potential members is missing. In a **study** ∗[Elser et al., 2010]▶ we thus investigate various **approaches to group management in P2PSN**, including more elaborate variants that go beyond the existing simple practice in existing SN platforms (e.g. Facebook or Google+). Among these are e.g. variants, where a single user or a group of users has control over membership in the group.

While the study ∗[Elser et al., 2010]▶ discusses technical means and concepts to implement various forms of group-management in P2PSN, a **second study** ∗[Groh and Rappel, 2009]▶ discusses aspects of the **sociological and socio-technical function and nature of groups in SN**. In SN, groups may be used as mere labels by users that are not socially closely related for expressing certain attitudes or positions. They may also reflect ‘true' groups in so far as the members of the group form a dense sub-network (in the sense of [Kosub, 2005]) or correspond to a dense graph cluster (in the sense of [Gaertler, 2005]). In this case the labeled group is more likely to be used by its members (besides the segregating and identity generating function of the label) for tasks such as group-based information management or group-based direct communication. Using a large social network of a German SN platform instance (StudiVZ) with information on groups and group membership, we empirically investigate and compare statistical properties of these forms of groups in SN. Since sociological function of groups in SN and technical concepts for group management in SN are intimately linked, additional results of this study are also discussed in ∗[Elser et al., 2010]▶.

3.3 Challenges and Opportunities for Future Research

In terms of group management concepts for P2PSN (and also for CSN), many opportunities for future research exist, extending and developing the concepts from ∗[Elser et al., 2010]▶, e.g. for democratic control over group information spaces or for building trust relations among group members.

Social Semantic Web is also an active area of research with numerous interesting challenges (cp. [Breslin et al., 2009b]), linking DSN to general distributed Knowledge Management, certain aspects of Computational Logic (e.g. efficient reasoning procedures for Description Logics, handling of contradictory knowledge typically occurring in SN scenarios etc.) and other fields. Although some prototypical applications have been realized [Breslin et al., 2009b], a convincing general model for a DSN scenario with good performance based on Social Semantic Web meta-data is still missing.

The proposed idea of personal SN agents and its relation to appropriate declarative representations for SN data (possibly using Social Semantic Web) implies a vast field of future research, linking DSN to Multi-Agent-Systems. However, pragmatic versions of such agents e.g. dealing with special aspects (e.g. as discussed in chapter 6) or as elaborate forms of peers in P2PSN may be realized without invoking the full complexity associated with distributed AI.

▷ ▷ ▷ Skip related publications and continue with next chapter ▷ ▷ ▷

Included Publications:

Groh, G. and Rappel, V. (2009). Towards Demarcation and Modeling of Small Sub-Communities / Groups in P2P Social Networks. *Proc. IEEE SocialCom SIN09, Vancouver, Canada.*

Elser, B., Groh, G., and Fuhrmann, T. (2010). Group Management in P2P Networks. *Proc. 10th Int'l Conf. on Computer Communications and Networks (ICCCN), Zurich Switzerland.*

Part II

Determining Social Context

Chapter 4

Enriching Social Relation Models

The explications of social relations in SN / MSN (as a key form of long-term social context) often are semantically quite flat from an ontological point of view. This chapter discusses alternative concepts for conceptualizations and other characterizations of social relations with a richer semantics. Several studies investigating folksonomies and polytopic ('vector-space-like') types of characterizations of social relations are discussed. A study investigating tagging-based conceptualizations for social relations and a follow up study researching socio-psychological phenomena in connection with tagging relationships identified several serious difficulties in relation to using folksonomies for the purpose of providing richer semantics for social relations. Thus several other studies investigated describing social relations along several axes: three of these studies investigated class-based and continuous assessments of a relation's valence (and / or intensity) via Natural Language Processing (NLP)-based sentiment analysis using email corpora. Two other studies investigated NLP-based methods for assessing intensity and valence of relations using editorial content instead of communication content.

Own publications related to this chapter: ∗*[Kammergruber et al., 2011]*, ∗*[Nauerz and Groh, 2008]*, ∗*[Groh and Hauffa, 2011,* extd. version*]*▶, ∗*[Hauffa et al., 2011]*▶.

Supervised theses related to this chapter: •*[Zec, 2008]*, •*[Richter, 2007]*, •*[Richter, 2009]*, •*[Liesenfeld, 2009]*, •*[Bossert, 2010]*, •*[Hauffa, 2010]*, •*[Lichtenberg, 2010a]*.

4.1 Overview of Part II: Detecting and Modeling Social Context

In this part of the thesis, comprising of this chapter 4, chapter 5, and chapter 6, we will discuss how **social context on all temporal scales** (short-, medium-, and long-term) may be acquired / modeled in SN- and MSN-scenarios. In this chapter 4, acquiring semantically richer characterizations of social relations (as a key form of **long-term social context**) using communication content and editorial content with the help of Natural Language Processing (NLP) is discussed. The next chapter 5 investigates, how Social Situations as special form of **short-term social context** may be detected analyzing human geometry of interaction, especially interpersonal distances and body angles. The third chapter 6 discusses, how other signal sources such as audio data may be used for Social Situation detection and how various different evidences (e.g. won from different data-sources) may be combined on various scales of abstraction.

4.2 Conceptualizations and Other Characterizations for Social Relations

Explicated Social Relations are a key characteristic of SN and MSN. However, most platforms provide only very coarse categories for social relations. In most cases only one class is provided (mostly labeled as 'friendship'), which thus has to subsume anything from coarse acquaintance to family relations. Mapping the whole variety of types of social relations to **only one class** will thus not allow distinguishing various classes or rely on other types of more fine grained characterizations for relations which may be desirable e.g. for fine grained privacy settings (see chapter 8), awareness applications as e.g. filtering awareness in view of relation type (chapter 7), or information applications as e.g. including only social relations of a certain type into a social search process (compare chapter 9). There are several basic alternatives for introducing more fine grained characterizations of social relations. These include the following:

Groups, as discussed in chapter 3 and as used in newer SN platforms such as Google + [goo, 2012b], may be viewed as (mostly extensional) individual characterizations of relation types. Each user may partition the set of other users that he or she has an unspecified social relation to into such named (possibly overlapping) sub-sets. While each individual may thus specify an ordering schema tailored to his / her needs, there are also **disadvantages**. **First** of all, as discussed in ∗[Groh and Hauffa, 2011, extd. version]▶ and ∗[Hauffa et al., 2011]▶, from a logical point of view, conceptualizations on the set of persons such as groups may not be equivalent to conceptualizations on the set of social relations. A tag 'great guy' may reveal an attitude towards the respective directed social relation and thus allow an indirect assessment of the valence of this relation, but it does **not explicitly tag the relation itself**. As especially the studies •[Liesenfeld, 2009] and •[Bossert, 2010] have shown, users have substantial difficulties in e.g. tagging their relationships with other users, while it appears to be more easy for them to tag the related persons themselves. While for certain applications this distinction might not be crucial, it may make a difference for others. **Second**, named partitions such as groups may **not be very expressive** as conceptualizations (compared to e.g. OWL ontologies [McGuinness and Van Harmelen, 2004]), because they may only be used for nominal comparisons and no reasoning involving intensional description elements may be used. **Third**, and most important, groups are **individual level only**, implying that they do not present a shared consensus, which means that reasoning involving a network of such relations will have to rely on shallow string comparison and other inexpressive heuristics.

Semantic Web [Antoniou and Van Harmelen, 2004] types of **formal Ontologies** for social relations are another alternative. E.g. with the FOAF [foa, 2011]-based Relationship [rel, 2011] ontology such ontologies do exist but are not in very widespread use as of 2011. While they provide formal, intensional and shared conceptualizations of relations and thus avoid the disadvantages of groups discussed before, they also exhibit disadvantages. First of all, formal ontologies are usually proposed and maintained by a set of experts. Although in principle anybody can provide or extend ontologies or parts of ontologies, their value can only be fully exploited if the 'sharing' consensus involves a significant number of users (compare [Flouris et al., 2008], [Tudorache et al., 2008], [Mizoguchi and Kozaki, 2009] and [Noy et al., 2006]) for tools and methods of collaborative ontology engineering). Thus usually standardization organizations, centralized SN / MSN platforms / large companies with their expert teams are the driving forces behind such ontologies. Furthermore, consistency, up-to-date-ness, and the required formal skills of engineers and contributors are prominent problems of collaborative ontology engineering. Furthermore, using such formal ontologies will usually require more skills and be more time consuming on behalf of the users than e.g. simple tagging.

Lightweight tagging-based **Folksonomies** ∗[Kammergruber et al., 2011] are another alternative that avoids some of the disadvantages of formal ontologies as the contribution hurdles are significantly lower and thus shaping those lightweight types of ontologies is not limited to experts but the whole wisdom of the crowd support of Social Computing can be harnessed. So e.g. up-to-date-ness, tailoring towards specific relation concepts in certain societal groups or regions, or flexible evolution of concepts via continuous changes to the tag-clouds (e.g. in terms of changing tag frequencies or adding new tags) associated with a concept may be improved in comparison. However, the discriminatory power and definition of Folksonomy-type of conceptualization can not be as precise as for formal logic-based ontologies. Thus for some applications they may be less convenient as e.g. for privacy settings, where a discrete sharp conceptualization of relations may be desirable. Furthermore, as discussed above, tagging relationships is not an easy task for users as the studies •[Liesenfeld, 2009] and •[Bossert, 2010] have shown, and is also perceived as extremely privacy invasive by users •[Bossert, 2010], even when the tags are not directly shared with other users.

Mixed conceptualizations, where folksonomies and formal ontologies are combined (see e.g. [Passant and Laublet, 2008],[Kim et al., 2008], or [Kim et al., 2010]) aim at mediating between the basic disadvantages of formal and Folksonomy-type of ontologies. In case of conceptualizing social relations, basic formal ontologies like Relationship may be extended or developed by (personal only or anonymously shared) tagging-based approaches. However, the basic difficulties that users have with tagging their own relationships (see above) still pertain, so extending or developing may have to take place on an abstract level. Recent approaches of Gamification [Deterding et al., 2011] or Crowdsourcing [Doan et al., 2011] may provide means for motivation (see e.g. [Bry et al., 2011]).

A further way of characterizing social relations is to employ **axes A_i of characterization** such as valence (e.g. via NLP-based sentiment analysis of communication data) ∗[Groh and Hauffa, 2011, extd. version]▶, ∗[Hauffa et al., 2011]▶ intensity (e.g. also via analyzing communication data) (see also ∗[Groh and Hauffa, 2011, extd. version]▶, ∗[Hauffa et al., 2011]▶) interaction balance (e.g. via analyzing turn taking patterns [Choudhury and Pentland, 2003] or email exchange •[Richter, 2007]) intimacy (e.g. via analyzing geometry of interaction ∗[Groh et al., 2010a]▶ or via other data sources (e.g. audio-data) [Choudhury and Pentland, 2003] degree of hierarchy or other axes (see also •[Hauffa, 2010, p7ff.]). The axes usually have associated discrete or continuous 'rating' intervals $A_i \in [a_i^{\min}, a_i^{\min}]$. Besides manually characterizing a social relation by locating it in such a **'relation-polytope' space** $A = \times_i A_i$, automatic methods using a variety of methods have been proposed. One method which will be discussed in this chapter in more detail is using NLP-based analysis of communication content or alternatively editorial content if the persons involved are of sufficient common interest to stimulate a sufficient amount of such editorial content to locate a relation in A (Aside of characterizing the relation in A, NLP-based machine learning methods such as Topic Models [Steyvers and Griffiths, 2007] may be used to characterize the topics of the relation.)

4.3 Folksonomies for Social Relations *

The **study** •[Liesenfeld, 2009] investigated Folksonomies for social relations. In an **online survey**, German Facebook users were asked to tag their relations to their Facebook friends. 88 users successfully participated and 5977 tags (1405 unique) were used to characterize 3045 relationships. Besides the usual problems associated with tags (such as spelling variants etc.) the survey showed that very few tags specifically characterized the relationship as such but rather described the target person, his / her role etc.. Furthermore, most of the tags were very general in nature. Thus operations such as clustering the tags or computing low rank decompositions or other data-mining techniques (see [Eldén, 2007]) in order to reveal any meaningful structure in view of a fine grained conceptualization of the underlying social relation types were not promising.

A **second study**, •[Bossert, 2010], investigated possible reasons for the failure. An interview with selected participants of the online survey showed that, besides statements expressing severe concerns in view of privacy and expressing vocabulary difficulties in English, the main difficulties were perceived in being unable to appropriately tag social relationships, because of a perceived lack of appropriate conceptual language to do so. Most participants expressed that they would find it easier to choose tags from a catalogue of predefined tags. Clearly, choosing a subset from a predefined set of options delivers a much easier to analyze structure (compare ∗[Groh, 2007]▶). In contrast to tagging the presumably much more numerous potential topics of social relationship, the more limited aspects of a relationship's general conceptual nature may allow using a finite number of conceptual building blocks (e.g. a limited tag set to choose from) to characterize them. However, many aspects of a personal relationship are very hard to describe in language or even by tag-sets as a much more condensed form because of socio-psychological reasons, e.g. because many fine grained aspects in regard to relations are habitually communicated by non-verbal communication (see [Argyle, 1969, p.63ff.(Section 'Language')], •[Bossert, 2010, p.37ff.]). Furthermore, assuming general feasibility, in order to arrive at more fine-grained conceptualizations of social relations, such as relationship phases, general types, group specific conceptual differences (e.g. cultural dependencies and language differences [Argyle and Henderson, 1985, p.53ff.]), a large body of characterizations (preferably with frequent re-iterations over time), would be required. Furthermore, connections with short-term social contexts (such as personal face-to-face interactions) would contribute to study the temporal evolution of social relations and thus also contribute to appropriate conceptualizations. However, as pointed to by the interviews, in order to contribute to overcoming the difficulties in describing relations by language, a subset of predefined alternatives or a conceptual classification space using axes of description (e.g. the personal relationship dimensions of Argyle and Henderson [Argyle and Henderson, 1985, p.5]) may be used (see also section 4.4) as a starting point.

The studies •[Liesenfeld, 2009] and •[Bossert, 2010] are discussed also in ∗[Hauffa et al., 2011]▶.

4.4 Characterizing Social Relations via NLP-based Analysis *

In a simple **first pre-study** •[Zec, 2008], aiming at characterizing social relations along certain property axes using NLP-based methods, a part of the Enron email corpus [Klimt and Yang, 2004] was annotated in view of three classes of valence (positive, neutral, negative) and type of relationship (professional, personal, miscellaneous). With the help of standard supervised classifiers (KNN, Naive Bayes, SVN, C4.5) implemented by the open source toolkit RapidMiner (version 4.1) [rap, 2011] and a standard tf-idf model of text [Manning et al., 2008], e.g. the valence classification performance was investigated. The best results ($\approx 74\%$ accuracy) were achieved for conventional Naive Bayes and using the top 20 % features according to tf-idf weight. In view of the high bias towards neutral emails (61%) these results show that simple straightforward use of standard classifiers on professional email communication will not provide an accuracy sufficient for characterizing social relations on a valence axis.

In a simple **second pre-study** •[Richter, 2007], it was the goal to predict the strengths of ties (in the sense of [Granovetter, 1973]) on a scale $[0, 10]$ in ego-centered networks via 'outer'-statistics of email-exchange, such as relative number of received and sent emails to a person, relative average length of mails to a person, relative number of emoticons used, etc. The predicted tie strengths were compared to manual ratings by the owners of the mailboxes also using a scale $[0, 10]$. The mean absolute error of 2.35 in this study is significantly lower than the random baseline of ≈ 3.64. However, the results are qualitatively not sufficient to reliably predict tie strength (or tie intensity) on the basis of 'outer' statistics of communication acts.

A **third pre-study** •[Richter, 2009] aimed at predicting the valence on a $[-5, 5]$ scale of relations of people of public interest on the basis of textual analysis of editorial content. A corpus of 409 valence ratings and 247 tag-sets for a directed social network of 77 public persons was won via an online survey, where users were asked to state three pairs of public persons and estimate the six directed valences of their social relation and tag them. In order to estimate the realism of the resulting social network, the distribution of the relative frequency of mentions of a given pair of persons in the survey was compared to the distribution of the relative number of Google hits that a query containing the two full names of the respective pair delivered. A Komolgorov-Smirnov test confirmed the hypothesis that the two samples were drawn from the same distribution (see •[Richter, 2009]). Of a corpus of 7249 articles from the New York Times Online retrieved by using the names of the respective pairs of persons as query, word-based and part of speech (POS) tag features were extracted from the text-passages containing the two names using three heuristics for these passages: sentences, paragraphs and a sliding window of 450 characters. For the POS-tagging and other linguistic analysis task, the library LingPipe [lin, 2011] was used. For the valence prediction a corpus of manual $[-5, 5]$ mean-free valence ratings of words of the four main POS classes noun, adjective, adverb and verb was established, enriched with synonyms, and used to compute a simple valence estimation for the respective social relations from the features extracted from the editorial texts (see •[Richter, 2009]). Of the MAE values for the three heuristics, only the paragraph-level feature generation was significantly better than the random base-line. Comparing the tag-sets for the relationships from the survey with the sets of words retrieved as features for the relationship from the texts employing Porter stemming [Porter, 1980] and stop-word removal using a method from ∗[Groh, 2007]▶, yielded very low values for precision and recall. One thus can (with the necessary precaution with respect to generalizability of the achieved results) conclude that such straightforward methods for assessing the valence of a social relation and for extracting word-based features characterizing the social relation from editorial texts do not yield the desired level of accuracy and expressiveness.

Motivated by the negative results of the pre-studies, a **final study** •[Hauffa, 2010] was conducted employing more refined means to assess intensity and valence of relations from text. A corpus of emails was retrieved from test-persons and rated according to the principles of the second pre-study •[Richter, 2007] with additional ratings of intensity besides the ratings of valence and together with the corpus of •[Richter, 2007] used for the study. After extensive preprocessing (see •[Hauffa, 2010] ∗[Groh and Hauffa, 2011, extd. version]▶), a large number of NLP features is extracted for every set of emails exchanged between a pair of persons. From the n dimensional space of features, a prediction of valence and intensity is computed with the help of three alternative $n \to 1$ dimensionality reduction techniques. The resulting prediction is then compared to the manual rating using four different scaling techniques.

The **features** considered where statistics of relative message frequency, message frequency balance, message length, use of first name, elongated and obfuscated words, text message abbreviations, words with positive / negative polarity, and colloquial expressions with positive / negative polarity (see •[Hauffa, 2010] ∗[Groh and Hauffa, 2011, extd. version]▶). The **dimensionality reduction techniques** considered where simple average, Principal Component Analysis (PCA) [Bishop, 2006, p561ff.] and Self Organizing Maps [Kohonen, 1982]. The alternative **scaling techniques** considered include assumptions concerning the distribution of ratings (uniform or normal) and whether information of the distribution of manual ratings is included (e.g. as for correcting for rating bias etc.). Each combination of these model elements is evaluated to be able to directly assess the influence of these elements (for the precise results see •[Hauffa, 2010]). The features involving sentiment analysis (which were used for the assessment of relation valence) where computed using a sophisticated expression level **sentiment analysis approach**, where, in contrast to the less successful word level sentiment analysis employed in •[Richter, 2009], a sequence or chunk-based model was used.

These studies are discussed in more detail in ∗[Groh and Hauffa, 2011, extd. version]▶, ∗[Hauffa et al., 2011]▶.

4.5 Challenges and Opportunities for Future Research

As has been discussed above, conceptualizations for social relations imply various difficulties. Instead, modeling the **topics of social relations** may be another way to detail long term social contexts with a wide range of applications (e.g. content-based recommendations (see e.g. ∗[Groh et al., 2011a]▶). Inferring topic models [Steyvers and Griffiths, 2007] from textual communication and investigating their temporal dynamics (e.g. by detecting substantial changes in the quality of 'fit' when comparing topic models with varying number of topics, e.g. using Bayesian Information Criterion (BIC) (see [Ajmera et al., 2004] for an analogous application of BIC for speaker change detection) may be a promising subject of future work. Analyzing the topic dynamics may also allow indirectly inferring underlying changes in the nature of a relation. In a **ongoing study** •[Lichtenberg, 2010a], SN gamification [Deterding et al., 2011] was used to evaluate various keyword extraction (see [Hasan and Ng, 2010]) methods to model topics of social relations. The approach tests various variants of the algorithm as a Facebook application directly on the user's communication data and communicates only the final results of the user's assessment of quality of this modeling, thus preserving privacy. The entertaining effect of the game of judging the model's quality is used to indirectly investigate the quality of algorithm variants. In this way, a significantly higher participation (and thus larger datasets) may be reached, compared to traditional surveys or laboratory experiments.

▷▷▷ Skip related publications and continue with next chapter ▷▷▷

Included Publications:

Groh, G. and Hauffa, J. (2011). Characterizing Social Relations via NLP-based Sentiment Analysis. *Proc. AAAI ICWSM2011, Barcelona, Spain.*

Hauffa, J., Bossert, G., Richter, N., Wolf, F., Liesenfeld, N., and Groh, G. (2011). Beyond FOAF: Challenges in Characterizing Social Relations. *Proc. IEEE Socialcom'11, Boston, USA.*

Chapter 5

Social Situations I: Geometry of Interaction

The chapter discusses how short term social contexts can be detected via pragmatic Mobile Social Signal Processing. After a very brief introductory look onto the fields of Social Signal Processing and Reality Mining, Social Situations as a special model for such short term social contexts are introduced. Basic scenarios for detecting Social Situations using mobile device sensors are discussed. Here, we will focus on the geometry of interaction (mainly body angles and interpersonal distances) as basic signal- or data sources for detecting evidences for or against the existence of Social Situations. An empirical study is presented that investigates and evaluates methods for Social Situation detection on the basis of interaction geometries using a social interaction data-set.

Own publications related to this chapter: ∗[Groh et al., 2010a]▶, ∗[Groh and Lehmann, 2011]▶, ∗[Groh et al., 2011d]▶.

Supervised theses related to this chapter: •[Hammerl, 2009]•[Reimers, 2010], •[Lehmann, 2010], •[Jentschke, 2010], •[Roth, 2010], •[Lizarraga, 2010].

5.1 Short-Term Social Context and Mobile Sensing

Complementary to methods that aim at detecting, modeling or further characterizing long-term social contexts (such as NLP-based methods discussed in chapter 4 or e.g. methods that make use of user modeling and behavioral analysis (see e.g. ∗[Nauerz and Groh, 2008]), we will now focus on methods for detecting, modeling and characterizing **short-term social contexts**. Short-term social contexts may be defined as encompassing models of social behavior and social constellations on the temporal scale of minutes to hours, whereas medium-term social context may be defined as encompassing models of social behavior and constellations with a temporal scope of days to weeks. Long-term social contexts, in that view, may be defined as encompassing of models of social behavior and constellations on the scale of months and years (here, the distinction between medium- and long-term social contexts will in most cases and not be strictly emphasized).

One of the main benefits of the growing availability of large amounts of data on the Web, especially in SN and MSN, which directly or indirectly allows **study-**

ing human social behavior via data-mining on these large publicly available data-sets, is that the “species” under investigation (Homo Sapiens Sapiens) can be observed in its “natural habitat” meaning that natural social behavior is not influenced by a laboratory setting. This growing availability of interference-free observation data has given rise to the term and concept of “**Computational Social Science**” [Lazer et al., 2009]. Besides the vast amounts of data available in SN in view of studying long term social behavior and deriving long-term social context for use in SN services, the mobile phone and its numerous sensors is a valuable tool for also studying medium-term and short-term social behavior and its connections to long-term social behavior [Eagle, 2009], as well as behavior that is not related to IT-based SN / MSN. A reason for this is that the mobile device is usually always carried along by users in a natural and often unconscious way. This implies that its sensors also allow observing the user in view of his / her natural behavior in an interference-free way, thus a deep and natural embedding of the attached sensors into the user's all day life may be established. Studying general human behavior with the use of mobile phones and other mobile sensing devices is usually referred to as **Reality Mining** [Eagle and Pentland, 2006] •[Jentschke, 2010], or a special flavor of Reality Mining, respectively. Mobile device based sensing of behavior and especially social behavior in our case also has the advantage of being infrastructure free, meaning that no further (mostly room-based) infrastructure such as cameras or RFID readers [Finkenzeller et al., 2010] has to be present for collecting the data.

5.1.1 Mobile Social Signal Processing and Reality Mining

The closely related field of **Social Signal Processing** [Vinciarelli et al., 2009] is concerned with analyzing raw sensor data of channels likely to contain behavioral cues which can be interpreted as social signals (see [Vinciarelli et al., 2009]). These channels include **audio** (e.g. via body worn microphones or stationary microphones close to the social interaction being investigated) (see e.g. [Dong et al., 2011]), **video** (e.g. via one or more room-fixed cameras or body worn cameras or camera glasses (‘first person video’)) (see e.g. [Cristani et al., 2011]), **photos** (see e.g. •[Lizarraga, 2010]) or **data from other sensors** such as gyroscopes, compasses, or accelerometers (see e.g. •[Lehmann, 2010]), or active ultrasound sensors (see •[Roth, 2010]). Usually, techniques from digital signal processing are used to preprocess the raw sensor data and extract time series of feature vectors. Machine learning techniques are then used to derive suitable generative or discriminative models (either supervised or unsupervised) in order to use them e.g. as classifiers in order to discriminate various social signals. Preprocessing, feature generation and learning often have strong interdependencies which becomes especially apparent in the case of audio (see chapter 6). Heuristics or further machine learning steps may then be used to **derive models for social behavior on higher levels of abstraction** on the basis of analysis results derived from models of lower level of abstraction. An example may be using audio data of several overlapping conversations to infer patterns of social interaction: After several preprocessing steps (involving Fourier transformation etc.) (see e.g. •[Loock, 2010]), feature-vectors for each time-slice of the signal may be computed, e.g. using Mel-frequency cepstral coefficients (MFCCs) (see e.g. [Zheng et al., 2001]). One may then employ various machine learning techniques (see e.g.

[Tranter and Reynolds, 2006]) to infer respective turn-taking models e.g. with the help of labeled corpora of such audio patterns and compute the most likely turn taking pattern explaining the audio data. Further machine learning steps may then infer models of the social interaction situation and compute the most likely pattern of social situations in a concrete case (see chapter 6). These higher level patterns (social situations) may then be used as a short term social context in various SN / MSN applications (compare Part III).

If sensors in mobile devices such as smartphones ([fun, 2012] [Ter Hofte, 2007]) or more specialized sensing hardware (see e.g. [Choudhury and Pentland, 2002] for an early sociometric device or [Jayagopi et al., 2010] for a more recent application) are used, we may speak of **Mobile Social Signal Processing**. The term especially emphasizes the mobile, autonomous (infrastructure-free) and personal *collection* of sensor data. This does not automatically imply that all the Signal Processing tasks have to be actually *computed* on the mobile devices as well, which can be prohibitive for a real application situation, e.g. because of battery consumption or other device limitations. An alternative can be to transmit the raw signals and compute the signal processing tasks on a server or, cooperatively and in a decentralized way, using techniques from Cloud Computing [Foster et al., 2008]. The delays implied in such a schema are well compatible with the human social dynamics and the temporal requirements of most applications using the derived short-term social contexts. However, in some cases it may also be possible to use pre-trained models of consequences of approximately near universal human behavior (such as interaction geometries) or well founded heuristics that allow the execution of all necessary computations on the mobile device itself ∗[Groh and Lehmann, 2011]▶.

As mentioned above **Reality Mining**, the concept of detecting and understanding (modeling) traces of general human behavior (not necessarily limited to *social* behavior and also including behaviors on medium and longer-term temporal scales) also puts a heavy emphasis on mobile devices but data-sources are not limited to mobile sensors. Patterns of phone calls, bank transactions or other data may be used as well. Modeled behaviors may also encompass *individual* behaviors, where an interpretation as (or establishing a relation to) social signals or social behavior is possible (e.g. compare Symbolic Interactionism [Blumer, 1969]) but only in a more indirect way. However, the overlap in techniques for recording and characterizing various aspects of human behavior is significant, so Reality Mining makes heavy use of Social Signal Processing techniques and both fields thus are closely related. Eigenbehaviors are a prominent example of Reality-Mining models [Eagle and Pentland, 2009], where a Principal Component Analysis (PCA) [Bishop, 2006] of temporal sequences of (e.g.) location data is able to identify typical temporal patterns ('Eigenbehaviors') in the daily behavior of individuals which may e.g. be used for location prediction. Other examples include studying the influence of face-to-face encounters (or, in other words, sequences of short-term social contexts) on the dynamics of diet, exercise-patterns and other factors influencing health, obesity etc. [Madan et al., 2010] or predicting app installations on mobile phones [Pan et al., 2011] by analyzing composite network influences via short term social contexts (e.g. a network of aggregated Bluetooth [Haartsen, 2000] encounters), long-term social contexts (a friendship social network) and other data.

The following sections will, among other aspects, discuss fundamental sociological properties of focused social encounters (social situations) in order to provide a foundation for the discussion of respective models in these sections, broadening and deepening the respective related work sections of the publications discussed here. We will discuss these foundations in more detail than other aspects in this thesis because of the fundamental importance of social situations for the rest of this chapter.

5.2 Social Situations

Social Situations, as a special form of short-term social context, may be defined as instances of a simple indicator model for the existence of co-located [face-to-face] social interaction of two or more persons ∗[Groh and Lehmann, 2011]▶, which may be detected via Mobile Social Signal Processing / Reality Mining techniques and used for SN/MSN applications in various ways (see Part III). In this section we will thus discuss the nature of Social Situations in more detail and discuss means to detect and model them on the basis of **human interaction geometry**. In the subsequent chapter 6 we will broaden the discussion by investigating other data sources and the combination of evidences for Social Situation detection.

The sociologist Ervin Goffman gave the following informal **characterization of a social situation** (see also [Argyle et al., 1981]):

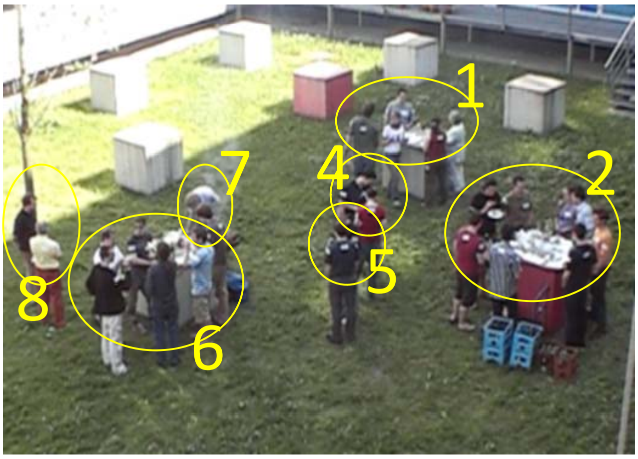
> "I would define a social situation as an environment of mutual monitoring possibilities, anywhere within which an individual will find himself accessible to the naked senses of all others who are 'present', and similarly find them accessible to him. According to this definition, a social situation arises whenever two or more individuals find themselves in one another's immediate presence, and it lasts until the next-to-last person leaves." [Goffman, 1964]

Figure 5.1(a) shows a typical social situation during a barbecue which was initiated to record a large audio-data set for Social Situation detection (see ∗[Groh and Lehmann, 2010]). Figure 5.1(b) shows a larger angle view of the same barbecue at another point in time where social situations are marked with yellow circles.

We define a **Social Situation** S as a three tuple $(P, \widetilde{X}, K)$ of (unique) ids of participating persons P, a subset $\widetilde{X} \subset \mathbb{R}^4$ of space-time (which for our purposes may be viewed as isomorphic to $\mathbb{R}^4$) and a set of key-phrases K. $\widetilde{X}$ demarcates the Social Situation in space-time and K is a simple model for the Social Situation's semantics. For some Social Situations it suffices to regard the temporal and spatial projections $T = \mathbb{P}_t\widetilde{X}$ and $X = \mathbb{P}_x\widetilde{X}$ of the spatio-temporal reference $\widetilde{X}$. If only a spatio-temporal and social demarcation of the social situation is intended or possible to detect, K may be empty. It is further possible to have singleton S with $|P| = 1$, so that for each given point in time, any given set of persons (a society G) may be fully partitioned into (possibly incomplete) Social Situations.

The **capitalized notation ('Social Situation')** denotes the model instance and the **non-capitalized notation ('social situation')** denotes the corresponding

(a) Social Situation



(b) Barbecue with Social Situations

Figure 5.1: Social Situations

modeled cut-out of reality involving the face-to-face interacting real persons, their behavior, thoughts, current emotional state etc.

We will further make the following **defining assumptions** concerning the social situations that we want to model by such S:

1. The participants are engaged in a **physically co-located, direct, synchronous social interaction**.

2. The participants have **immediate full mutual awareness** of (at least) the fact that they are currently interacting at all times during the situation

3. This interaction may involve **all forms** of verbal and non-verbal interaction

The **last assumption** accounts for the fact that even without explicit verbal conversation intense social interaction is possible (e.g. couples kissing or looking each other in the faces etc.).

Assumption (1) effectively **excludes technology mediated social interaction** (aside from e.g. devices compensating for disabilties). It is certainly possible to drop each or all of “physically co-located”, “direct” or “synchronous” and also investigate mediated social situations as in e.g. telephone calls, but here the mere *detection of the existence* of the social situation is usually not difficult. In contrast to that, for social situations involving physically co-located, direct, synchronous social interaction, the rich world of non-verbal signal sources such interaction geometry (relative spatial arrangement of persons, posture etc. (measured via appropriate sensors)) can be and has to be used (possibly in combination with other sources such as audio) to detect their existence, especially in urban settings where other non-involved persons are close and simple techniques such as Bluetooth encounters are prone to produce many false positives. It may, however, be interesting as future work to investigate mediated social situations (e.g. within a public common chat room or a Massive Multi-Player Online Game (see [Ducheneaut et al., 2006])) where no or less explicit markers for interaction are present (as e.g. in contrast to in the telephone call example).

Assumption (2) (together with (1)) is employed to contribute to **excluding nested and overlapping social situations** and to contribute to **sharp demarcatability** of the social situation via X and P, which is necessary for S to be a good indicator model for this social situation. Furthermore, this assumption excludes situations where conscious interaction is only **one-sided**, when e.g. two persons watch a third person and react to this third person looking around by hiding their watchfulness.

As for the **exclusion of nested and overlapping Social Situations**, the basic model $S = (P, \widetilde{X}, K)$ with a more liberal notion of situation awareness and co-locatedness, and without the demand of the interaction being “direct” and “synchronous” would conceptually allow almost arbitrarily (within the boundaries of human consciousness) nested and overlapping Social Situations (or more precisely nested and overlapping tuple-elements of Social Situations) ∗[Groh and Lehmann, 2011]▶. E.g. consider a set of four friends, three of whom visiting a fourth friend over a time period of a week, attending a party of a common old colleague of all four during that week in the apartment of that colleague, during which two of the four are engaged in a vivid discussion in the kitchen of the apartment. In this scenario the week-long visit in the fourth friend’s city may be modeled as the all encompassing situation $S_1 = (P_1, \widetilde{X}_1, K_1)$ while the party may be modeled as a second situation $S_2 = (P_2, \widetilde{X}_2, K_2)$ with $\widetilde{X}_2 \subset \widetilde{X}_1$ and $P_1 \subset P_2$, and the discussion of two of the four may be modeled as the third situation $S_3 = (P_3, \widetilde{X}_3, K_3)$ with $P_3 \subset P_1$ and $\widetilde{X}_3 \subset \widetilde{X}_2$.
The **more “abstract” social situations** in such a possible hierarchy of social situations (S_1 and S_2 in the example) are *hard to immediately detect* with the help of “physical” signal sources and will typically have spatio-temporal references $\widetilde{X}$ with a larger extension and thus are better viewed as medium-term social contexts. It thus appears to be reasonable to investigate how they may be **induced from sequences of “immediate” Social Situations** compliant to assumptions (1)-(3) above. We will thus restrict ourselves to a **strict definition of immediate full mutual awareness** which (together with the demands of a direct, synchronous social interaction in a physically co-located way) contributes to **excluding nestedness and overlap** (see also ∗[Groh et al., 2011d]▶ which adds a more specific

demand of the interaction of being "face-to-face").
It may certainly be possible to model a **whole hierarchy** of justified partitionings of social interaction ranging even below the level of social situations in the sense of (1)-(3) above, e.g. into dyads of persons leading small sub-dialogues while the other persons in the social situation are listening. In this sense, each partitioning $S^{(j)}$ at abstraction level j would be linked to or contributed to by partitions $\{S_i^{(j-1)}\}$ at at the next lower level of abstraction $j-1$, where the extensions of $P_i^{(j)}$, $\widetilde{X}_i^{(j)}$ and $K_i^{(j)}$ typically become smaller with decreasing level of abstraction. However, subdivisions of social situations (in the sense of (1)-(3) above) may be hard to detect and hard to precisely demarcate. We assume that within such a complete hierarchy social situations in the sense of (1)-(3) are justifiable social partitions that are especially suited to be detected from 'physical' signal sources that allow a sufficiently precise demarcation in view of the tuples of a Social Situation model, and that are meaningful short-term social contexts (e.g. optimal partitions in view of episodic memory (compare [Baddeley, 2009], ∗[Groh et al., 2010b]▶ and Part III))

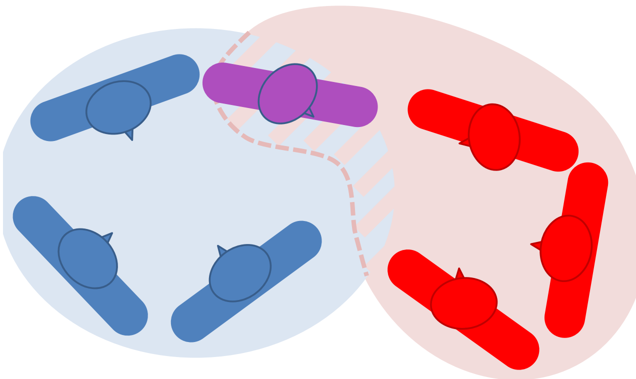


Figure 5.2: Overlapping Social Situations

Even without nestedness and overlapping nestedness in the sense of abstraction, the **relation between precise demarcatability** of social situations and possible **overlaps** between them on their "immediate" level of abstraction **on the one hand** and the **definitions / assumptions (1)-(3) on the other hand** has to be discussed in more depth. If we assume two Social Situations S_1 and S_2 adhering to (1)-(3) above, a substantial overlap occurs if $P_1 \cap P_2 \neq \emptyset \ \wedge \ \widetilde{X}_1 \cap \widetilde{X}_2 \neq \emptyset$. As an example consider a setting as in Figure 5.2. If social situations are not precisely demarcatable, the definition of Social Situations becomes blurred. If sufficiently profound overlaps between Social Situation exist, we can still model it with our simple formalism for S, but we cannot assume that each set G of persons at each point in time can be *partitioned* into exclusive Social Situations $\cup_i S_i = G$.

Immediate full mutual awareness of (at least) the fact that a mutual social interaction takes place as a key ingredient of social situations is supported by [Kendon, 1990, p.4]: "An interactant, thus, must be constantly be attentive to the relationship between his performance and that of others in the encounter and adjust this performance in relation to this". Or, in other words, "In a face-to-face encounter the participant is faced with the necessity of sustaining a complex organization of his behavior which can meet the fluctuations of the situation and maintain him as a fully incorporated participant" [Kendon, 1990, p.4]. It may be concluded that when this complex behavioral organization is not sustained any more, the participant's incorporation into the situation will (automatically) end. Goffman [Goffman, 1966] and [Goffman, 1974] (as cited in [Kendon, 1990, p.240]) and Garfinkel [Garfinkel, 1963] (as cited in [Kendon, 1990, p.240]) argue that a basic set of situational assumptions (where full mutual awareness in our sense is one of the most basic of such assumptions) about the other interactants has to be present (and will be automatically developed via mechanisms discussed in [Kendon, 1990, ch.8]) to be able to conduct "focused" social interaction [Kendon, 1990, p.240]: "In such circumstances participants cooperate together to establish and maintain an offical or common focus of attention on the topic at hand" [Kendon, 1990, p.240], qualitatively citing Goffman's work. "Focused" interaction in the sense of Goffman [Goffman, 1966] is roughly synonymous to social situations as modeled by our Social Situation models. Goffman also significantly contributed to coining the term and concept of "frame" which refers to bracketing interpretational schemata which determines allowed actions for the interactants, guides their perception and allows them to classify and label (e.g. in view of episodic memorization) the interaction situations [Goffman, 1974, p.21]. Mechanisms that bound social situations and bind participants to them are also referred to as Frame Attunement [Kendon, 1990, ch.8]. "Goffman pointed out that in any focused encounter a particular 'definition of the situation' comes to be be shared by the participants [. . .]. A frame comes to be placed around the actions and and utterances of the participants, which both determines the sense in which they are to be taken and servers to define whole ranges of possible acts as irrelevant (not to be taken)" [Kendon, 1990, p.240]. As Kendon points out, Goffman in [Goffman, 1974] emphasizes that in social encounters (social situations) various *attentional tracks* are present: besides the *main-line or story-line track*, a *directional track* is present which is associated with "a stream of signs which is itself excluded from the content of activity but which serves as a means of regulating it, bounding, bounding articulating and qualifying its various components and phases" [Goffman, 1974, p.210] (as cited in [Kendon, 1990, p.243]). These signs or social signals in the sense of [Vinciarelli et al., 2009] may then be used to detect the presence of social situations and their boundaries in terms of P and $\widetilde{X}$.

Interrelations between fine-tuned behavioral patterns and full mutual awareness in particular, on the one hand, and sharp boundaries and the non-overlapping nature of social situations, on the other hand, also become manifest when investigating establishing and ending social situations. In relation to **establishing social situations**, Goffman suggests that such explicit interaction is usually preceded by a number of "clearance signals" [Goffman, 1966, p.91f.] as cited by [Kendon, 1990, p.205], which will not occur by chance (also compare [Kendon, 1990, ch. 6]). "Communication about interpretative perspectives appears as a kind of prior in interaction. It seems that coherent interaction requires this commonality of interpretative perspectives to be established first." [Kendon, 1990, p.240f.]. While actions and social signals preparing the interaction could be observed well before actual salutational actions [Kendon, 1990, p.257], salutations "serve as a bracketing ritual" for social situations [Kendon, 1990, p.258], and thus are good examples for **phatic communication** [Kendon, 1990, p.258]. In terms of their bracketing function and the relation to full mutual awareness, rituals of good-bye or social behavior targeted towards **ending**

a social situation, Kendon states that "In maintaining themselves as participants in a focused interaction, the participants have negotiated a common perspective of relevance for each other's actions. For this to be changed or to be brought to an end, it is necessary for all of the participants to agree to the change or termination before it actually occurs" [Kendon, 1990, p.242]. The complex social behavior required for establishing and ending a social situation as well as changing its nature (e.g. in terms of changing the set of interactants) suggest that boundaries in terms of P and $\widetilde{X}$ may assumed to be sharp and overlaps do not typically occur.

Backed by the sociological research results just discussed, we further assume that **clarity in regard to bracketing** and full mutual awareness in social situations is something that humans strive to either fully establish (e.g. via greeting rituals or body language) or not to establish (e.g. communicated via social signals (e.g. conveyed via body language)) or to end (via rituals of good-byes). In other words, people have a tendency to clear up situations where the "status" of an looming social interaction is uncertain by referring to some commonly accepted mode of communication or by forcing denial of interaction (compare [Goffman, 1966, p.92], ∗[Groh et al., 2011e]▶). This tendency to resolve unclear interaction situations also contributes to avoiding substantial overlaps in Social Situations. It is reasonable to assume that usually a person 'in' an overlap as in Figure 5.2 will decide in favor of one group or, if assuming sufficient social influence, will attempt to unite both situations by establishing full mutual interaction awareness in the whole group by exerting her / his social influence. Furthermore, the tendency towards establishing full mutual awareness also contributes significantly to the precise demarcatability of Social Situations since it will counteract fuzzy states of "partial interaction".

The **class of social situations which is defined by the assumptions (1)-(3)** and which we aim to detect and model via Social Situations appears to be sufficiently **well founded**, conceptually, to be able to decide upon a partitioning of an arbitrary set of persons G into (possibly incomplete) Social Situations $\cup_i S_i = G$ for each point in time t in an unambiguous way. This decision is assumed to be objectively agreeable with small individual deviations among an assumed set of socially competent human observers, given full sensory (visual, audio, etc.) observational data for a sufficiently long history $[t - \tau, t]$. Thus it is reasonable to assume that a **ground truth** may be formulated for each scenario, which can be used to compute performance measures for any Social Situation detection approach.

Furthermore, as is repeatedly emphasized in the respective sociological literature (e.g. reviewed in [Kendon, 1990], [Argyle et al., 1981] and other contributions) **general rules and principles governing social interaction in social situations** exist (see e.g. [Kendon, 1990, p. 4]). This point of view was especially present in the works of Erving Goffman: "He proposed that face-to-face interaction constituted a species of social order, a position he maintained throughout his career. By this he meant that a pervasive set of norms could be described which governs all occasions in which people must communicate with each other It is this completely general set of norms that is the focus of Goffman's interest" [Kendon, 1990, p.39] (compare e.g. Goffman's work [Goffman, 1966]). We thus may hope to construct **valid general or universal models** for certain aspects for social situations and their relation to certain behavioral cues that do not require extensive training or modification in view of a concrete individual's behavior.

The argumentation above supported the assumption that Social Situations may be regarded as **sharply defined in space and time**. However, since the rituals establishing and ending a social interaction (e.g. a greeting) will be divided into several phases themselves (compare [Kendon, 1990, chapter 6] and the discussion in section 5.2) and thus will take a certain amount of time and incorporate a certain space (e.g. the phase of approaching each other (cp. [Kendon, 1990, fig. 17, p. 162])), the **boundary $\partial\widetilde{X}$ of spatio-temporal reference $\widetilde{X}$ of a Social Situation is usually not absolutely sharp** in terms of milliseconds or cm. However, since the temporal duration (and spatial extension) of these initializing rituals can be considered short (several seconds (cp. [Kendon, 1990, chapter 6])) in relation to the temporal extension of the Social Situation itself and since interaction (and thus the Social Situation) can be considered to have started during these rituals already, these potential **inaccuracies in view of defining and detecting Social Situations can be neglected**, especially in view of the targeted applications of Social Situations as short-term social contexts in SN and MSN.

5.3 Detecting Social Situations via Interaction Geometry

The universal social behavior involved in greetings and good-byes may be a means to define **criteria for determining the boundaries of a Social Situation** [Kendon, 1990, p.11 and ch.6]. However, as emphasized in the work by Scheflen [Scheflen, 1964] (see [Kendon, 1990, p.10]), Mehrabian [Mehrabian, 1969], Goffman (e.g. in [Goffman, 1966]) and other researchers and as reviewed by Kendon in [Kendon, 1990, ch.7 and p.247ff], **geometry of interaction** (as manifested in bodily orientation, interpersonal distances and other posture signals) "frames", "brackets" and characterizes social interaction events (social situations) [Kendon, 1990, p.11] in all of their phases of interaction [Kendon, 1990, p.252] including (but not limited to) beginning and ending rituals. Since these social signals and behaviors associated with interaction geometry are considered "transindividual" [Kendon, 1990, p.12] the analysis of interaction geometry may serve as a general means to identify and demarcate Social Situations: "as long as these [spatial] relationships are sustained, so long do we have the same unit of interactional behavior" [Kendon, 1990, p.12] (e.g. a Social Situation or sub-phases of it) (see also [Kendon, 1990, p.247]). In [Kendon, 1990, ch.7], Kendon describes spatial formations of interaction geometry, so called **F-formations**, which are characteristic for social interaction in our sense. In view of detecting Social Situations, he states on [Kendon, 1990, p.250] that "[…] the kind of arrangements that arise in the F-formation provide a means of clearly demarcating the 'world' of the encounter from the rest of the 'world' Entering into an F-formation, thus is an excellent means by which interactional and therefore social and psychological 'withness' may be established". Interaction geometry as a means for bracketing and as a means to communicate and establish awareness in view of the existence and nature of the social situation is also emphasized on [Kendon, 1990, p.209f., p.247 and p.253].

F-formations as defined by Kendon are a synonym for constellations of interaction geometry that arise when two or more people interact and in the course of interacting organize the space between them and in their immediate vicinity according to the universal behavioral patterns discussed before. **Interpersonal distance and relative orientation** are the two main parameters characterizing this spatial arrangement [Kendon, 1990, p.211]. The space that a person is using for his or her current activity (possibly including social interaction) is referred to as his / her **transactional segment** [Kendon, 1990, p.211]. The overlap of transactional segments of the interactants in the F-formation (the participants of the associated social situation) is called the **o-space** of the F-formation. Besides the o-space and the space covered by the bodies of the interactants (the **p-space**), there is a further space of influence of the F-Formation (called the **r-space**) which "functions as a buffer zone, protecting the system from outside influences" [Kendon, 1990, p.211], and which influences the behavior of persons not belonging to the formation (e.g. when passing it). F-formations as arrangements of interaction geometries are a characteristic of social situations and can act as an important criterion to demarcate Social Situations [Kendon, 1990, p.212, 235f.]. They are stable [Kendon, 1990, p.221, 232f.] behavioral manifestations of the "working consensus" (in the sense of Goffman [Goffman, 1966]) "by which behavior in focused encounters is governed" [Kendon, 1990, p.220] and that participants cooperate to maintain [Kendon, 1990, p.216, p.220]. Since the structure of F-formations is governed by general behavioral rules, they are easy to identify [Kendon, 1990, p.232f.] and thus such constellations of interaction geometry may thus be used to detect (demarcate) Social Situations. The interrelation between full mutual awareness of interaction, sharp boundaries (in space, time and interactants) and F-formations as marked constellation of interaction geometries is further emphasized e.g. by investigating the role and behavior of so called *associates* that may arrange their geometry relative to the F-formation because of some relation to it (e.g. waiting for someone in the formation) but that are not members of it [Kendon, 1990, p.233] and by the mechanisms of persons leaving or joining an f-formation (see [Kendon, 1990, p.227ff.]).

As stated above, **interpersonal distance** is one key parameter characterizing F-formations, contributing to shaping its o-space. Hall's famous theory of interpersonal zones, as e.g. briefly discussed in ∗[Groh et al., 2010a]▶, ∗[Groh and Lehmann, 2011]▶ was one of the first investigations, quantizing interpersonal space into four zones and characterizing personal transactional (interactional) segment. The importance of **relative orientation** can be concluded from the very important role that gaze direction plays in maintaining and regulating the social interaction in social situations (cp. [Kendon, 1990, chapter 3]). Kendon defines interpersonal distance and relative orientation characterizing the individual's transactional (in this case interactional) segment with respect to the **lower body**, due to the relative rotational degrees of freedom of upper body and head [Kendon, 1990, p.212, p.248f.]. While it is possible to look out of his transactional segment e.g. via rotating the head, incongruences between transactional segment and orientation of head and upper body are usually of short duration [Kendon, 1990, p.212]. Besides behavioral conventions it is also due to anatomical reasons that it is reasonable to assume a tendency to roughly align the direction of gaze and the direction normal to the upper and lower body on behalf of the interactants at least as far as socio-petal and socio-fugal forces (as e.g. exerted by furniture or other architectural boundary conditions) (cp. [Watson, 1968]) will allow, because ongoing torsions of the upper cervical spine are uncomfortable. When defining the relative orientation of interactants within a spatio-temporal formation we will thus assume that the interactional axis (cp.[Kendon, 1990, p.6, p248f.] of a person characterizing his / her transactional segment is, on average, directed in a normal direction to the surface spanned by the shoulder-line and hip-line, which, in turn, is assumed to have a zero curvature on average (the torsion of the spine is assumed to be zero on average).

While the interaction geometries in social situations are emergent consequences of related general social rules and social behavior, and thus in the absence of constraints imposed by architecture or other influences, F-formations will be well articulated, meaning that a similar number of interactants will lead to a similar F-formation, there may be fine grained variations due to various influences (cp. [Kendon, 1990, p.213f.]). Among these are variations due to the phase of the interaction [Kendon, 1990, p.252], gender or status distribution among the participants, or the greater current social or physical environment (furniture, density of other people (as in a subway) etc.), which have not been very well studied [Kendon, 1990, p.214f.]. E.g. seating arrangements (where (in the absence of corresponding degrees of freedom) posture may take over certain roles of interpersonal distances and orientation [Kendon, 1990, p.227]) are influenced by the competitiveness or cooperativeness of the participants [Russo, 1967] [Vinciarelli et al., 2009]. However, in view of automatically detecting Social Situations via building general quantitative algorithmically processable models, we may assume that these variations are, on average, small compared to the general spatio-temporal properties and building principles of F-formations. Further refinements may then take into account other contexts for refining these models in view of these variations.

5.3.1 Infrastructure-Free Measurement of Interaction Geometry

Interaction geometry in social situations (focused encounters) is mainly characterized by the **interpersonal distances and relative orientation** of the interactants. In •[Lehmann, 2010], •[Roth, 2010] and •[Lizarraga, 2010] and ∗[Groh et al., 2010a]▶, ∗[Groh and Lehmann, 2011]▶ basic methods for **measuring these parameters** were investigated and discussed. Of special interest in view of contextual mobile social networking are methods that are *infrastructure free*, meaning that no specialized measurement equipment has to be installed into the infrastructure surrounding the encounters such as rooms, halls and other architectural environments. In particular, the main focus for MSN must be on the sensors in mobile devices unobtrusively carried by the users such as smart phones, as discussed in section 5.1. Infrastructure free does, however, not mean that present environment sensors are excluded from being used. Neither do we exclude infrastructure that is ubiquitously available such as wireless network access or the GPS system.

However, for the acquisition of training data for the intended algorithmic detection of Social Situations on the basis of interaction geometry, infrastructure dependent methods for measuring relative distances and orientations such as tracking via infrared beacons (see ∗[Groh et al., 2010a]▶, ∗[Groh and Lehmann, 2011]▶), and computer vision methods (either from photography (see •[Lizarraga, 2010]) or video [Cristani et al., 2011]) may be used. A coarse estimation of distance and orientation may also be achieved by using specialized RFID technology [Scholz et al., 2011].

In terms of infrastructure free measurement, standard sensors in mobile devices such as accelerometers, gyroscopes and compasses (magnetic field sensors) (see •[Lehmann, 2010]) and non-standard sensors such as ultrasound-sensors •[Roth, 2010] may be used. As for the direct measurement of interpersonal distances, the feasibility study •[Roth, 2010] has shown that accuracies in the range of 10cm may be achieved. The study •[Lehmann, 2010] investigated measuring interpersonal distance (and thus indirectly also of certain aspects of orientation) via absolute positioning via inertial navigation using sensors with accuracies in the range of those used in modern smart-phones. Unfortunately, the adverse effects of error propagation (see [Woodman, 2007]) could not be overcome with sufficient overall accuracy, despite using sophisticated hardware and algorithmic techniques for error correction and smoothing (•[Lehmann, 2010]). However, the main focus was on methods using absolute position and direct measurement of device orientation with the aforementioned sensors can be considered feasible.

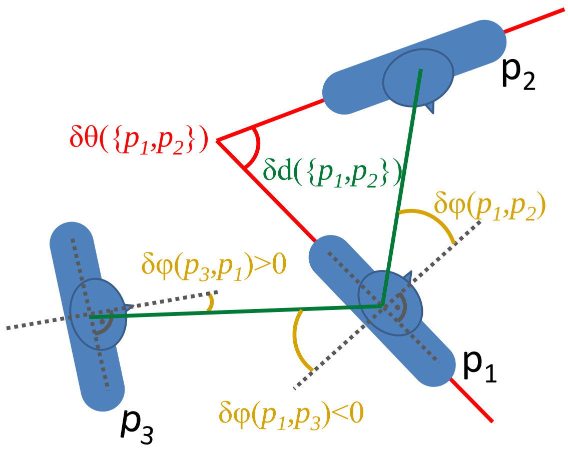


Figure 5.3: Parameters of dyadic interaction geometry

Besides the symmetric dyadic interpersonal distance $\delta d(\{p_1, p_2\})$ and the (in principle also symmetric) dyadic relative orientation of the bodies $\delta\theta(\{p_1, p_2\})$ of interactants p_1 and p_2 ∗[Groh et al., 2010a]▶, it may also be interesting to consider the (unsymmetric) polar angle $\delta\phi(p_1, p_2)$ of person p_2 viewed from person p_1 (see Figure 5.3). In the study ∗[Groh et al., 2010a]▶, this additional quantity was very coarsely represented via introducing a sign to the interpersonal distance representing whether a person p_2 was positioned in the back or in the front of person p_1, which can heuristically be determined cooperatively from the device sensors. However, for proper determination of $\delta\phi(p_1, p_2)$ some knowledge of the position of both p_1 and p_2 relative to some reference point is required. Furthermore, the proper assessment of the spatial formation of the involved bodies from the spatial formation of the mobile devices attached to these bodies must also be taken into account.

The question of how to properly measure interaction geometry with the help of mobile device sensors is still an active area of research, which is an interesting field for future studies.

5.3.2 Detection of and Applications for Social Situations *

As discussed in the previous sections, social situations (n-ary focused encounters) are associated with certain interaction geometries (named F-formations by Kendon), whose arrangement follows certain general rules due to general human social behavioral patterns and which allows precisely demarcating these situations (see e.g. [Kendon, 1990, p.212]). Furthermore, these arrangements of interaction geometry are easy to detect and maintain rather stable throughout the encounter [Kendon, 1990, p.232]. A more fine gained analysis of these interaction geometry may allow temporally partitioning the encounter into certain phases [Kendon, 1990, p.252f.] and additionally analyzing distinct patterns of looking at each other, gestures and facial expressions or turn taking patterns may allow temporally further partitioning the social situation or to infer properties of social relations between the interactants. However, when abstracting from these fine grained structural dependencies and when focusing on the *general properties* of arrangements of interaction geometry in social situations one of the most basic challenges is the detection of Social Situations. This means detecting the presence of focused n-ary encounters on the basis of general models for their characteristic constellations of interaction geometry and demarcating them spatio-temporally ($\widetilde{X}$) and in terms of the set of interactants P, in view of using the detected Social Situations as short-term social contexts in SN and MSN services. **A general algorithmic and technological framework** may incorporate means for measuring interaction geometries, learning and representing the general rules of construction of characteristic arrangements of interaction geometries of Social Situations with the help of Machine Learning techniques and models, and using the resulting formal models to detect Social Situations. Such a framework may also be used to study more fine grained aspects of interaction (such as inferring characteristics of the (long-term) social relation between interactants (as mentioned before) (see e.g. [Cristani et al., 2011]) and for other applications discussed below.

In relation to this general problem field, several (interrelated) **research problems** may be of interest, a subset of which is discussed in ∗[Groh et al., 2010a]▶, ∗[Groh and Lehmann, 2011]▶, and ∗[Groh et al., 2011d]▶:

First of all the right **parametrization of interaction geometry** (or selection of appropriate features in the language of Machine Learning) is an interesting problem. In an n-ary social situation (with an associated n-ary F-formation of interaction geometries) we have to derive expressive features from the full set of $3mn$ absolute positions and orientations $\{x_{ijk}, \theta_{ijk}\}_{i\in\{1,2,3\},j\in[1,n],k\in[1,m]}$ of m bodyparts / limbs of n interactants. One meaningful parametrization of interaction geometry (set of features) discussed above in subsection 5.3.1 is pairwise dyadic interpersonal distances δd (which is symmetric), relative orientation of hip-line or shoulder-line in the xy-plane $(1,2$-plane) $\delta\theta$ (also essentially symmetric) ∗[Groh and Lehmann, 2011]▶ and the relative angle of position (polar angle) $\delta\phi$. This set of features has the advantage of not including absolute references (except for an absolute direction of the xy-plane $(1,2$-plane). For n interactants this set corresponds to $2n(n-1)$ parameters, which have to be represented efficiently in view of the ML algorithms for training a quantitative model (e.g. properly representing the periodic parameters (angles) (see e.g. [Bishop, 2006, p.105ff.]) or quantizing some or all of the parameters into meaningful equivalence classes without loosing relevant information (e.g. quantizing $\delta\phi$ into {inFrontOf(+), behind(-)} or {inFrontOfRight(+r), inFrontOfLeft(+r), behindRight(-r), behindLeft(-l)} etc.). Which parametrization / set of features is optimal in relation to the models or applications is an interesting field of study.

A related problem is whether the analysis of interaction geometry in **n-ary social situations may be approximated by decomposing it into analyzing pairwise interaction geometries** and subsequently inferring n-ary Social Situations (e.g. via appropriate graph clustering methods on the resulting network of pairwise interactions (see ∗[Groh et al., 2011d]▶)), which, especially for large n may result in deviations.

Proper methods for infrastructure free **measurement of the selected features** with mobile devices (for detecting Social Situation for (M)SN services and applications) and for infrastructure dependent measurements with high accuracy (for the development of models and algorithms and for sociological research) is another important field of problems (see subsection 5.3.1). E.g. modeling the error in orientation induced by the (semi-heuristic) body-to-device mapping e.g. induced by variations in carrying the mobile device relative to the body has to be investigated. Further context elements and sensors can be used to contribute to assessing the parameters of the body-to-device mapping e.g. assessing whether it is worn close to the body at all via device temperature and humidity vs. outside temperature and humidity). These questions have to be investigated via appropriate empirical field tests or laboratory tests, e.g. comparing high accuracy infrastructure dependent measurements with infrastructure free mobile device measurements and adapted methods for dealing with local sensor inaccuracies and variations (e.g. in terms of smoothing) as well as higher order abstraction methods to detect and incorporate various other types of context (such as detection of the current activity via mobile sensors and incorporating the results into models for smoothing sensor measurements or body-to-device mappings etc.).

Thus another problem field is detecting and **incorporating other context elements**, either directly related to interaction geometry (such as the the overall 'social density', possibly represented by a parameter $\overline{\delta d}$, e.g. in order to model the influences by a general situation in a full subway wagon compared to an open space), or context elements not directly related to interaction geometry (such as turn taking patterns via audio-sensors).

The detection and incorporation of these other context elements as well as detection of interaction geometries may require or profit from **interaction with sensors in other mobile devices**, either in own devices or in those of other users in spatial proximity. In a decentralized MSN setting users may be represented by social agents (see Part I) and thus this problem may also be formulated in a multi-agent scenario (see [Wooldridge, 2009]). Thus further fields of related problems are sensor fusion for social signal processing, multi-agent-communication and -cooperation evolve, which will be discussed in chapter 6 in more depth. In connection with exchanging raw measurements of analysis results, privacy obviously is a very important aspect, which is discussed in chapter 6 and chapter 8.

As for constructing **quantitative probabilistic models** for the relation between Social Situations and interaction geometries, the alternatives range from binary classifiers that classify constellations of interaction geometry as either belonging to interacting individuals or non-interacting individuals to Dynamic Bayesian Networks (e.g. Hidden Markov Models) that may be trained and tested with temporal sequences of interaction geometries corresponding to F-formation (focused interaction, Social Situations) and sequences not corresponding to F-formations. It may also be possible to incorporate qualitative results from the social sciences to guide the training process. If besides being used in an engineering fashion (e.g. for delivering context instances for the improvement of services) the models' function is also to formalize sociological knowledge, it must be ensured that they are sufficiently human interpretable. E.g. a neuronal net classifier may be less intuitively interpretable than a low dimensional Gaussian Mixture Model, or e.g. latent variables (e.g. in DBNs) should also be sociologically interpretable.

In terms of **applications**, it has been stated many times before that the most basic application of quantitative models for the relation between Social Situations and interaction geometries is the detection of Social Situations (determining P and $\widetilde{X}$). The detected Social Situations may then be used as short-term social context for privacy management chapter 8, in social recommender systems chapter 10, social life logging chapter 7, mobile social games and many other applications and (M)SN services (see Part III).
The models may also be understood as valid quantitative models for proxemics in the social sciences, which may also be used as a basis for future studies, quantitatively investigating the interrelation of interaction geometry and gender, current activity, status etc. The respective results may then be incorporated into one more fine grained, unified quantitative statistical model of this aspect of human behavior (which in turn can then be used for e.g. improved Social Situation detection).

5.4 Challenges and Opportunities for Future Research

There a numerous problems in connection with modeling Social Situations in general and more specifically with the detection of Social Situations from interaction geometry.

One interesting problem in modeling Social Situations is to **derive a meaningful set of keywords**. Investigating suitable non-invasive UIs for manually assigning keywords is a promising field as well as investigating automatic methods using speech detection. For both concepts suitable privacy precautions have to be set up, which, in case of Social Situations is especially interesting because the participants will have to agree upon a **suitable privacy setting for the Social Situation**. The required mechanisms to do that are not yet well understood, neither for a mobile case (as for Social Situations) nor for a more abstract case of an arbitrary community on the Social Web with a more complicated set of items to be protected.

As for some assumptions and some questions raised in section 5.2 more precise sociological justifications have to be found, possibly with the help of large scale studies using mobile phones. One such problem is the question of the identity of a Social Situation: E.g. if one person in a Social Situation of six persons lasting for half an hour leaves for five minutes, it may not be appropriate to model this as a new Social Situation, but is this still true if 2 persons leave for 15 minutes? A related set of problems relates to the question of situation hierarchies discussed in that section: Can we formulate an algebra of Social Situations (possibly akin to Allen's algebra of temporal intervals [Allen, 1983]) that allows 'constructing' higher level (longer-term) Social "Situations" from (lower level) Social Situations and to 'link' Social Situations of the same level of abstraction?

Analyzing histories of Social Situations in terms of contributing to deriving long-term social contexts such as long-term social relations, following the sociological viewpoint of interactionism ("in which individual personality and social structure are regarded as the product of interaction processes" [Kendon, 1990, p.39]) may also be an interesting field of study.

▷ ▷ ▷ Skip related publications and continue with next chapter ▷ ▷ ▷

Included Publications:

Groh, G., Lehmann, A., Reimers, J., Friess, R., and Schwarz, L. (2010a). Detecting Social Situations from Interaction Geometry. *Proc. IEEE SocialCom 2010, Minneapolis USA*.

Groh, G. and Lehmann, A. (2011). Deducing evidence for social situations from dynamic geometric interaction data. *Int. J. Social Computing and Cyber-Physical Systems*, 1(2):206–222.

Chapter 6

Social Situations II: Audio Signals and the Combination of Evidence from Multiple Sources

The chapter discusses audio as an interesting source for social signals allowing the detection and characterization of social interaction and Social Situations in particular. A special focus is on turn taking patterns which exhibit characteristically different coordination properties within social encounters (Social Situations) as compared to turn taking patterns of e.g. pairs of persons in different spatially close Social Situations. An HMM-based approach for the detection of social interaction on the basis of turn taking patterns is introduced. In order to compute turn taking patterns, techniques for privacy preserving speaker diarization have to be investigated and developed that perform well in noisy social environments and situations where not all candidate participants deliver a audio-measurement of their own or no appropriate speaker training data for all persons is available. A pragmatic approach is presented which performs well on two different data-sets and which allows directly inferring probabilities for social interaction. Furthermore, an agent-based approach based on Subjective Logic is presented that allows the exchange and combination of data in view of detecting and characterizing Social Situations of users which are assumed to be associated and represented in a hypothetical decentralized social networking scenario by intelligent social agent applications (partly) running on their mobile devices. The data which can be exchanged and combined range from raw measurements, and intermediate results of analysis (e.g. opinions on the nature and probability of the social interaction), to higher level results (such as Social Situations that the respective users are or are not involved in). Evaluation results confirm that the combination of audio and interaction geometry yield better results than either data source on its own.

Own publications related to this chapter: ∗[Groh et al., 2011e]▶, ∗[Groh and Lehmann, 2010]▶, ∗[Groh et al., 2011d]▶.

Supervised theses related to this chapter: •[Loock, 2010], •[de Souza, 2010], •[Peppmeier, 2010], •[Fuchs, 2010].

6.1 Audio in Social Signal Processing

Important classes of social signals and behavioral cues are detected and communicated visually (and partly tactilely) such as gestures, facial expressions, or those related to interaction geometry [Vinciarelli et al., 2009]. Besides the optical and tactile senses (and besides more exotic 'channels' such as chemical social signals (e.g. exchanged via pheromones) [Rodriguez et al., 2000] [Lundström et al., 2003]), the hearing sense is another major sensor for receiving social signals and the voice its conjugate social signal source. Thus the **analysis of audio data has been a major focus in Social Signal Processing** (see [Vinciarelli et al., 2009]) and related (heavily overlapping) fields such as Reality Mining (see e.g. [Choudhury and Pentland, 2003]), or Affective Computing (see e.g. [Eyben et al., 2009]). As an example consider inferring emotions from speech prosody and other features (see e.g. [Clavel et al., 2008]). Besides high-level prosodic features such as pitch, intensity, or speech rate, low level features e.g. based on Mel cepstral coefficients may be used for this task [Kwon et al., 2003]. Models and methods used for this problem cover the whole range of Machine Learning, such as e.g. Dynamic Bayesian Network approaches (e.g. HMMs [Schuller et al., 2003]), margin-based classifiers (such as SVMs [Schuller et al., 2004]) and other approaches (see [Zeng et al., 2009])).

In view of Social Situations (see chapter 5), [Gatica-Perez, 2009] gives an excellent review of research on **Social Signal Processing focusing on non-verbal social signals in face to face conversation in small groups**, including vision-based analyses of e.g. facial expressions but also reviewing many important studies focusing on audio signals. An emphasis is put on computational methods for modeling and detecting higher level social phenomena and not specifically on the lower level methods aiming at extracting the behavioral cues from the raw data streams. Some studies focused on (short-term) internal states of the participants (such as levels of interest), or (long-term) aspects such as modeling personality (e.g. dominance) while others focused on the social relations between the interactants (e.g. aspects of roles). Especially interesting in view of the detection and demarcation of focused small group interactions (Social Situations) are studies focusing on social signals involved in and mechanisms for the **management of interaction** (e.g. in terms of addressing, turn-taking mechanisms or backchanneling) since the presence of these universal and general behavioral elements used by humans can be used for algorithmic detection and demarcation of these focused encounters (see chapter 5).

Among the social phenomena involved in and resulting from interaction management, **turn taking patterns** [Weilhammer and Rabold, 2003] have great potential for distinguishing persons in social interaction from persons not in social interaction and thus for the detection of Social Situations (see chapter 5). It can be assumed that the coordination of turn taking patterns within focused social encounters will be characteristically different from the (non-existant) coordination of turn taking patterns of persons in different but nearby social spatial constellations ∗[Groh et al., 2011e]▶. A significant share of the work analyzing turn-taking patterns in small group interactions focuses on identifying conversational phases and types (such as monologues, dialogs and presentations) occurring within Social Situations [Gatica-Perez, 2009]. A bias exists towards conversational types occurring in meeting scenarios in a large share of these studies. This can be attributed to the fact that most of the publicly available annotated corpora are in fact acquired from meetings. So while in most of the studies the principal Social Situation was assumed to be known, only a few studies (e.g. [Brdiczka et al., 2005] ∗[Groh et al., 2011e]▶) have been concerned with the problem of detecting it via turn taking patterns, which we will discuss in section 6.2.

In order to compute turn taking patterns from audio data, the temporal segments in an audio stream where each speaker is actually speaking must be correctly identified with the help of (privacy preserving) **speaker diarization** techniques which together with direct methods for social interaction detection will be discussed in section 6.3.

Furthermore, as is emphasized by [Gatica-Perez, 2009], [Vinciarelli et al., 2009] and by many other studies, the use of **multi-modal features** (e.g. audio-based features together with video-based features) is very promising and often yield better results than analyses of isolated modes (e.g. audio only) (see e.g. [Zhang et al., 2004]). Techniques and approaches for **combining and fusioning models and instances of social behavior, social signals, and behavioral cues from different sensor sources and modalities** are identified as key challenges of future SSP. Thus we will also discuss a study on combining evidence for Social Situation detection in section 6.4.

6.2 Detection of Social Interaction via Turn-Taking Patterns *

In a **study** ∗[Groh et al., 2011e]▶, the characteristics of turn taking patterns of pairs of persons within a Social Situation compared to pairs of persons not in a Social Situation were used to **classify a turn taking sequence as either associated with a social interaction or not associated with social interaction**. For that purpose an audio sequence of a 30 minute social interaction sequence with several persons was annotated in terms of the exact turn taking patterns. From that dataset, a set $S^{\oplus}$ of turn taking sequences of pairs of persons in Social Situations and a set $S^{\ominus}$ of turn taking sequences of pairs of persons not in Social Situations (and also a set of 'mixed' turn taking patterns) was derived. Using $S^{\oplus}$ as training set, a four state HMM $\lambda^{\oplus}$ was learned using the standard Baum-Welch EM algorithm [Bishop, 2006]. The same was done with $S^{\ominus}$ yielding $\lambda^{\ominus}$, and for each test sequence s the likelihood for each HMM ($l(s|\lambda^{\oplus})$) and $l(s|\lambda^{\ominus})$) was computed via a simple forward algorithm [Russell and Norvig, 2010, p.573]. These likelihoods (after proper normalization) can be interpreted as probabilities for social interaction $p^{\oplus}(s)$ $l(s|\lambda^{\oplus})$ or for non-social interaction $p^{\ominus}(s)$ $l(s|\lambda^{\ominus})$) of the respective pair of persons associated with s. Using a simple maximum likelihood decision criterion to decide between these two classes yields an accuracy of 0.713, a precision of 0.702, and a recall of 0.774. Using a sliding window approach $s = s_{(t-\Delta t):t}$, we may thus determine for each point in time t a short-term snapshot social network for a set of users using the binary classification for each potential edge. We may then use a hierarchical graph clustering algorithm on this network to yield the actual Social Situations (see ∗[Groh et al., 2011d]▶ for a detailed discussion on this technique and a quantitative evaluation).

An additional related approach [Brdiczka et al., 2005] (which we unfortunately became aware of not until after writing ∗[Groh et al., 2011e]▶) also uses a very similar HMM-based technique to detect conversation subgroups in established social meeting encounters [Brdiczka et al., 2005].

6.3 Speaker Diarization and Direct Audio Based Methods for Social Interaction Detection

As has been mentioned in section 6.1, suitable speaker diarization techniques are required for computing the turn taking patterns. [Tranter and Reynolds, 2006] give an excellent review of state of the art approaches (see also manuals for audio segmentation toolkits such as [Gravier et al., 2010]). Specialized settings (e.g. more than one microphone (e.g. one microphone per speaker, preferrably spatially fixed)) or prior knowledge (speaker specific training data) may allow special variants of speaker diarization or general audio diarization techniques (e.g. via Independent Component Analysis (see e.g. [Parra and Spence, 2000])). However, in a general setting these special conditions do not hold, so the **most general speaker diarization problem** only operates on one or more audio recordings without any further knowledge on the number of speakers or other prior knowledge.

6.3.1 General Speaker Diarization

[Tranter and Reynolds, 2006] describe several **subproblems involved in this type of general speaker diarization**, which sometimes are treated in different orders or in a way where several such subproblems are treated together. Before addressing these subproblems, as discussed above, appropriate **features must be extracted from the raw audio signal**, in most cases involving Fourier analysis, filtering (e.g. MEL filtering) and proper selection of frame lengths (see e.g. [Campbell et al., 2003], [Kotti et al., 2008], or [Ajmera, 2004]). Proper feature selection is a key step for speaker diarization [Ajmera, 2004]. Having computed feature vectors for each frame, the first subproblem consists of **speech / non-speech classification of the frames**. In many cases, adapted variants of Viterbi-segmentation [Gravier et al., 2010] are used, using Gaussian or Gaussian mixture models (GMMs) as sensor models for the involved classes (hidden states / latent variables) (which are often sub-divided e.g. non-speech into music, laughter, breath, lip-smack, and silence and speech into vowels and nasals, fricatives, and obstruents) [Tranter and Reynolds, 2006]. Another subproblem consists in **speaker change detection** in segments of connected frames classified as speech. A usual approach is to use a sliding window approach where the 'suitability' of a model for one speaker (e.g. a single Gaussian) in the window is compared to the 'suitability' for a model for two speakers (e.g. via two Gaussians), which may iterated from coarse detection (e.g. via large windows) to a finer grained step (a smaller window around previously detected change points). Formalizations of 'suitability' and 'comparison' and the involved 'decision' are achieved (see [Tranter and Reynolds, 2006], [Ajmera, 2004], [Gravier et al., 2010]) by using Generalized Likelihood Ratio (GLR) tests (possibly penalized e.g. to account for model complexity) (see e.g. [Green, 2007]) or thresholds based on Bayesian Information Criterion (BIC) (or similar Information criterion measures) (see e.g. [Bishop, 2006, p.216]), other general approaches of Bayesian Model Selection (see e.g. [Bishop, 2006, p.216]), or techniques that compare models to the right and left of the window center with the help of KL-divergence (see e.g. [Bishop, 2006, p.55]). Besides other, more specialized sub-problems that aid the aforementioned ones (e.g. gender detection (e.g. to aid the segmentation step) or bandwidth detection (e.g. to distinguish speakers participating via phone or other technology mediated communication channels) [Tranter and Reynolds, 2006], the central remaining step is to **cluster the detected 'one speaker only' segments**, in order to identify all segments originating from one particular speaker. Here, usually standard hierarchical agglomerative clustering [Jain and Dubes, 1988] is used where appropriate distance measures between the clusters are often established via GLR and the resulting dendrograms are cut via BIC-based cluster validity measures [Tranter and Reynolds, 2006]. If appropriate training data for each speaker is available, a subsequent **speaker identification** step (see e.g. [Reynolds and Rose, 1995][Tranter and Reynolds, 2006]) may be added. This is obviously a crucial step for Social Situation detection based on turn taking patterns (see section 6.2), because without speaker identities, the person ids P interacting in the Social Situation could not be assessed.

A number of standard annotated corpora exist (predominantly from meeting scenarios and broadcast media) which are used for testing the relative performance gain of a new approach. Performance is usually measured by integrating the possible errors (wrongly identified speaker, speech-nonspeech errors etc.) into an overall error measure. The approaches reviewed in [Tranter and Reynolds, 2006] achieve errors on standard corpora roughly between 7 % and 21 %. However, as our own studies showed, these performances are not easily achieved using the published state of the art method stacks in more demanding general scenarios (apart from the rather 'clean' scenarios of the standard corpora) which are more realistic for mobile Social Situation detection.

6.3.2 Specific Approaches for Social Interaction Detection

In an **initial pre-study** •[Loock, 2010] we compiled a survey on state of the art methods for solving the speaker diarization problem in view of computing turn taking patterns for Social Situation detection. The study was focused on a one microphone setting (ideally in a mobile device) and training data for the speaker identification task for a subset of the spatially nearby 'Social Situation candidates'. We implicitly assume a distributed MSN scenario, where each user is represented by his / her social agent (see section 6.4), running on his / her mobile device. E.g. speaker specific audio training data (voice profiles) may be exchanged among such spatially close agents. Thus the study aims at investigating in how far each such agent is able to solve the the general speaker diarization problem using its own microphone to assess as much of the turn taking patterns in its spatial neighborhood as possible in view of ultimately detecting the Social Situation its user is currently in. Practical experiments investigated in how far the current state of the art approaches available as open toolkits for discover were able to be used for the given problem 'out of the box', or, more precisely, to investigate in how far these approaches were more or less specifically tailored to specific settings or corpora for competition (see below). Although a thorough research was conducted in view of retrieving a set of state of the art method-stacks, in our experiments, none of these approaches was able to deliver adequate performance on a small annotated audio corpus representative for the Social Situation detection problem (see •[Loock, 2010] for details).

We thus conducted a larger and more general **study (•[Peppmeier, 2010])** broadening our focus by deepening the investigation and also incorporating other speaker diarization approaches e.g. involving more than one microphone, which would then require exchanging raw audio data (recordings of the same scenario by different microphones) between agents. Clearly such an exchange of raw audio data is problematic in terms of privacy. If possible, such approaches should exchange only derived features of the audio signal, which do not allow reconstructing the content. Unfortunately, many popular features such as MFCCs are problematic in this regard [Wyatt et al., 2007]. We thus also investigated approaches using simple and privacy preserving energy-based features only. Furthermore, we also investigated pragmatic direct methods for social interaction detection avoiding the detour over turn-taking patterns. The study also involved a much broader range of realistic corpora and testing of methods for solving the general (one-microphone) speaker diarization problem discussed above and investigated in the pre-study •[Loock, 2010].

6.3.2.1 Problem Conditions and Corpora

As discussed in chapter 5, the Social Situation detection problem is generally addressed by reducing to detecting social interaction between two potential interactants of the Social Situation and subsequently using methods discussed in section 6.4 to distill the Social Situation from the assessments of binary interaction. More precisely, in a scenario involving m persons in spatial proximity, we will now discuss **methods to determine for each pair of persons** $\{u_{i1}, u_{i2}\} \in \binom{m}{2}$ **a probability** $p^{\oplus}(\{u_{i1}, u_{i2}\})$ **that these persons are socially interacting and a probability** $p^{\ominus}(\{u_{i1}, u_{i2}\})$ **that these persons are not socially interacting** on the basis of audio data. It is the goal to investigate techniques for assessing these probabilities in two ways: first by computing turn taking patterns for each pair $\{u_{i1}, u_{i2}\}$ and applying the technique discussed in section 6.2, and second by assessing them in a direct way.

Usually, the **scenario** involves **heavy background noise** and naturally **heavy cross talk** (otherwise no parallel Social Situations would exist, which this research is attempting to distinguish automatically). Audio or speaker segmentation in such a scenario is often referred to as called cocktail party problem [Haykin and Chen, 2005]. Furthermore, the microphones are assumed to standard microphones of low quality, integrated into mobile devices often attenuated and overlaid by additional noise by carrying them in pockets etc. These aforementioned conditions are usually not present in the standard corpora for speaker diarization and make the speaker diarization especially hard. We take **different microphone settings** (and thus implicitly also different agent cooperation and privacy settings associated with these microphone settings) into account:

- SDM: single distant microphone: if using turn taking based methods, this corresponds to one agent having to solve the general speaker diarization problem discussed above for persons in its spatial proximity including its associated user
- MDM: multiple distant microphones: as for one distant microphone but with agents exchanging recordings of the same scenario, allowing different approaches to speaker diarization, but with increased problems for privacy.
- SNM: one microphone per user, worn close to the body: allowing privacy preserving one speaker turn taking calculations (e.g. on the basis of privacy preserving energy-based features) or direct social interaction detection methods without having to compute turn taking patterns.

The methods investigated and developed are evaluated via **two annotated, realistic own corpora reflecting realistic scenarios** for Social Situation detection. The first corpus ('Barbecue corpus') which is extensively described in ∗[Groh and Lehmann, 2010]▶, involves 25 persons at an outdoor barbecue. Each of the persons wore a microphone (standard MP3-player type) on their chest. For a 30 minute interval of the barbecue, the turn taking patterns for each person and the addressee of each utterance (and thus implicitly the Social Situations) were manually annotated with a frame granularity of 0.5 seconds. The second corpus ('Indoor corpus') is the corpus used for the studies discussed in chapter 5 and extensively described in ∗[Groh and Lehmann, 2011]▶ This corpus involves 9 persons, also interacting in various constellations for 30 minutes. The audio was recorded in the same fashion and all Social Situations and the turn taking patterns for 6 of the nine persons (for calibration purposes only) were also manually annotated.

6.3.2.2 Performance of State of the Art Approaches

In order to **estimate the performance of state of the art systems in the SDM setting**, available **open source toolkits** for solving the associated general speaker diarization problem discussed in subsection 6.3.1 were researched that performed in the top range in state of the art world wide annual competitions on standard well known annotated standard corpora. We investigated the performance in the prestigious NIST competitions (see [nis, 2009]) from 2005 on, and the ESTER 2 evaluation campaign [Galliano et al., 2009] from 2007 on. Of those solutions where respective open source toolkits were available and whose performance on corpora as close as possible to our application scenario (e.g. on annotated meeting corpora with moderate cross talk) were in the top range, the **LIUM toolkit [Meignier and Merlin, 2011][Meignier et al., 2011] was chosen as representing the state of the art** •[Peppmeier, 2010]. Comparing the results of the participating systems over time reveals that in the inspected time domain, no 'quantum-leaps' in performance are present that would give rise to designate very recent advances in the field that did not provide an open source implementation against the system chosen (see •[Peppmeier, 2010]). LIUM uses MFCC- and energy-based features and detects change points using GLR with full covariance Gaussians as models. A standard ΔBIC-based agglomerative approach is used for speaker clustering and a Viterbi segmentation approach with 8 classes (several variants of silence, music, speech etc.) and respective GMMs as sensor models trained separately on annotated corpus data are used for speech / nonspeech detection. Further components to improve performance e.g. consist of a GMM-based gender and bandwidth detection step (see also [Zhu et al., 2006][Zhu et al., 2005] for a closely related approach). It can be seen from the combined values of diarization errors of LIUM and other systems in the aforementioned competitions that the performance of all systems degrades substantially with more cross talk present in the respective corpora (see •[Peppmeier, 2010] and cp. the NIST competition results from 2005 [Istrate et al., 2006][Fiscus et al., 2006b], 2006 [Fiscus et al., 2006a][Zhu et al., 2006] and 2007 [Zhu et al., 2007][Fredouille and Evans, 2008]).

We tested the **performance of LIUM in a series of experiments on the Barbecue corpus** and an own small corpus of a meeting. While the performance on the comparatively 'clean' meeting corpus (clean in terms of amount of cross talk and background noise) was in accordance with the published results (which ensures that the toolkit is used in a correct way), the performance on the Barbecue corpus was unusable for the computation of even approximate turn taking patterns •[Peppmeier, 2010] mostly because of the very heavy crosstalk due to several Social Situations sharing the same acoustic space. From these experiments we conclude that state of the art systems for solving the general speaker diarization problem in an SDM setting are **not appropriate** for turn taking based Social Situation detection •[Peppmeier, 2010] without suitable Blind Source Separation preprocessing steps (see below).

In order to **compensate for the heavy crosstalk in typical situations** with several parallel Social Situations, the performance of **approaches using multiple distant microphones** (an **MDM** setting) was also evaluated. If recordings from more than one microphone are available, techniques of Blind Source Separation (BSS) (see e.g. [Pedersen et al., 2008]) may be applied as a preprocessing step. Here it is basically assumed that the signals X_m from M microphones ($m \in [1, M]$) stem from J original sources S_j with $j \in [1, J]$, where a mapping A maps S to X: $X = A(S)$. (e.g. in the linear case via a mixing matrix A_{mj}). BSS techniques aim at approximately inverting the mapping A to yield $W \approx A^{-1}$ with a variety of techniques applying to specific cases (assumptions about A and S). In our case and the corresponding two corpora, we assume $M = J$, since there were very few persons besides the actual participants not carrying a microphone and those were only speaking very occasionally.

The first considered alternative is assuming a time independent mixing matrix ('**instantaneous mixing**' [Pedersen et al., 2008]). Under certain assumptions, simple PCA- or Independent component analysis (ICA)- based methods may be used on the matrix of the sampled time domain signals X_{mn} (where $n \in [1, N]$ count the samples in a time interval $T \subset \mathbb{R}$) to compute W and the approximated source signals U_{jn}. If the sources are assumed to be uncorrelated (which is certainly not exactly true for our case but can be assumed approximately), we may compute W by a Singular Value Decomposition (SVD) [Eldén, 2007] / PCA which delivers an approximation W yielding a diagonal covariance matrix. Since the SVD is not unique (only unique up to an additional rotation) [Eldén, 2007], a variant of linear ICA [Hyvärinen et al., 1999] distinguishes the particular result among the possible SVD results that maximizes the non-Gaussianity of the approximated sources. Non-Gaussianity is a justifiable assumption [Faundez-Zanuy et al., 2002] if sources are human speakers. We also considered a gradient-based ICA variant [Bell and Sejnowski, 1995]. For all three approaches (PCA, PCA + linear ICA, PCA + gradient-based ICA), Matlab library implementations were used to ensure correctness. We applied all three strategies to the Barbecue corpus as a preprocessing step before applying LIUM on each resulting approximate source in order to compute the corresponding turn-taking patterns. We then compared each resulting turn taking patterns to the annotations for all of the speakers (due to the possible permutation involved in the BSS preprocessing step). The very low quality of the overall results of the experiments indicates that neither of the straightforward BSS approaches under the assumption of instantaneous mixing is able to substantially improve the diarization. We thus conclude that the **assumption of instantaneous mixing cannot be upheld for our case**. Two main contributing factors to why we cannot assume instantaneous mixing are **reverberation** effects and the **motion of the participants** (and thus the motion of their attached microphones) •[Peppmeier, 2010].

To overcome the problem of reverberation, we thus also investigated the assumption of **convolutive mixing** [Pedersen et al., 2008], which results in a time dependent mixing mapping (in the time domain) but allows convenient solutions if Fourier-transformed to the frequency domain. We tested Matlab implementations of frequency domain backward gradient-based ICA [Parra and Spence, 2000] and frequency domain PARAFAC (PARAllel FACtor Analysis) [Nion et al., 2010] which also did not lead to substantial improvements. We conclude that the temporal dependency of the mixing due to the movements of the users which cannot be compensated via the assumptions of convolutive mixing is a key complicating factor for our problem. Furthermore, since in real settings the number of speakers will usually be larger than the number of microphones and further noise will be introduced by relative movements of body and microphone (e.g. when the mobile device is carried in a trouser pocket and since the computational cost for BSS is considerable, **the generalization from a SDM setting to a MDM setting and corresponding usage of BSS techniques cannot be reasonably used to substantially improve the speaker diarization for our case**.

6.3.2.3 Direct Energy-based Detection of Turn Taking and Social Interaction

Due to the failure of state of the art approaches in SDM and MDM scenarios, we investigated possible **solutions that exploit the specifics of an SNM setting**, where each user carries one microphone close to his / her body. Instead of having to handle all the difficulties of the cocktail party problem with a distant microphone setting, we concentrate to solve the binary classification problem of deciding for each user at any point in time, whether this user is currently speaking or not. In a distributed MSN scenario, the agents can then exchange and combine the resulting single user turn taking patterns and perform the Social Situation detection e.g. as described in section 6.2. We called the resulting approaches **Main Voice Activity Detection (MVAD)**. The **energy of the audio signal and derived**

statistics are especially suitable as features for this task, because the sound energy density $E(r,t) \sim p(r,t)^2$ of a spherical acoustic wave $p(r,t)$ emitted by an idealized point-like signal source has a spatial dependency of $E(r,t) \sim 1/r^2$. Thus the time-averaged energy density E_A (and the resulting sound intensity) of speech of a person A registered by a microphone worn by A in a distance of 1 meter to the mouth (e.g. of a mobile in a trouser pocket) will be twice as large as the time-averaged energy density E_B of speech of a person B, whose mouth is 2 meters away from A's microphone, neglecting other spatial influence factors (such as direction dependencies of a real microphone). Thus energy-based features are good candidates to be used for solving the binary classification problem.

The **first variant of MVAD (MFCC-MVAD)**, uses the log mean energy and MFCCs as features. The log mean energy is assumed to contribute to distinguishing the closest audio source (speaker) and the MFCCs are assumed to contribute to distinguishing the type of source. With X_n denoting the audio sample values and using slightly overlapping 30 ms windows, the (average) log energy in a window w is $e_w = log \sum_{n=n_0(w)}^{n_1(w)} (X_n)^2$ where $[n_1(w), n_0(w)]$ are the sample indices belonging to the 30 ms window in question. In order to develop an approach which is universally usable in different audio settings (e.g. outdoor, noisy indoor, quiet indoor), we investigated an unsupervised classification approach by clustering the feature vectors with an EM trained [Bishop, 2006, ch.9] GMM because providing user specific training data for each audio setting for a supervised approach (which would be necessary in view of the comparatively complicated MFCC feature space) is hardly possible. Each frame is classified (assigned to a GMM component k) according to the respective posterior probability (responsibility $\gamma(z_k)$ [Bishop, 2006, p.432]). The components of the GMM corresponding to the highest values of log-energy were assumed to correspond to speech of the microphone carrier. This allowed the desired binary classification (person wearing the microphone speaking vs. other acoustic events) for each feature vector. Finally, a sliding window based smoothing with a window length mirroring typical temporal dynamics of human conversation [Weilhammer and Rabold, 2003] is performed to yield the final single speaker turn taking patterns. Unfortunately, the overall performance of this approach is not sufficient for our purposes, because the MFCC beased features cannot be well modeled with Gaussians (see •[Peppmeier, 2010]) and the number of GMM components in this complicated feature space is hard to determine a priori without specific training data.

We thus decided to concentrate on the **energy-based features**, because the dependence of energy discussed above is a simple and straightforward heuristic which is simple enough to not require specific training data for various speakers in various acoustic settings to yield an acceptable binary classifier. For the **second variant of MVAD (E-MVAD)** we use frame-based featues: normalized averaged log mean energy $\tilde{e}_k$ of each frame k (as in MFCC-MVAD assumed to contributing to the selection of the closest audio source), variance of log mean energy $\text{Var}\{e_w | w \in [w_0(k), w_1(k)]\}$ of each frame k, and (optionally) zero crossing rate of each frame k (both assumed to contributing to differentiating between various types of audio sources because these features are characteristic for human voices (see •[Peppmeier, 2010])). For a frame length of 0.5 seconds (which was chosen to match the manual annotation of our cor-

pora), the log mean energy values are averaged $\overline{e}_k = 1/(w_1(k) - w_0(k)) \sum_{w=w_0(k)}^{w_1(k)} e_w$ (where $[w_0(k), w_1(k)]$ are the window indices belonging to the 0.5s frame k in question) and normalized. The normalization is intended to compensate for different levels of background energy and subtracts the background energy $\overline{e}_{\text{back}}(k)$ assessed with several approaches over a longer (normalizing-)interval of e.g. 10 seconds from $\overline{e}_k$: $\tilde{e}_k = \overline{e}_k - \overline{e}_{\text{back}}(k)$.
In order to account for the problem of missing training data in a real application, we did **not perform a speaker specific training** at all but rather trained a **model for the respective overall audio situation**. In a real application, we estimate that distinguishing indoor and outdoor setting and several carrying positions of the devices is sufficient •[Peppmeier, 2010], so that the resulting overall approach can be designated as '**semi-supervised**'. In a real application, the basic acoustic setting can be detected from audio •[Peppmeier, 2010] and typical carrying positions of the device can be manually configured by each user, with heuristics based on other sensors selecting among the predefined positions. Thus one of the background models may be chosen automatically.
For the E-MVAD approach we used the frame-based feature vectors corresponding to the **two classes** *speaking* and *notSpeaking* of a subset of the annotated single speaker turn taking patterns to train an SVM-based **classifier** with quadratic kernel. The quadratic kernel was chosen on the basis of inspecting the distribution of feature vectors of the two classes in the feature space. We investigated using a KNN classifier with various values of K. For the SVM-based approach the accuracy on the Barbecue corpus was 0.81 and for the KNN-based approach, the accuracy was also ≈ 0.8 only varying very slightly with K. We conclude that the E-MVAD approach unites a good performance not sensitive to the level of background noise with the advantage of only having to provide a coarse non-speaker-specific speech/non-speech model for each acoustic situation in the simple two-(or three-)dimensional feature space.
We then used the **HMM approach** discussed in section 6.2 with a sequence length of 15 seconds **on the turn taking patterns** computed by E-MVAD to **yield**, for each pair of users and each 0.5 s frame k a **probability** $p^{\oplus}(k)$ of social interaction and a probability $p^{\oplus}(k)$ of non-social interaction. We then used the general **clustering based approach** described in ∗[Groh et al., 2011d]▶ **to retrieve the Social Situations**. The only difference (in comparison to ∗[Groh et al., 2011d]▶) is the actual clustering algorithm used. Here we used the Louvain method [Blondel et al., 2008]. The Louvain method as well as the linkage based agglomerative techniques used in ∗[Groh et al., 2011d]▶ both use Modularity [Newman, 2006] to cut the dendrograms. Unfortunately, neither the results on the Indoor corpus nor on the Barbecue corpus were of sufficient quality for our purposes. While the quality of the turn taking patterns computed by the E-MVAD approach is appeared to be sufficient a priori, this may be attributed to the missing total accuracy of the computed turn taking patterns that the HMM approach is very sensitive to, because the subtle differences in correlation between the turn taking patterns of two users in or not in social interaction are crucial for the success of this method and errors in the turn taking of only a few frames may destroy or blur the respective differences.

We therefore investigated a third approach that aims at **circumventing the detour over turn taking patterns** and assess the probabilities $p^{\oplus}(k)$ and $p^{\ominus}(k)$ for each pair of users and each 0.5 s frame k directly. This approach is called **Energy-Based Pairwise Conversation Detection (E-PCD)**. The main idea is to rely on the correlation in energy-based features between the audio signals of microphones of two people talking to each other in their respective socio-consultative zone (interpersonal distances of 1.2m up to 2 m) or even friendship zone (0.5 m to 1m) [Hall, 1968].

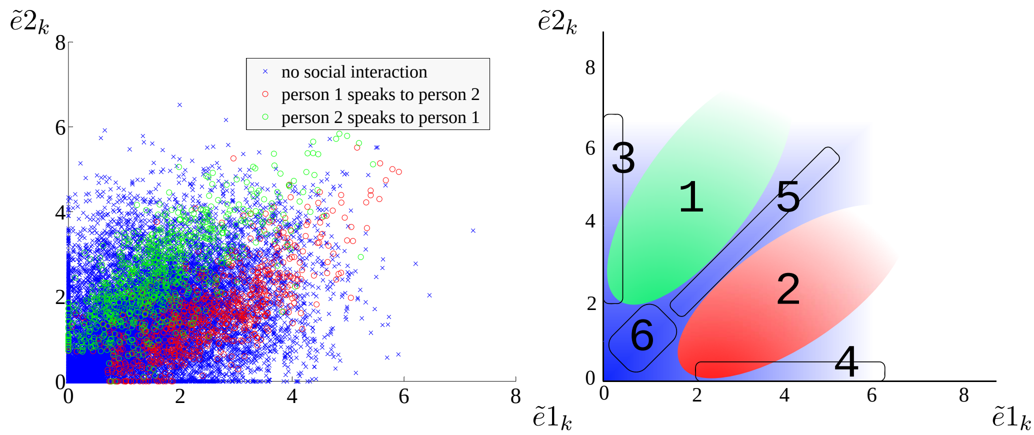


Figure 6.1: Plot of the normalized averaged log mean energies $\tilde{e}1_k$ for speaker 1 and $\tilde{e}2_k$ for speaker 2 for several frames k (left subfigure). Right subfigure: Basic schematic regions of the plot

Figure 6.1 shows a plot of the normalized averaged log mean energies $\tilde{e}1_k$ for a speaker 1 and $\tilde{e}2_k$ for a speaker 2 in the Barbecue corpus. Each point represents one 0.5 s frame. From the annotation we can distinguish the three cases: Speaker 1 speaks to speaker 2 in that frame (red color), speaker 2 speaks to speaker 1 in that frame (green color) and other (blue color). The right sub-figure schematically distinguishes 6 zones occurring in the plot that can be mapped to the following cases (see also •[Peppmeier, 2010]):

1. Person 1 and person 2 are located near each other:

    (a) Person 1 speaks to person 2. Here, on person 1's microphone person 1 will be loudest, while still being substantially represented on person 2's microphone (cross-recording). How much the damping factor on person 2's microphone is depends on the general audio setting. This situation corresponds to zone 2.

    (b) Person 2 speaks to person 1. Symmetric arguments hold as in previous case. This situation corresponds to zone 1.

    (c) Neither person 1 or person 2 speaks. This situation corresponds to zone 6, because the energy level of the background noise has been subtracted in the normalization process.

    (d) Both persons speak (either during overlapping turns or when they do not address each other). In this case both energies are likely to be approximately equal, so that the corresponding feature vectors for events of this class will be likely located in zone 5

2. Person 1 and person 2 are not located near each other.

   (a) Both persons speak. In this situation, symmetric arguments hold as in previous case 1d, so respective feature vectors will also be likely located in zone 5.

   (b) Neither person 1 or person 2 speaks. Again, as above (case 1c), this corresponds to zone 6.

   (c) Person 1 speaks but person 2 does not speak. Because both persons are not immediately closely co-located, the cross-recording effect will not occur and features will be located in zone 4.

   (d) Person 2 speaks but person 1 does not speak. Symmetric arguments hold as in previous case and features will be located in zone 3.

Technically, the approach requires exchanging and temporally synchronizing (privacy preserving) features between pairs of agents. The resulting **feature set** incorporates the **normalized averaged log mean energies** $\tilde{e}1_k$ for speaker 1 and $\tilde{e}2_k$ for speaker 2 with the goal of being able to distinguish conversation from non-conversation according to the case differentiation discussed above. The respective zones will have to be learned by a classifier trained with non-speaker specific examples representing the overall acoustic situation only. Thus this approach can also be considered semi-supervised and is assumed to not have to be trained further if used in real devices. Furthermore the feature set contains the **variance of log mean energy** $\text{Var}\{e1_w | w \in [w_0(k), w_1(k)]\}$ for speaker 1 and $\text{Var}\{e2_w | w \in [w_0(k), w_1(k)]\}$ for speaker 2 (with the same function as in the E-MVAD approach), and furthermore the **covariances of log mean energy** $\text{Covar}\{(e1_w, e2_w) | w \in [w_0(k), w_1(k)]\}$ and $\text{Covar}\{(e2_w, e1_w) | w \in [w_0(k), w_1(k)]\}$ of speakers 1 and 2. The more the two energies of the two microphones are correlated as measured with the covariance, the more likely it is assumed to be that both microphone record the same audio 'micro'-setting (pairs of persons with small interpersonal distances in their respective communication zones). Employing a **KNN classifier** trained by using two random pairs of persons to model the overall acoustic situation, the probabilities for each frame and each pair of persons $p^{\oplus}$ can be coarsely estimated by the proportion of the number of positively labeled vectors to K in the K-neighborhood of a vector to be classified. We can then employ a normalization approach to $p^{\oplus}$ and the derived $p^{\ominus}$ described in ∗[Groh et al., 2011d]▶ or a threshold-based approach to decide the class $\oplus$ or $\ominus$. After having decided the class we furthermore employ a sliding window based smoothing of the resulting binary series with a window length of $\approx 10s$.

On the **Barbecue corpus**, the approach performed better than E-MVAD with an average **per-frame classification accuracy** of ≈ 0.95 •[Peppmeier, 2010]. However, as also even more present in the E-MVAD, while the approach is good at positively identifying pairs of persons at times not in social interaction (which is the by far most frequent case if the number of participants is large) the performance on the subset of actual social interaction events is not as good as on the class of non-social interaction. However, performing the Louvain clustering on the binary series for each pair of persons in each frame k and comparing with the annotations of the Social Situations delivers a much better result than for the E-MVAD approach with the intermediate HMM step. As a measure for the comparison of the partition into Social Situations computed by the approach and the partition from annotation we used the Rand index R [Rand, 1971] and an adjusted version of the Rand index R_{adj} [Hubert and Arabie, 1985] compensating for a non-zero random expectation of the original Rand index. This random correction is especially relevant when the number of participants grows, since random partitions will then result in a large number of singletons which will lead to a large Rand index when compared with each other. However, in the case of human interaction scenarios where several people are co-located for a longer period of time forming changing Social Situations (as in the scenarios of both testing corpora), singleton partitions (persons not interacting with other persons) can usually be assumed to occur only infrequently. The **results of Social Situation detection** on the Barbecue corpus were $R_{\text{adj}} \approx 0.54$ and $R \approx 0.93$ which can be considered **good results** that show that the approach is able to coarsely detect the Social Situations on the basis of audio.

On the **Indoor corpus**, the approach showed a good performance as well. We also used manual annotations of a randomly chosen pair of participants as training data to model the dependencies discussed above in the indoor acoustic situation with a KNN classifier. We used varying values of K (5, 10, and 15), which did not substantially change the quality of the results. The length of the normalization interval was chosen as 10 seconds (other values also did not substantially alter the performance). The smoothing window length was chosen as 60 seconds. The approach yields a good **classification performance** (averaged over all pairs of persons and all frames) of accuracy=0.737, precision=0.709, and recall=0.695 ∗[Groh et al., 2011d]▶. Using various clustering approaches discussed in ∗[Groh et al., 2011d]▶, the average results of the resulting **Social Situation detection** were $R_{\text{adj}} \approx 0.56$ and $R \approx 0.73$. We conclude that for an indoor situation which due to much more profound variations in the energy features was acoustically substantially different from the outdoor (Barbecue) case, the approach worked equally well. Furthermore the detailed results (see ∗[Groh et al., 2011d]▶ show) that neither the clustering method employed nor the detailed heuristic settings discussed above does not have a profound impact on the results. Thus the approach can be considered robust as well.

We conclude that **E-PCD is a robust, suitable approach to audio-based detection of social interaction** with a good classification performance yielding situational social networks which can be used with good success for the underlying Social Situations with the help of appropriate graph clustering.

In chapter 5, methods based on interaction geometry for detecting pairwise social interaction and detecting the resulting Social Situations were discussed, which yield comparable results. The next section will investigate, in how far agents can combine evidence from different signal sources for an improved Social Situation detection.

6.4 Combining Multiple Evidences for Social Situation Detection *

In the **study** ∗[Groh et al., 2011d]▶, we investigate general approaches for the collaboration of personal agents in view of Social Signal Processing and especially for Social Situation assessment in distributed MSN scenarios. This includes protocols for exchanging raw data and features, intermediate low level and and high level results and deciding upon agreements for improving the single agent's assessments. It also investigates approaches and formal frameworks for formulating and combining (intermediate) analysis results. We especially investigate in how far interaction geometry and audio can be combined as signal sources for Social Situation detection.

We develop an **approach** using **Subjective Logic** [Jøsang, 2007] for formulating and combining analysis results in view of agent collaboration that is able to quantitatively deal with uncertainty e.g. in cases where the decision for or against social interaction on the basis of assessments of $p^{\oplus}$ and $p^{\ominus}$ computed from e.g. one of the approaches discussed previously is not clear. The approach is suitable as an abstract language for agent collaboration on all levels of abstraction because it allows formulating and combining uncertain intermediate results with full compatibility to probability theory as well as more discrete results on higher levels of abstraction (e.g. Social Situation assessments) due to its full compatibility with propositional logic.

Using **audio and interaction geometry as examples**, we are able to show that Subjective Logic opinions formed from the raw probabilities $p^{\oplus}$ and $p^{\ominus}$ derived from SSP analysis of these two sensor sources and combining these opinions with the help of suitable Subjective Logic operators for a suitable approach to agent collaboration using intermediate SSP results from other agents and fusion of results from different signal sources: the per-frame classification results as well as the results of the Social Situation detection are **better in the combined cases** as for each signal source separately.

6.5 Challenges and Opportunities for Future Research

The challenges and opportunities in view of **audio-based detection of social interaction** and Social Situations are extremely manifold, because the field of audio-based Social Signal Processing has become so vast. This induces a huge spectrum of methods and approaches that can be applied to and compared for the Social Situation detection problem. Advances in the field of speaker diarization in an SDM or MDM cocktail party problem scenario with proper BSS preprocessing step should allow more accurate turn taking patterns to be computed, which would allow more precise tests of the Social Situation detection method discussed in section 6.2. Direct methods for the detection of social interaction such as the E-PCD approach show a great potential and numerous investigations are possible, such as investigating expanded feature sets. Furthermore, larger scale comparative studies need to show in how far the basic models of acoustic and microphone carrying situations are sufficient to maintain a good performance across various scenarios and in how far an automatic detection of these situations is reliably possible.

In terms of the collaboration of agents in view of SSP, many additional studies are possible as e.g. investigating other suitable approaches for sensor fusion in this scenario, or testing the influence of uncertainty or deliberate deception of agents (and appropriate countermeasures) e.g. in view of gaining advantages in terms of MSN services using the SSP results e.g. via faking the membership in Social Situations to gain access to common information items. E.g. a current study with promising results is investigating agent protocols for reaching agreements on higher level SSP results such as Social Situations.

All the approaches discussed in this chapter and chapter 5 need to be further investigated in realistic scenarios with help of larger corpora, involving more users, larger periods of time and more diverse forms of social interaction in order to be able to assess the level of accuracy and reliability of the detected short and medium term social contexts.

▷ ▷ ▷ Skip related publications and continue with next chapter ▷ ▷ ▷

Included Publications:

Groh, G., Lehmann, A., and de Souza, M. (2011e). Mobile Detection of Social Situations with Turn Taking Patterns. *Proc. WAC2011, Rome, Italy.*

Groh, G. and Lehmann, A. (2010). A New Data-Set for Research on Audio-Detection and Modeling of Social Micro-Contexts. *Tech.-Report TUM-I1011, Institut für Informatik, TU-München, Germany.*

Groh, G., Fuchs, C., and Lehmann, A. (2011d). Combining Evidence for Social Situation Detection. *Proc. IEEE Socialcom'11, Boston, USA.*

Part III

Applications of Social Context

Chapter 7

Awareness and Communication Services and Activity Prediction

The chapter elaborates on the interrelations between Social Networking's Awareness, Matchmaking, and Communication services and service elements and activity prediction as a service element, on the one hand, and social context on the other hand. Visualization techniques for social contexts such as dynamic social network visualization and their connection to Awareness services are discussed. Approaches for Social Life-Logging services, communication services involving Social Situations and Matchmaking services are also presented. The chapter concludes with a discussion on the role of social contexts for activity prediction which, in turn, may represent an interesting service element for Social Networking.
Own publications related to this chapter: ∗[Hanstein and Groh, 2008], ∗[Groh et al., 2009]▶, ∗[Groh and Daubmeier, 2010]▶, ∗[Groh et al., 2010b]▶, ∗[Bapierre et al., 2011]▶, ∗[Falkenmayer et al., 2011].
Supervised theses related to this chapter: •[Hanstein, 2007], •[Goby, 2008], •[Wang, 2009], •[Hammerl, 2009], •[Huber, 2009], •[Klein, 2009], •[Klepper, 2010], •[Goby, 2008], •[Simon, 2010], •[Theiner, 2010].

7.1 Overview of Part III: Social Networking Services and Social Context

In this part of the thesis, comprising of this chapter 7, chapter 8, chapter 9, chapter 10, and chapter 11, we will discuss how **social context on all temporal scales** (short-, medium-, and long-term) may be used in SN- and MSN-services and service elements. In this chapter 7 we will discuss applications in **awareness services**, **Social Life-Logging**, **communication services**, and **mobility prediction**. chapter 8 will discuss applications for **privacy management** and related services. chapter 9 will discuss how social context can be used for **special forms of information retrieval in distributed SN**. **Social Recommender** services and other recommender services using social context are subject of chapter 10, and in chapter 11 we will elaborate on application fields in the domain of **Open Innovation**.

7.2 Awareness and Visualization

Awareness Services are an integral part of Social Networking (SN) and Mobile Social Networking (MSN) ∗[Groh and Schlichter, 2005] ∗[Groh and Daubmeier, 2010]▶. In this context, awareness services may be defined as services or service-elements that inform a user A about events or states which are directly linked with other users B_i of the social network that are participating in Social Networking, both proactively and on request. We may also refer to the notion **Awareness aspect** in case of services that may only partly be characterized as awareness services. In order to maximize usefulness, the states or events linked to B_i must be relevant with respect to a conscious or unconscious information need of A (see also section 9.1). Typically, in view of relevance, it is beneficial if the spatio-temporal reference of these states or events is similar within certain boundaries to the spatio-temporal reference of A, and also beneficial if the B_i are socially closely linked to A, e.g. represented by a short path distance in a graph modeling aspects of the social network (see also the discussion in chapter 9). It may, however, also be relevant to be informed about events or states with a different temporal reference, e.g. **histories** of events or states of B_i as in dynamic social network visualization (see below), or with a different spatial reference or where the social link between A and B_i is weak, e.g. a Chinese teenager 'following' an American movie star on Twitter [twi, 2012].

Examples of such services, represented by questions modeling the corresponding conscious or unconscious information needs they aim to satisfy, may include:

- "Where are my friends? What are they doing?" (examples: Plazes, a geo-social SN platform [pla, 2012], the Activity Feed of Facebook [fac, 2012b], or Twitter [twi, 2012] (of course, besides its strong Awareness aspect, Twitter may also be perceived as a communication service)),
- "What is the communicative state of availability of B_i?" (example: the availability indicator service element in the 'Contacts' panel of Skype [sky, 2012]), or
- "Who's currently interacting with whom?" (no established examples as of August 2011. Compare also chapter 5),
- "Who's socially linked with whom?" (example: Friendwheel Facebook application [Fletcher, 2011], visualizing the subgraph induced by a user's friends), etc.

A **review of such services in the MSN domain** may be found in ∗[Groh and Daubmeier, 2010]▶.

7.2.1 Visualization of Social Context Dynamics as an Awareness Service in (Mobile) Social Networking

Social context on all dynamical scales is intimately linked with Awareness services. The state of a user (or a group of users) conveyed may correspond to his/her short-term social context, as in "Who's currently interacting with whom?", or his/her medium-/long-term social context, as in "Who's socially linked with whom?". As has been mentioned above, in view of relevanve, it can be the case that information may be restricted to events and states linked with B_i that share a short-term or medium-/long-term social context with A (e.g. A's 'friends' on Facebook or people that are currently in a social situation with A).

A **class of examples for the first aspect** where the social context of B_i itself corresponds to the 'state' (and changes in the social context roughly correspond to the 'events'), are services for the **visualization of dynamic social networks**. Here, longer or shorter histories of states and events, as discussed above, are communicated via visualization. A service for the visualization of the short-, medium, or long-term structures and structural changes in a subnetwork of the social network involving $\{B_i\}$ and/or A can serve as an Awareness service for A. An application field, where such visualizations may be useful is the field of Open Innovation, where it is useful to visualize the complex network of possible innovators and its dynamics to identify possible co-innovators, or highly dynamical areas, which may give hints to trends or 'hot-spots' of innovation (compare chapter 11).

7.2.2 Hierarchical Temporal Visualization of Communication Events and Resulting Social Relation Abstractions

In a study in the context of a Bachelor's thesis •[Klein, 2009], we investigated concepts for the **visualization of the hierarchical evolution** of

- social relations of certain types (seen as medium-term and long-term social contexts) from
- series of social interactions (e.g. Social Situations as short-term social contexts (see chapter 5)) and those from
- series of communication acts (e.g. dialogues) and those from
- series of speech acts [Searle, 1965] and those optionally as
- series of simple acoustic utterances.

The **broader focus** of the study was on visualization techniques for **abstraction hierarchies of general temporally ordered events and states**. Besides the social relation case study, a second case study aimed at investigating visualization techniques for a support software for command and control centers, where the abstraction hierarchy evolves from events such as approaches, on-site operations and departures of ambulance-, police-, or fire-fighting-units, over complete operation cycles for single units, to coordinated multi-unit operations, e.g. for the management of larger, multi-party traffic accidents or other disasters. A third case study involved the visualization of art history, where the abstraction ranged from individual works to creative periods in an artist's or a group of artists' body of work to whole art-historic epochs involving many artist contributors.

Considering the understanding of **socio-psychological rules** governing the conceptual hierarchical mapping or grouping of the communicative and social events and states on lower levels of abstraction into events and states of higher levels of abstraction (and especially their translation into appropriate algorithms for mapping or grouping their model counterparts), there is still a **micro-macro gap** [Morris, 2003, p. 174], although numerous contributions to understanding these rules and developing algorithmically usable formulations have been made (for the short-term range see e.g. [Vinciarelli et al., 2009], or chapter 5 (especially ∗[Groh et al., 2011e]▶) for a discussion on how social situations (here perceived as short-term states) may be induced from conversational turn taking patterns, possibly in combination with other social signal sources ∗[Groh et al., 2011d]▶). Where necessary for the visualization, one thus has to rely on the existing rules and methods, heuristic clustering (see [Klein, 2009, section 3.5]), or manual annotation, preferably as a result of or assisted by the insights gained from visualization itself.

As time was chosen as the main organization dimension for hierarchies of temporally evolving states and events in this study, several **options for visualizations** of temporally ordered objects were considered. (Network-centric visualizations as an alternative option for a class of visualizations for dynamic social contexts are covered in the study described in subsection 7.2.3.) Sequentially geometrically ordering objects according to their temporal reference along some curve or line representing a 'temporal axis' has been characterized as one of the most fundamental and most intuitively comprehensible visualization concepts (see [Luz and Masoodian, 2007, p. 197] [Tufte and Howard, 1983, p. 28]; [Klein, 2009, section 4.2]). Naturally, there have been a variety of visualization proposals of incorporating levels of temporal abstraction, e.g. variants proposing two dimensionally splitting up time into divisions on a macro time axis (e.g. hours) and corresponding subdivisions on a micro-time axis (e.g. the minutes of the hour) as in [Hoeber and Gorner, 2009] or for the PCA analysis and visualization in [Eagle and Pentland, 2009] or even as in various forms of calendar visualizations in time planning systems etc. However, the various levels of abstraction of social events and states are likely to cross boundaries of purely temporally abstraction units such as minutes, hours, days, weeks, months etc. and may require more than two (or three) abstraction levels.

Our solution is therefore based on a variant of **Multi-Gantt diagram** (see [Görg et al., 2007]), which is a stacked view of multiple single Gantt diagrams [Gantt, 1913]. Implementing the "Visual Information Seeking Mantra" - 'overview first, zoom and filter, details-on-demand' [Shneiderman, 1996] in a special way. The Gantt charts in increasing y direction visualize higher level events and states, like long-term social relations, usually involving coarser time divisions, while the lower Gantt charts visualize lower level events and states like turn-taking patterns etc. Shneiderman's mantra is thus implemented in a special way because overview and details at the respective desired abstraction level are provided alongside each other ordered by decreasing y position of the respective Gantt diagrams. Thus "zooming" corresponds to investigating a Gantt diagram further below. Similar approaches like [Plaisant et al., 1996] often do not allow viewing abstractions (overview) and details at the same time. Figure 7.1 shows the GUI with the Multi-Gantt visualization for an artifical data-set.

The right part of each Gantt diagram, which is organized in lines with x extension corresponding to to time usually shows textual representations of the entities for

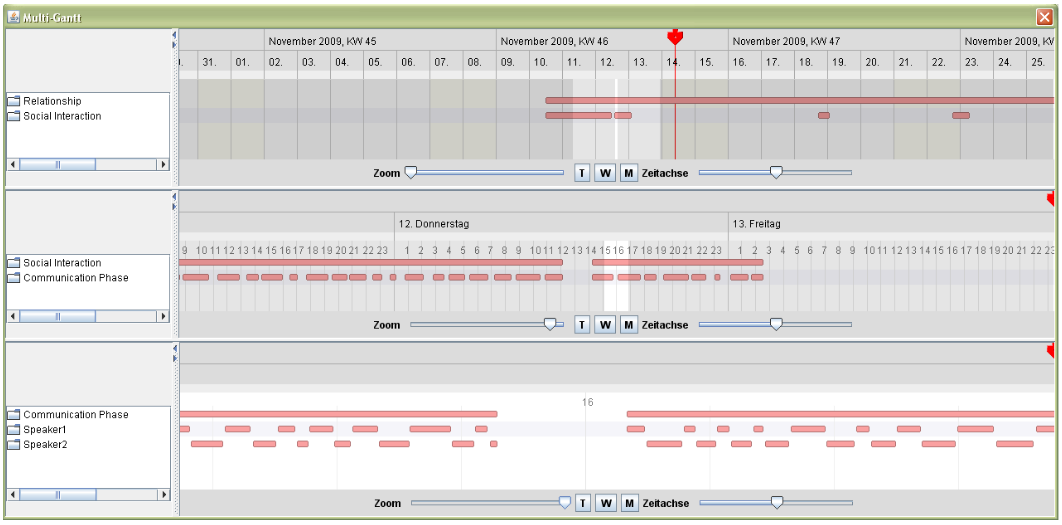


Figure 7.1: Multi-Gantt visualization of social events and states with 3 levels of abstraction (3 Gantt diagrams), each with two sub-levels of abstraction •[Klein, 2009]

which temporal durations are shown. Entities are taken from the domain 'Actors' × 'Type of event / state'. Tool-tips with more accurate descriptions are available for each temporal instance and the hierarchical relations between elements are visualized via brushing and linking [Buja et al., 1991] (see [Isenberg and Fisher, 2009]) when clicking on a member element of a hierarchy. Within each Gantt diagram representing abstraction level n, elements of sub-levels of abstraction $n_1, n_2, \ldots$ (e.g.speech events of various actors on the one hand and their immediate abstraction into communication phases) may be contained. The highest sub-level n_2 of Gantt diagram at level n is also shown in lowest sub-level $(n+1)_1$ of the Gantt diagram at level $n+1$ to ensure visual continuity, while the temporal zoom level of each Gantt-diagram may be individually set as a measure of fine tuning. While the current time is depicted in each level's Gantt diagram as a red marker, the different abstraction level Gantt diagrams are centered in the temporal direction (x-direction), showing the temporal extension of the whole Gantt diagram at level n as a marked (grey) area in the Gantt diagram of level $n + 1$.

The implementation of the **abstraction relations** between level n states and events and level $n + 1$ states and events is achieved by heuristic clustering and/or by manual labeling. The chapters of Part II provide various results that contribute to a better algorithmic assessment and instantiation of these abstraction relations in the domain of short-term events and states. Algorithmic models with respect to the question how medium and long-term relations depend on short-term social situations is an interesting field of research in Social Networking and Mobile Social Networking, where large amounts of data on social contexts of all temporal scales are available for research in view of relating their various levels of temporal abstraction.

7.2.3 Visualization of Social Network Dynamics *

The Multi-Gantt proposal discussed in the previous subsection 7.2.2 simultaneously provides a useful, interactive view on abstract and more detailed aspects of social relation's dynamics for a limited number of actors. Usual network visualizations are able to provide an overview of social relations of a larger number of actors but in their basic forms are not able to visualize relational dynamics.

In another study, ∗[Groh et al., 2009]▶ (see also ∗[Hanstein and Groh, 2008], •[Hanstein, 2007]) we thus investigated techniques for **interactive visualization of network dynamics for social subnetworks with a medium number of actors**.

While numerous techniques for static social network visualization exist (see e.g. [Kaufmann and Wagner, 2001] for a basic overview of graph visualization and e.g. [Brandes and Cornelsen, 2011] for recent approaches), creating useful (interactive) visualizations of the **dynamics** of networks (nodes (actors) or edges (social relations) appearing, disappearing or changing with respect to certain aspects) is still a hard problem within this field (see •[Hanstein, 2007] for a review of related work). When using arrangements or sequences of temporal snapshots of the graph, one of the main challenges is to **preserve the Mental Map** [Eades et al., 1991] of the graph's larger topology while still emphasizing the important dynamical changes. The Dyson system ∗[Groh et al., 2009]▶ thus uses a variation of a tube metaphor (see ∗[Groh et al., 2009]▶) in an interactive 2.5d visualization of time dependent medium scale social networks to preserve the Mental Map by smoothly connecting the time slices of network. Each time slice of the network is laid out by a modified force-based approach [Fruchterman and Reingold, 1991] resulting in proximity coding for tie strength. Forces e.g. inversely proportional to changes in the node's degree or adjacent nodes, attracting nodes to their positions in the previous time slice also contribute to preserving the Mental Map (see ∗[Groh et al., 2009]▶, ∗[Hanstein and Groh, 2008] for the corresponding related and inspirational basic work). Tie strength may be represented as a function of common events of the nodes adjacent to the corresponding edge (compare the discussion in the previous subsection 7.2.2 but the sociomatrix (weighted adjacency matrix) of the network at time t may also be input externally. Color and radius of the tubes may be used to code further attributes of corresponding nodes, e.g. frequency of events associated with that node in the respective time interval in order to portray activity or degree centrality [Koschützki et al., 2005] of the node, which is also associated with a gravitational center force in order to contribute to a immediate visual translation of centrality (see also [Brandes, 1999]).

The major case study for **evaluation** used a self collected, crawled large **dataset** of **Jazz** musicians and (common) activities corresponding to (co-)recordings on albums. Dyson allows various ways to interact with the visualization in order to satisfy the information need of the user.

Figure 7.2 shows the dynamics of the 'co-recording' network of contributors of the soundtrack to the film 'Buena Vista Social Club' as a Dyson screenshot, with color and tube diameter encoding for degree centrality. We see that after the actual collaboration for the recording of the soundtrack, the musicians did not substantially

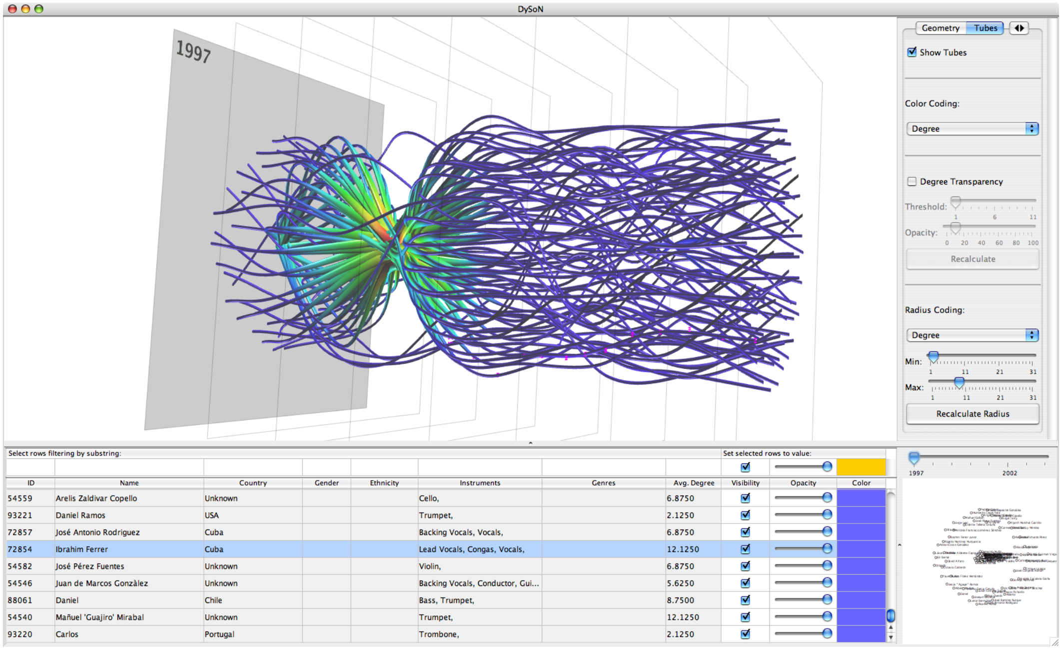


Figure 7.2: Screenshot (added material in •[Hanstein, 2007]) of Dyson, showing the development of the network of contributors of the soundtrack to the film 'Buena Vista Social Club'.

collaborate in the following years. A Dyson-like visualization component with events corresponding to physical social interaction in Social Situations contributing to tie strength and shorter subdivisions of the temporal axis may be useful as an Awareness service element for Mobile Social Networking.

7.2.4 Challenges and Opportunities for Future Research

All visualizations require a certain amount of data-preprocessing to optimize utility. In case of the Multi-Gantt approach an algorithm or manual annotation is required that models the **abstraction relations between social contexts over time**. In case of the visualization of dynamic social networks, also a notion of a temporal mapping between lower level (shorter term) social contexts (e.g. participation in recording an album) and medium and long-term social contexts such as tie strength is required. While research in these mappings certainly is deeply rooted in disciplines such as Sociology and Socio-Psychology, useful algorithmic approximations of these mappings are an interesting interdisciplinary field of research. Other challenges in view of the discussed activities encompass continuing research on techniques for preserving the Mental Map, on choosing the right initial zoom levels in view of potentially interesting dynamical changes, **suitable mobile UI concepts** for interacting with the visualizations, and further use cases in SN or MSN services.

7.3 Social Life-Logging & Socio-Casting *

Life-Logging (see e.g. [Byrne et al., 2008] [Sellen et al., 2007]) is an interesting application field for social context. In conventional Life-Logging, large multimedia streams documenting a single user's life are created with the help of body-worn devices such as SenseCams (see [Sellen et al., 2007]) as a form of electronic diary. **Social Life-Logging** aims to capture the short-term social context as social situations (e.g. modeled as a tuple of a set of persons, spatio-temporal reference and a set of keywords as discussed in chapter 5), mostly also with the help of mobile devices. As proposed in ∗[Groh et al., 2010a]▶, smartphones may be used for the detection of Social Situations. The Social Situations may then either be e.g. used as **retrieval keys in conventional Life-Logging**, where efficient retrieval of multi-media subsequences is still a problem (see ∗[Groh et al., 2010b]▶), or used as 'topics' in a **'pure' Social Life-Logging** application e.g. as a form of social diary. With such a class of applications, we make use of the **episodic memory** [Baddeley, 2009] using episodes and especially the social context of these episodes as one important form of natural 'retrieval keys'. Another interesting alternative is to use Social Situations (or their respective person-sets) as senders and recipients of communication acts, which may be referred to as **Socio-Casting**. Socio-casting may also refer to using other sets of persons derived from medium-term or long-term social contexts as senders or receivers in communication services. In all these services, medium and long-term social context may also be incorporated, e.g. for privacy settings or for determining possible communication forwarders in Socio-Casting (see subsection 7.3.2).

7.3.1 Social Life-Logging

In a **first study on Social-Life-Logging** ∗[Groh et al., 2010b]▶ •[Wang, 2009], an application concept was developed and qualitatively evaluated with a small user study. Assuming that sufficient means for the detection of Social Situations $S_i = (P_i, T_i, X_i, K_i)$ (compare chapter 5) via mobile devices are accessible ∗[Groh et al., 2010a]▶ ∗[Groh and Lehmann, 2011]▶ ∗[Groh et al., 2011d]▶ ∗[Groh et al., 2011e]▶, and histories $\{S_i\}$ of Social Situations involving a user A are available, Social Life-Logging poses a number of interesting problems. How to efficiently and usefully support **browsing** in such a history is one of these problems. A suitable user interface has to provide useful visualizations of and means of navigating the 'landscape' of Social Situations. Another problem is retrieval of Social Situations in view of an explicit **search**. Here, the application has to provide efficient means of interacting with the episodic memory of the user in order to efficiently find one or more Social Situations matching explicit query criteria. Efficient support for formulating queries, efficient index structures, useful matching of query-elements and candidate S_i, and a useful visualization of the result set are challenging.

In the study ∗[Groh et al., 2010b]▶, an **integrated UI concept for browsing and searching** was developed providing solution concepts for some of the problems. For each of the four elements of a Social Situation, an appropriate UI concept for searching and browsing is presented. E.g. for the spatial reference X_i, a map view with icons is provided, which may interactively be used for searching and browsing by changing zoom-levels and map location (center) or by optionally proving addresses or points of interest that are related to map views via third party services. The map is used as an additional visual reference, stimulating the mental reference to X_i and thus finally to S_i. The set of persons P_i of S_i is visualized with the help of a suitably chosen subgraph of the ego-centered network of Social Networking 'friends' or acquaintances, which is also used as a frame of reference for the mental link to P_i, both for browsing and for searching (compare ∗[Groh et al., 2010b]▶).

Generally, for the mapping and comparison of a Social Situation query $S^{(q)} = (P^{(q)}, T^{(q)}, X^{(q)}, K^{(q)})$ to candidate Social Situations S_i, a **similarity measure** $\mathrm{sim}(S^{(q)}, S_i)$ is required. As also partly discussed in ∗[Groh et al., 2011d, (extd. version)]▶, a normalized weighted sum of similarities for each field can be employed. For the comparison of sets of keywords, information retrieval techniques may be used, such as token-based semantic comparison (e.g. via synonym expansion using a semantic lexical database (see ∗[Groh, 2007]▶)), string-comparison (e.g. via edit-distances [Navarro, 2001]), or even machine learning techniques for learning topic patterns in the keywords (such as Topic Models [Blei and Lafferty, 2009], [Steyvers and Griffiths, 2007]). Optionally, special concepts dealing with sparseness and comparison symmetry of such tag-sets may be employed (compare ∗[Groh, 2007]▶). The spatial reference X_i of S_i may be defined as the convex hull of the union of the set of location measurements of P_i during T_i. A similarity measure $\mathrm{sim}(X^{(q)}, X_i)$ between a query geometry $X^{(q)}$ and X_i may be defined via a generalization of the Jaccard index as

$$\mathrm{sim}(X^{(q)}, X_i) = \frac{\int \mathrm{d}^3x \, \min(\rho_{X^{(q)}}(x), \rho_{X_i}(x))}{\int \mathrm{d}^3x \, \max(\rho_a(x), \rho_b(x))}$$

where the $\rho(x)$ are spatial densities for $X^{(q)}$ and X_i on $\mathbb{R}^3$, approximated by the set of location measurements. It is possible to restrict considerations to $\mathbb{R}^2$. It is also possible (see ∗[Groh et al., 2011d, (extd. version)]▶) to generalize separate spatial and temporal references X_i and T_i to a spatio-temporal reference $\widetilde{X}$ for both $S^{(q)}$ and S_i. In this case, it is necessary to integrate over $\rho(x)$ for $x \in \mathbb{R}^4$. This can be beneficial if longer lasting social situations have to be compared or the space of S_i is spatio-temporally very dense and thus more precision may be required. E.g. a Social Situation S_1 corresponding to a group hiking trip from location a to location b in a time interval T_1 and a Social Situation S_2 corresponding to a group hiking trip from location b to location a in the same time interval T_1 will lead to a very high purely spatial similarity and also to a very high purely temporal similarity but to a low spatio-temporal similarity.
For the set of persons, Jaccard index may be sufficient. It may be an interesting field for future studies to weight the persons P_{ij} in P_i with e.g. the path distance in A's social network, because more distant persons may be more interesting and thus a more efficient natural retrieval key considering episodic memory. It may also be interesting to use differences between A and P_{ij} in spatial distances between current location and location of residence using similar arguments (compare chapter 9).

In a **second study** •[Klepper, 2010], the special design implications for a **mobile Social Life-Logging UI**, especially for browsing were investigated and simplified versions of the aforementioned considerations were used for a prototypical IPhone application with Facebook. The recording of Social Situations is manually triggered.

A Web-Service implements a simplified version of the similarity measure between Social Situations, discussed in the previous paragraph, using a weighted sum of the component similarities. The Social Situation data are exchanged between the devices with the help of proprietary protocols •[Klepper, 2010]. If S_i recorded by A is sufficiently similar to S_j recorded by B, A is added to P_j and B is added to P_i. Manual editing is possible and mutual privacy settings (via tresholding the social network distance in Facebook) delimit the set of possible participants in S_i.

Each of the aspects of S_i can be browsed via list or map views on a different screen and each S_i has a detail-page associated with it. For an optimal spatial overview, for each zoom-level, the centroids of X_i matching the current map section are clustered with a simple k-medoids approach [Park and Jun, 2009], which is slightly more stable with respect to outliers than k-means. Clusters of S_i whose centroid distance is below a certain limit are visualized with a common symbol to avoid an overloaded visualization. Other clustering techniques such as DBScan [Ester et al., 1996] are a valid alternative because they allow incorporation of social heuristics via appropriate parameters (compare section 7.4, ∗[Bapierre et al., 2011]▶). Clustering can, in principle, also be used to determine default zoom levels. Despite the rather simplis-

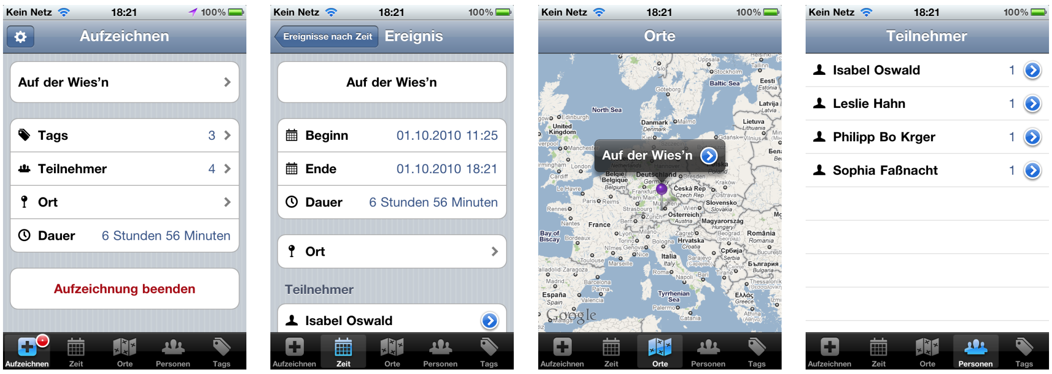


Figure 7.3: (Screenshots from •[Klepper, 2010]). From left to right: Recording Screen, managing starting and stopping the recording; Detail-page of the current Social Situation (here denoted as "Ereignis"); Map view with high zoom level currently containing only one Situation; List of Persons ($\cup_i P_i$)

tic UI concepts, which are shown as screenshots in Figure 7.3, the **evaluation** with 10 participants over 3 weeks, who recorded 60 Social Situations ("Ereignisse") and were each interviewed after the evaluation phase, showed a broad acceptance for the general idea of the application (see •[Klepper, 2010]). In contrast to the social view (person lists), the temporally ordered list of Social Situations was predominantly used for searching particular Situations, while the spatial (map) view and the tags were predominantly used for browsing. Participants stated that precise information was only required on the details-pages of the S_i. As for improvements, the connection of social situations and multi-media content (especially videos and fotos) was stated as a desirable add-on which supports the idea of Social Situations as episodic 'retrieval keys' for these types of content.

Another study, ∗[Falkenmayer et al., 2011], which also takes on the concept of episodes as information management primitives, also investigated mobile UI concepts in the broader field. However, in this study, the focus was on more general episodes, optionally involving only the user himself / herself.

7.3.2 Socio-Casting

While using Social Life-Logging as a social diary or using the S_i as retrieval keys for other types of information associated with them may be useful in itself, such a system and the S_i managed with it (searched, browsed, edited etc.) may also have other applications. One of these applications is using S_i as sources or recipients of communication acts. Such a service may be referred to as **Socio-Casting** in analogy to Geo-Casting [Navas and Imielinski, 1997] where the recipients of communication acts may be determined with respect to their current location. Socio-casting is investigated in a study ∗[Groh et al., 2010b]▶.

Using **Social Situations as senders** in a communication act C may be useful with respect to various aspects. Distributing the sending responsibility to not only a group of people but to a group of people P_i in the context of an S_i may relieve the individual person $P_{ij} \in P_i$ from having to take general social responsibility for acting as a part of the group. It will only require him / her to take the social responsibility for acting as part of a group P_i in the context of S_i, if a receiver is appropriately made aware of S_i as the context of the communication act (e.g. by listing the elements of S_i as part of C's content). Social Situations as senders of communication acts should require the consent of each $P_{ij} \in P_i$, which can e.g. be formally enforced by each P_{ij} having to explicitly state consent to the communication act with his mobile device. In order to implement Social Situations as a senders in a communication act, suitable UI means have to be constructed to allow members of a Social Situation to express the desire to establish such a communication act, to possibly vote on this desire, and to produce and agree on the content and recipients of this act.

Using **Social Situations as recipients** is useful if the sender does not possess the communication-addresses of all persons P_i of the recipient situation S_i. From a 'strength of weak ties'-perspective [Granovetter, 1973], these cases may be especially interesting in view of broadening the personal social network via communication. In contrast to other multi-casting criteria (such as location) which potentially include many unwanted recipients, Social Situations represent a natural frame for casting because P_i can be estimated more easily by the sender. Instead of privacy critically broadcasting the communication addresses of all persons in P_i among P_i during the social situation, intermediates may be used to forward the message. These intermediates may be chosen according to social context starting from the short-term social context S_i itself. If none of the other persons $P_{ij} \in P_i$ is able to or wants to forward to some P_{ij_x}, long-term social contexts (such as the first degree social network of the P_{ij} may e.g. be used (see ∗[Groh et al., 2010b]▶). Employing more general social contexts is usually associated with a decreasing chance of success of the communication act, since privacy settings may prohibit forwarding if the forwarder is not part of P_i himself / herself and credibility of the social link between sender and ultimate recipient as estimated by the ultimate recipient usually dramatically decreases the more forwarding steps are used (see ∗[Groh et al., 2010b]▶, •[Huber, 2009] where candidate algorithms for social forwarding are discussed and evaluated using the Reality-Mining data-set [Eagle et al., 2009]).

Furthermore, analogous to the case of S_i acting as sender, the recipient Social Situation acts as a context which the sender can implicitly refer to. This may relieve him / her from having to make this context explicit by e.g. explaining it verbally as part of the communication act's content ("I am writing to You all because You were at John's party"). The automatically included reference to this situational social context adds another degree of expressiveness to a communication act which allows expressing (as a part of the protocol) that a particular recipient is only addressed as part of a group referring to this context. This explicit, possibly suitably visualized reference as part of this communication type's protocol may give the message a different, more casual character compared to addressing each recipient separately (e.g. as one of an e-mail's recipients) and explaining the context verbally and may contribute to establishing Socio-Cast as a new type of communication in Social Networking, in addition to using groups as recipients of communication acts, which is a standard part of the messaging service in many Social Networking platforms (such as Google Plus' 'Circles' [goo, 2012b]).

Determining senders or recipients of communication acts according to **any social context** (not just Social Situations) and attaching a representation of this social context to the content of this message may be referred to as **Generalized Socio-Cast** and some forms of Generalized Socio-cast are already used in Social Networking, as just discussed. More exotic forms of recipient determination involving social contexts are easily conceivable as e.g. sending a message to users whose Shortest-Path-Betweenness centrality [Koschützki et al., 2005] is above a certain threshold. These forms of Generalized Socio-Casting represent interesting fields for future studies. Socio-Casting and Generalized Socio-Casting may also contribute to individual communicative information management (e.g. by filtering out Socio-Cast messages if $|P_i| > n$, grouping Socio-Casting messages by X_i or T_i, grouping messages by a long-term social context relating sender and receiver etc.).

7.3.3 Challenges and Opportunities for Future Research

The challenges in connection with Social Life-Logging and (Generalized) Socio-Casting are manifold, and some have already been stated in the previous subsections. **Visualizing Social Situations** and their elements is one key challenge in this context. If used for browsing or searching as in Social Life-logging or as communication context as in Socio-Casting, the problem of how to design an (interactive) visualization that efficiently stimulates episodic memory and satisfies related conscious or unconscious information needs is an open problem. New forms of **appropriate UIs and mobile UIs** that allow browsing and searching all forms of social context efficiently are still a challenge (compare subsection 7.2.4). In many cases the UI elements and visualizations will profit from **depending on the short-term social context** as well. As an example consider a UI for choosing a S_i as recipient of a message. If the situation is still ongoing, the UI interaction may have to be different from the case where the situation has already passed. In Socio-Casting efficient means to **collect consent** in the case of using S_i as a sender is an interesting field of study. But prior to collecting consent, the problem arises how to determine a S_i that all participating users or user agents can **agree** upon. This problem is discussed in ∗[Groh et al., 2011d, (extd. version)]▶ and chapter 5. Furthermore, when investigating services like Social Life-Logging and (Generalized) Socio-casting that make extensive use of social context, the problem of **privacy management** is also an obvious field for future research (see chapter 8), e.g. how to efficiently specify and enforce contexts in which a user is willing to be recognized by other users as an element of a social context. E.g. a user may be willing to be recognized by other users (or their mobile agents) as part of Social Situations in the spatio-temporal context 'Saturday night in a club' or in the long-term social context of being other users Facebook 'friend' but not in other contexts. **Reliability of automatic detection of social contexts** (as investigated chapter 5 in the case of Social Situations) is a further special aspect in connection with services that use these automatically detected social contexts. While this problem exists with all context aware applications, mis-detections of social contexts may have other unwanted consequences than e.g. in case of a failed detection of a location context in case of a child-tracking software. These consequences, means of services adapting to these mis-detections, and the perception of users with respect these possible inaccuracies and their consequences are also an interesting case for future investigations.

7.4 Social Activity Prediction *

Activity prediction is about predicting a person's activities from series of this person's activities in the past. In most cases prediction is confined to the *immediate* future (see [Russell and Norvig, 2010, p.573] for a basic reason) considering the *immediate* past (because e.g. standard Bayesian Networks such as Hidden Markov Models will suffer from a strong (often exponential) increase in the number of conditional probabilities to be estimated if the order of the model is increased) (see ∗[Bapierre et al., 2011]▶). Since changes in activities and changes in locations are very often mutually dependent, successfully predicting a user's **location** is a key element and special simplified form of activity prediction. In essence, most systems for location prediction at time t_n take a series of past locations $l_{n-m}, l_{n-m+1}, \ldots, l_n$ and predict the location for t_{n+1}, assuming a suitable definition of 'location' and time-granularization $|t_n - t_{n-1}|$ (see ∗[Bapierre et al., 2011]▶ for related work).

While it is computationally often necessary to limit the *extension* of the series of context-elements used for prediction, using information from **other types of context** such as **temporal context** or social context may improve the quality of the location prediction. In the study ∗[Bapierre et al., 2011]▶ we investigated the impact of using such additional forms of context on prediction quality using two large datasets. First of all, using an representation efficient Variable Order Markov Model (VOMM) with Prediction by Partial Matching [Begleiter et al., 2004], the study is able to confirm several advantages of this technique compared to conventional fixed order Markov Models for basic location prediction, such as improved accuracy and improved cold-start behavior and improvements with respect to the zero-frequency problem. Using temporal context of location visits for location prediction as well, integrating this new type of context information into the VOMM tree constructed purely from location contexts with help of a straightforward subtree technique, the accuracy is again improved substantially. Spatial and temporal context may be linked in various ways: purely temporal context of location visits is largely independent from spatial context. Its representation in the model formalizes habits such as "Every evening at 7 p.m. the user goes home, irrespective of his current location". Spatio-temporal context representations of location visits may correspond to connections such as "every weekday, visits to location B, followed by location C, will result in a following visit to location A with high probability, while on weekends, BC is followed by location F".

Social context may also be incorporated into the model and there is evidence that it also is able to improve prediction accuracy ∗[Bapierre et al., 2011]▶ although the datasets do not provide very much social context information and thus the improvements are not statisticially significant, unfortunately. An example for **short-term social context** influencing location visits may e.g. be represented by a formalization of "When currently playing Badminton at location C, I usually go for a drink afterwards at the bar at location D. If my girlfriend plays with me, I am more likely to visit the vegetarian restaurant E instead". In the VOMM model, for each location $l^{(i)}$, for each person constellation P_j associated with a Social Situation S_j at location $X_j = l^{(i)}$, a model quantity is established which allows the representation of this person constellation and which influences location prediction. This type of influence of short-term social contexts modeled by Social Situations, where the user U himself is in P_j, gives rise to the notion of a type I socializable location $\{l_j^{(i)}$. Type II socializable locations are locations where users from the **long-term social context** of U (in our case the 'friend' network of U) have been together. These are also separately modeled and allow representing connections as in "My friends always go to the bar X after having visited bar Y. Although I have neither been to X or Y, it is likely that I will go to X, when currently with the same friends in X". The information concerning type II locations may e.g. be passed to U during a Social Situation with the corresponding users via their mobile devices.

Successful location prediction can be **used** in a number of ways in Social Networking. Short time planning tasks involving others can profit from probability estimations of their upcoming activities, either on an individual basis or as an accumulated version involving smoothed predictions (e.g. in the form of 'hot-spot densities') for whole parts of the social network. Using only smoothed or coarsened predictions for services can also be a solution in view of the highly privacy sensitive nature of activity and location prediction. Furthermore, for special Social Networking platforms targeting people that require assistance (e.g. because of mental diseases or disabilities) and their assistants, it may be helpful to detect deviations from the routine with the help of Location or Activity Prediction.

7.4.1 Challenges and Opportunities for Future Research

The main challenge in relation to investigating possible uses of social context for activity prediction or location prediction is the **lack of a sufficiently large dataset** that incorporates the necessary social context information. The datasets used in ∗[Bapierre et al., 2011]▶ have only limited usable social context information. Furthermore, Social context may also be helpful when broadening from mere **location prediction to true activity prediction**. While augmenting the location information with e.g. point-of-interest databases or other geo-spatial information may allow induction of activities strongly linked to certain locations (as e.g. a football stadium), social context may provide even more information to induce activity from location. First of all, manual tags for short-term social contexts and activities may be used. E.g. Social Situations contain a keyword element that may be manually filled by one person and shared with the others in P_i. As an example for a short-term social context that does not meet the definition of Social Situation as given in chapter chapter 5, consider a cinema audience. If one or more of the people in the audience tags the activity as 'watching a movie' and that information is made available to others sharing the social context, the other users or their mobile agents may use that information to enrich the description of their perception of the current social context. In that way, the **strong contextual bracket** that especially short-term social contexts provide, may generally be used for a similar way of **analogous reasoning** that is employed e.g. in recommender systems ('if user A likes X and A is similar in taste to B, than B will likely like X as well'). Here the reasoning would follow some variant of 'if user A has information/informationNeed/activity/resource/etc. X, and A is in a Social Situation with B, then B is likely to also have information/informationNeed/activity/resource/etc. X'. Chances and limits of such a type of reasoning involving social contexts are an interesting field of study in view of useful services.

▷ ▷ ▷ Skip related publications and continue with next chapter ▷ ▷ ▷

Included Publications:

Groh, G., Hanstein, H., and Woerndl, W. (2009). Interactively Visualizing Dynamic Social Networks with DySoN. *Proc. ACM IUI 2009 Conf., Workshop Visual Interfaces to the Social and the Semantic Web (VISSW 2009), Sanibel Island, FL.*

Groh, G., Lehmann, A., Wang, T., Huber, S., and Hammerl, F. (2010b). Applications for Social Situation Models. *Proc. Int'l Conf. Wireless Applications and Computing Conference, Freiburg, Germany 2010.*

Bapierre, H., Groh, G., and Theiner, S. (2011). A Variable Order Markov Model Approach for Mobility Prediction. *Proc. STAMI2011@IJCAI2011, Barcelona, Spain.*

Chapter 8

Privacy Management

The main topic of this chapter is privacy management for Social Networking using social contexts. First, we will discuss techniques for the inference of missing profile elements using, among other techniques, clique-based methods which thus make use of a form of long-term social context. Although the corresponding publication focuses on large scale data-mining and not on attacks on the privacy of individuals in particular, this part deals with contrasting methods to those immediately aiming at privacy protection. Privacy management and its relation to the general problem of controlling information flows and its relation to information markets are topics of the second part of the chapter. After introducing several studies on privacy-management and contextual privacy management in Social Networking, we discuss a study relating a new concept for social context sensitive privacy management, control of information flows and information markets in Social Networking.

Own publications related to this chapter: ∗[Kozikowski and Groh, 2011]▶, ∗[Groh and Birnkammerer, 2011]▶

Supervised theses related to this chapter: •[Schmidt-Loebe, 2008], •[Osiander, 2009], •[Boening, 2010], •[Kozikowksi, 2010], •[Birnkammerer, 2010], •[Hammerl, 2011].

8.1 Privacy Management in Social Networking

One central purpose of Social Networking is the **collaborative maintenance of aspects of the social existence** of a network of users **by means of communication** of many types: Direct, 1:1 or 1:n communication (e.g. via messaging), indirect 1:n communication (e.g. via publishing elements of the own context or short text elements for awareness services or publishing a profile with many different types of content such as text, photos etc.) and other forms or communication. While, on the one hand, it is natural to *limit* communication efforts to a subnetwork of acquaintances (e.g. 'friends'), relevant to the own social existence, on the other hand, certain aspects of the communication has to be kept *open and accessible* to non-acquaintances. Especially certain aspects of indirect forms of communication dedicated to self portrayal such as personal profiles are at least partly directed to unknown users, e.g. in order to prepare new social relations to these users. This becomes especially apparent in social networking or community sites dedicated to dating or finding sex partners. Thus a user of Social Networking is often in a dilemma of having to **balance openness and privacy**. Users have to carefully decide which elements of his / her information space or communication content to open to which other users. As a context-centric formulation of the problem, users must decide which elements of his / her information space or communication content (including context information) to open to which other users considering his own set of contexts (social, spatio-temporal etc.) and the contexts of the other users. Most Social Networking platforms rely more or less exclusively on long-term social contexts such as 'friendship' relations to state access rights.

Numerous **problems** arise in connection with providing optimal support for the SN user in accomplishing the task of privacy management. Suitable models of relevant entities and the formulation and execution of access policies must be constructed and suitable (mobile) UIs have to be provided. This also may have to include establishing a culture of privacy management across Social Networking and possibly across society as a whole, which has implications on law-making and social etiquette. In this chapter we will briefly touch upon concepts in relation to these problems.

8.2 Inferring Profile Attributes *

Once the decision has been made which elements of the information space to show to which users (possibly on the basis of contexts), there are however still numerous ways to **infer elements** of this information space which a user has hidden from public view or which have been left out for other reasons, especially in case of user profiles (see related work in ∗[Kozikowski and Groh, 2011]▶ and •[Kozikowksi, 2010]) and many of these methods make use of social context.

Studying such inference methods for profile elements and their rates of success can also give certain **insights in view of privacy management**. These studies can e.g. suggest which elements should be protected as a group, because each element of such a group can be inferred from other elements with a high success rate (as a trivial example consider protecting gender but not protecting first name). Furthermore, these studies can provide insights into the relations between social context and elements of the personal information space of a user. E.g. since education level can be induced from the education level of the group of friends with high precision, it is worth investigating in how far e.g. default privacy settings should protect such profile elements e.g. outside certain groups or subgraphs. Furthermore, these studies can also make a contribution to general awareness in view of the limits of privacy protection.

In a study ∗[Kozikowski and Groh, 2011]▶, we investigated **methods for inferring missing profile elements** with a special emphasis on **large scale datamining**. In contrast to methods aiming at attacking the privacy of decided users, which often exploit structural characteristics of one particular SN platform, the study operates on very large datasets of profiles crawled from over one hundred SN sites. Several classes of heuristic methods that can deal with large datasets are investigated. Among these methods are methods which consider local long-term social contexts such as cliques in the ego-centered 'friend'-networks of users. The success of these methods supports that important connections between social contexts and privacy in Social Networking exist, which supports investigating privacy concepts that make extended use of social contexts. Studies investigating such concepts will be introduced in the following sections.

8.3 Contextual Privacy Management in SN and MSN

We will now discuss **two studies on contextual privacy management**, investigating context elements as *antecedent* model entities / means to express conditions for privacy settings on the one hand (as e.g. the set of friends (long-term social context), space and time, or Social Situations (short-term social context)), and context elements as *consequent* model entities / parts of the personal information space which need privacy protection on the other hand. The first study was an earlier **online survey** investigating user attitudes towards privacy management and contextual privacy management in SN and MSN. The second study presents a design science **investigation on contextual privacy management** in SN and MSN.

As with all studies referenced in this chapter, the **focus** was not on investigating security models in view of preventing privacy attacks (as e.g. via encryption-based systems) and also not primarily on the underlying systems processing or enforcing the privacy settings made (as e.g. rule engines etc.). The ultimate goal is rather to contribute to determining *which context elements* (with a special emphasis on social context) are well suited for use in SN or MSN privacy management, and *how they may be used* and furthermore how they may be *represented* in a suitable user interface.

8.3.1 An Online Survey

In a **study** •[Schmidt-Loebe, 2008], a small online **survey** was conducted in November 2008, investigating **attitudes towards privacy and context in Social Networking and especially Mobile Social Networking**. 230 participants, with an average age of 22.7 years, and, according to self perception, mostly well educated and experienced with respect to IT and the Web, completed the survey of 26 questions. The participants (21.3 % female) were mainly recruited from the social networks of one computer science BA-student on four SN platforms.

As a general trend, the study's results are roughly **compatible with results from previous studies** such as e.g. [Gross and Acquisti, 2005], [Acquisti and Gross, 2006], [Lampe et al., 2007], [Dwyer et al., 2007], [Tufekci, 2008], [Young and Quan-Haase, 2009], (investigating aspects of SN privacy) and e.g. [Motahari et al., 2007], [Anthony et al., 2007], [Chen and Rahman, 2008] (investigating aspects of MSN privacy) (see also ∗[Groh and Birnkammerer, 2011]▶, •[Boening, 2010], •[Birnkammerer, 2010] for related work).

Due to their background, a larger share of participants expressed awareness, involvement and thorough experience with privacy and privacy settings in SN and MSN, than in other studies. The degree of concern in view of SN/MSN-privacy was roughly proportional to the level of active involvement (e.g. by studying privacy settings, changing defaults etc.) with the topic. Of a list of answer possibilities, in view of context, participants confirmed concerns about others being able to construct behavioral profiles, while concerns with respect to combining elements from the public SN information space profile and subsequent inference of other information, or the general concern of others getting to know confidential information about oneself were confirmed less often in relation to other answers. More often confirmed suggestions for concerns were those of the SN platform operator passing data to third persons and the near impossibility to really effectively delete SN data. It may be concluded that a potential desire to 'personally' exert control over the own information space exists which points to **decentralized** SN solutions [Yeung et al., 2009]∗[Groh and Birnkammerer, 2011]▶ (see also section 8.4), or retro-fitted solutions for centralized SN platforms involving encryption such as [Lucas and Borisov, 2008]. In the absence of a fully established context aware MSN service landscape (in 2008), the **negative perception of abuse potentials of context** acquisition is clearly visible in the answer statistics of several survey questions dealing with context and mobility. Actual bad experiences with data abuse or privacy violations were, however, rather low.

A significant share of participants confirmed answer-possibilities expressing desire for **more detailed privacy management possibilities** on the platforms, which platform operators since 2008 have indeed made efforts to improve. Users expressed a disposition to invest on average 18 minutes for an initial privacy setting on a SN platform and users wishing more detailed options, even roughly twice that time. These quantities provide a frame for the **required quality of a possible privacy management UI concept** in mediating between expressiveness and complexity on the one hand and ease of use and efficiency on the other hand.

In view of elements of **social context** as a major **antecedent expression entity for privacy management**, a majority of participants confirmed answer possibilities suggesting the option of subsets of 'friends' (groups) as antecedent entities, which indeed have become a substantial trend in new SN platforms such as Google Plus [goo, 2012b]. It may cautiously be concluded, (confirmed by other surveys and series of expert interviews (see later subsections)) that more fine grained social contexts may be useful as antecedent expression entities.

In view of usefulness of **context aware services**, more than one quarter of the participants not using SN on mobile devices, confirmed that they would use SN on a mobile device (in the sense of true MSN) if it offered a number of simple context sensitive MSN services which were textually described as answer alternatives. This generally **supports the potential of using context** in SN and MSN services.

In terms of **context as consequent model entities** / parts of the personal information space which need privacy protection, using location as an example, only very few participants confirmed answers suggesting access to everybody and still only few (10 %) participants confirmed answers suggesting restricting access to all friends. Over 40 % confirmed the answer suggesting the option to restrict location access to *subsets* of the set of friends. It may be concluded that context information is generally considered to be highly sensitive by users which poses implications for context aware services as well as implications for the protection of context elements.

In terms of **combining social context and other contexts** (such as spatio-temporal context) **as antecedent model entities** for privacy rules, still roughly a third of the users confirmed it as reasonable alternative to provide access to certain friends (social context) that are located 'nearby' (spatio-temporal context), which supports the idea of combining contexts in this way.

In view of differentiating between the **usefulness of certain contexts as antecedents** for rules involving examples of context as consequent entities, participants answer confirmations express that e.g. for access to current user location, temporal context (e.g. access only at certain times of the day) appears to be less useful as antecedent than certain forms of spatial context (e.g. location white-lists). Answers suggesting controlling access by **explicitly stated contexts** (e.g. an 'invisible mode' setting) or manually deciding access on the basis of contexts (e.g. on the basis of social context: "*who* is currently attempting access?")) had by far the most confirmations.
Together with the results of other questions investigating user attitude towards delegating access control to 'automatic' components (e.g. a rule engine) of the privacy management system, this may be an indication that users are not (yet?) fully comfortable with delegating access control to such systems. However, a significant majority expressed a **positive attitude towards learning privacy systems**, when confronted with the option to review and correct access decision histories by an automatic privacy system.

Together with other studies conducted (see following sections), the study supports further investigating limits and chances of context aware privacy management systems in MSN and SN.

8.3.2 A Study on Context-Aware Privacy Management Concepts in SN

In a subsequent study •[Boening, 2010], partially building upon the insights from the online survey referenced in the previous subsection, concepts for contextual privacy management with a special focus on MSN were developed and evaluated in a series of interviews.

Several studies such as [Strater and Lipford, 2008], the experiences gained in the COSMOS project (see e.g. ∗[Groh, 2004], ∗[Brakel et al., 2004]), and also the online survey referenced in the previous subsection, suggest a certain tendency of users to treat privacy settings on an "All or Nothing" [Strater and Lipford, 2008] basis, some users revealing everything to everybody and some use the highest level of restriction possible ("Nothing") for users outside of their circle of friends. Those users usually **invest little time** for fine-tuning privacy settings. For these user groups it is reasonable to provide *default settings* that cover average needs. As antecedent model entities for these default settings, social contexts (e.g. explicitly stated, in form of 'friendship' relations, or implicitly stated via automatic detection, e.g. in case of Social Situations) are especially worth investigating, since it is reasonable to assume that social context reflects social preferences. Social context may function as a good casting reference (see subsection 7.3.2) and thus opening elements of the own information space (e.g. the profile) to groups of people defined via shared social contexts may generally be in the interest of users (see also [Lampe et al., 2007]). Besides the "All or Nothing" group of users, other user groups are, however, found to be willing to **invest substantial time** into fine tuning and desire more detailed options for privacy settings (see previous subsection). At least for those users, a privacy management system should, besides the expressive social contexts, incorporate the possibility to also use other forms of contexts (e.g. spatio-temporal context) or combinations of these as antecedent entities.

Related work in view of privacy management systems using social contexts (e.g. by further qualifying long-term social context e.g. by computing 'intensities' for social network edges [Banks and Wu, 2009], further qualifying 'friendships' by employing graph partitioning techniques for the automatic partitioning of the ego-centered network into groups [Danezis, 2009], combining social roles with spatio-temporal contexts for antecedent privacy management entities [Mitseva et al., 2006], general fine grained combinations of spatio-temporal context elements [Sacramento et al., 2005] etc.) is reviewed in •[Boening, 2010].

For the study, a set of typical context entities, assumed to be representative for SN and MSN platforms and useful in terms of the previous discussion and in terms of results from previous studies, was considered as **antecedent privacy management entities**:

- **Location** and time representing *spatio-temporal context*.
- **Binary social interaction events** between users (as derivable from Social Situations) approximated by location proximity, as an element of *short-term social context*.
- The set of **friends**, labeled **subsets** of this set, the set of **friends of friends**, named freely joinable user **groups**, and '**everyone**', as elements of *long-term social context*.
- **Relation intensity** measured via interaction frequency derived from statistics of social interaction events, messaging, wall-posts, or photo-tagging within certain time periods, as an element of *medium-term to long-term social context*.

As consequent model entities, the following entities were considered:

- As *context* element: the user's **location** in varying degrees of granularity.
- As *non-contextual* elements of a user's information space: his / her **profile**, **guest-book** / Facebook "Wall", and set of **photos** and **photo tags**.

The concept relies on access rules, specifying for each consequent, and for each long-term social context (each "audience") whether access is granted 'always', 'never' or 'conditionally'. For the 'conditionally' case, atomic rule-elements may be constructed using time, or location (via places defined on a map), or proximity of users, or relation intensity (see Figure 8.1). The named rule-elements may then be combined by boolean operators to form rules for the 'conditionally' case. Combinations add additional degrees of freedom for expression (e.g. generally disclosing private information such as location to all ‘friends’ may be considered inappropriate but disclosing it to friends nearby or friends that currently or in the last few hours socially interacted with the user may be more appropriate). Furthermore, combinations of medium-term / long-term social contexts and short-term social contexts appear to be useful due to the lack of full reliability of the automatic detection mechanisms of short-term social context.

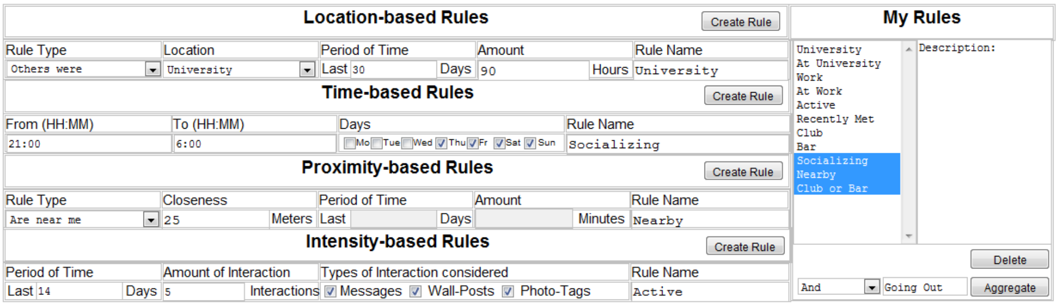


Figure 8.1: Mock up of the UI for defining atomic rule elements •[Boening, 2010].

As an **evaluation** of the concepts, a series of ten 90 minute **semi-structured interviews** were conducted with 5 male and 5 female participants (average age: 21.8 years) at the end of 2010 with a majority being computer science students. Most, but not all of the participants were experienced and regular users of SN sites and mobile devices with typical usage patterns and motives. Most of the participants had no extensive experience with true (contextual) MSN.

Supporting the **general findings** of the previous online survey, participants were concerned about data-abuse by the SN platform providers but less concerned by other users accessing elements of their data that they considered private. Most were satisfied with the usual ‘friend’-based privacy concept of most SN platforms but some avoided uploading very private data, e.g. their phone number, at all because of the coarse granularity of this approach. Most participants expressed willingness to invest substantial time to initially set up privacy settings matching their needs, which supports the idea of offering fine grained privacy management at least as an option. Freely joinable groups aside from the network of friends and friends of friends were not considered to be very useful as antecedent entities, because of lack of control of the composition of these groups. Users generally had a positive attitude towards distinguishing different levels of detail of consequent entities. In view of context-aware MSN services, the findings of the previous studies were confirmed. While e.g. location-based services were regarded as useful, location was considered a very sensitive consequent entity with a tendency to not share it and concerns about criminally abusing location information were uttered.

Evaluating the use of **social context elements as antecedent privacy management entities**, the participants were first introduced to the system-suggestion described above. **Location** was considered a suitable antecedent entity by most participants, but as a sole antecedent entity could be imagined by most only for controlling location as a consequent entity. In accordance with the study •[Schmidt-Loebe, 2008], **temporal context** received a mixed acceptance (e.g. because users considered their activities to be too unstructured or unpredictable, temporally).

Proximity-based rule elements were judged positively by 30 % of the participants as being useful in certain situations (e.g. certain locations), while the majority's concerns where e.g. a lack of control of who may be nearby. This shows that decided short-term social contexts such as Social Situations may be more useful than mere proximity criteria. 40 % viewed the combination of proximity-based rule elements and long-term social context rule elements as useful e.g. for revealing location, which again supports combinations of contexts. Negative views towards proximity as a criterion to reveal 'more' also resulted in most cases from a general unwillingness to use MSN as a means to get into contact with strangers. In respect to **histories of contexts** as antecedent entities, users could not identify suitable use-cases, but some users uttered that location histories may be a sufficient hint that someone actually belonged to a certain freely joinable group, which was judged before as an unsuitable antecedent. Again this supports combinations of contexts as more expressive than atomic contextual rule elements alone. Proximity histories were also largely disapproved because of inaccuracies (see above). **Relation intensity** was judged as a suitable antecedent entity, but concerns were uttered that inferring relation intensity via interaction frequency might be misleading since e.g. with very very close friends, real life interaction may be preferred to interaction via SN communication services. This points to also using "non-virtual" short-term social contexts such as Social Situations as additional antecedents.

In general, the study showed that combinations of context elements may be more useful than single context elements. Inducing social context from overly simple criteria may lead to unwanted results, so social context detection must be reliable in order to be used for privacy. Since the concerns in view of inaccurately detected social contexts may also be transferred to services using these contexts (as e.g. Socio-Casting (see subsection 7.3.2)), it can be concluded that a thorough understanding of the detection of social context is a necessary ingredient of contextual Social Networking.

8.3.3 Challenges and Opportunities for Future Research

Psychological studies may be able give more insights into how users perceive the simple IT models of context and social context as means to manage privacy, e.g. how well these models are able to map their privacy relevant emotional perception of physical and social space.

While the studies discussed in the previous subsections were able to give some initial and basic insights into contextual privacy management for SN and MSN, **more empirical and design studies** are necessary to determine which elements from context and especially social context may be used for useful privacy management in SN and MSN and how they may be used and presented.

The **difficulty** of such studies lies in the enormous **complexity** of the space of **alternatives** which can only be realistically explored step by step which makes it difficult to compare a broader range of alternatives and their combinations in a realistic setting.

A promising sub-field of privacy management systems for SN and MSN are **recommendation**-based privacy management systems, which can contribute to reduce the complexity for the single user by recommending him / her suitable privacy settings that other users found helpful or that other users made on average (see e.g. [Liu and Terzi, 2010], [Maximilien et al., 2009] or [Bonneau et al., 2009] for related approaches). Furthermore, privacy management systems **learning from user feedback** to a privacy management system's decisions in view of access to a certain item / with a certain degree of granularity / on the basis of current settings and current contexts are also promising.

8.4 Privacy, Information Flow Control and Information Markets

In a **third and more extensive study**, ∗[Groh and Birnkammerer, 2011]▶ (see also •[Birnkammerer, 2010], •[Hammerl, 2011]), the problem of contextual privacy management in SN and MSN was set into context with the general concepts of **information flow control** and **information markets** and a new form of contextual privacy management concept for decentralized SN / MSN was developed.

In essence the **goal of privacy management** in SN and MSN corresponds to ensuring that an information item is not used by other users against the interest of a user with a high probability (if a probability of 1 is desired, the item should not be part of an SN information space). 'Using against interest' may include viewing a private photo as well as showing it around to other users or an insurance company or employer analyzing SN profile-elements and deciding to deny the user an insurance contract or deny promoting him to a better job. Thus in essence, privacy management is about attributing the right set of rights in relation to an information item owned by user A to any other user B attempting to handle (e.g. read or communicate) the information item. Here, 'user' can also refer to a particular role of a person as well.

Since the **key idea of social computing** is the '**prosumer**' concept (users producing useful content for other users), and the number of information items produced is very high, from an information management perspective, it is important for each user to **control his / her incoming information flow**. Means to control incoming information flows correspond to e.g. subscribing to the right feeds or to employ information filtering techniques etc. (see ∗[Groh and Birnkammerer, 2011]▶, •[Birnkammerer, 2010]). In SN it is also important to **control outgoing information flows**. On the one hand because this also supports information management by specifying suitable audiences. But even more important than that, on the other hand because information items are produced that are not intended to be accessed by the greater public, since a main purpose of SN is to support users in managing their social existence. Means and goals of controlling outgoing information flows are essentially congruent to those of privacy management: users (or systems on behalf of users using appropriate settings) have to decide, which other users are given rights to read or re-distribute certain information items to in order to best support their positive social interests (maintaining social contacts, social recognition and acceptance etc.) as well as in order to best support them avoiding other users' negative interests (cyber-mobbing, crime, etc. or the cases discussed above). Thus privacy management has to be seen in the greater context of controlling information flows in SN and MSN, with implications on the way a privacy system is constructed and also with implications on how it is perceived by the users and made an integral part of SN / MSN platforms or decentralized SN / MSN protocols.

Going even further, the exchange of information items in SN and MSN may be modeled by mechanisms of an **information market** with social capital as an abstraction of property / assets, information items as objects of trade and the dynamics of incoming and outgoing information flows governed by supply and demand and respective price building mechanisms. Prices may be used as an indicator of common valuation of usefulness of an information item and trading may be used as an additional means to control incoming and outgoing flows of information items and maximize social utility. Implications of this view are discussed in ∗[Groh and Birnkammerer, 2011]▶, •[Birnkammerer, 2010].

8.4.1 Contextual Privacy Management Concept *

A **contextual privacy management concept** ∗[Groh and Birnkammerer, 2011]▶, •[Birnkammerer, 2010], •[Hammerl, 2011] was developed in view of the aforementioned considerations and in view of the results of the surveys presented before. The concept is mainly targeted for a **decentralized SN / MSN scenario**, where each user has full control over the flow of his / her information items. It is designed on the basis of existing elements from Social Semantic Web [Breslin et al., 2009b], XACML [OASIS, 2011] and GeoXACML [OGC, 2011b]. The only **rights** are 'read' (which corresponds to the right to consume the item) and 'repost', (which corresponds to the right to communicate the item to other users). These rights are not necessarily enforced by the system but together with **complete traceability** of each information publishing or re-publishing **speech act** (see ∗[Groh and Birnkammerer, 2011]▶) the system ensures that in case of conflict a challenged user must prove that he had sufficient rights to accessing or reposting the item. However, enforcement is an option. Traceability is realized via signatures and a special form of **sticky policies** and reposting is bound to only narrow down the rights associated with the original post, which guarrantees third party privacy. These elements together realize what is referred to as the **Matryoshka principle** ∗[Groh and Birnkammerer, 2011]▶. The antecedent entities for the rules defining the respective rights for an information item (which can be combined with Boolean operators) are Social Situations as short-term context (see chapter 5), spatio-temporal context, and subnetworks of the social network (as long-term social context). The relations of the social network are qualified via intrinsic 'vector-space-like' or more precisely 'relation-polytope' descriptions ∗[Groh and Hauffa, 2011] ▶, because of the problems that ontologies for social relations pose (see chapter 4, ∗[Hauffa et al., 2011]▶ and •[Bossert, 2010]). XACML entities and mechanisms are used to acquire the required antecedent information which is otherwise not publicly accessible. The framework's expressiveness includes and substantially extends all antecedent expressions that have been found useful in the previous studies without substantially increasing complexity.

Two evaluations of the concept were conducted: an online survey involving 61 participants mainly investigating the basic assumptions ∗[Groh and Birnkammerer, 2011, extd. version]▶, •[Birnkammerer, 2010] and a series of expert interviews •[Hammerl, 2011].

8.4.2 Challenges and Opportunities for Future Research

This research is coupled and related to many **other fields** discussed in this thesis, such as those discussed in chapter 5 in view of the reliability of short-term social context detection, or chapter 4 in view of appropriate descriptive modeling of (long-term) social relations. Thus, research in each field may stimulate and direct research in one of the other fields.

The association of information flow, control, privacy management and **information markets** in SN / MSN gives rise to a number of interesting research questions, such as questions in view of representations of social currency, questions in view of market mechanisms and price building, game theoretic models of information markets in SN and MSN, possible business models and many more.

The privacy management / information flow control concept presented, also implies many questions which have to be investigated more thoroughly: **enforcement**-based concepts vs. non-enforcement concepts relying on openness through traceability and new forms of social conventions (see •[Birnkammerer, 2010], ∗[Groh and Birnkammerer, 2011]▶); questions concerning the usefulness of the required **set of rights**, questions concerning which **expressions involving the long-term social network** are useful for privacy management / information flow control (e.g. providing 'read' to everybody but restricting 'repost' to users with an above threshold centrality); questions concerning the **protection and efficient handling of antecedent context elements** in the XACML framework (see ∗[Groh and Birnkammerer, 2011]▶, •[Hammerl, 2011]); questions concerning how privacy management / information flow control actually **affects** the flow of information items in a decentralized SN / MSN scenario, e.g. by realistically simulating such an environment and many other questions.

Last but not least, an important and challenging question is the question of **suitable user-interfaces** for such a privacy management system, given the (on average) rather small time, users are willing to invest into privacy setting. Selecting certain Social Situations as 'typical' and computing a suitable generalization (via similarity measures on Social Situations ∗[Groh et al., 2011d, extd.version]▶ and relational clustering (see ∗[Groh, 2007]▶)), interactively marking subnetworks of the social network, or suitably process named spatio-temporal contexts that other users have used in their settings and offer them for constructing spatio-temporal contexts for privacy settings are only a few problems in this context. The last problem shows that entities and service elements used for privacy management should also be used for other services (e.g. location-based information retrieval in this case) to achieve maximum synergy effects and better integrate privacy management with other services of the platform (as e.g. also discussed above in connection with the relation between controlling the flow of information and privacy management). An obvious class of synergeticly linked class of services are those discussed in section 7.3.

▷ ▷ ▷ Skip related publications and continue with next chapter ▷ ▷ ▷

Included Publications:

Kozikowski, P. and Groh, G. (2011). Inferring Profile Elements from Publicly Available Social Network Data. *Proc. IEEE Socialcom'11, Boston, USA*.

Groh, G. and Birnkammerer, S. (2011). Privacy and Information Markets: Controlling Information Flows in Decentralized Social Networking. *Proc. IEEE Socialcom'11, Boston, USA*.

Chapter 9

Information Applications

The main focus of this chapter are foundations and options for an alternative, agent-based information retrieval system for decentralized Social Networking and Mobile Social Networking that makes use of long-term social and spatio-temporal contexts in oder to satisfy conscious as well as unconscious information needs. After a brief discussion on information services in SN and MSN, foundations and options for such an approach based on principles of human information retrieval and an possible architecture using spatio-temporal embedding as a key element and bracket for several other types of context are shortly discussed. We discuss elements of a study providing an implementation of key elements and its functional evaluation with the help of a large Wikipedia dataset. The last section discusses current and future work activities evaluating the aforementioned alternative, agent-based IR approach and its basic heuristic foundations using a large Twitter dataset.
Own publications related to this chapter: ∗[Groh and Straub, 2010]▶, ∗[Groh et al., 2011f]
Supervised theses related to this chapter: •[Pötzl, 2009], •[Koster, 2010].

9.1 Information Services

As major conceptual flavors of services in SN and MSN, direct communication , information , and awareness services may be distinguished ∗[Groh and Schlichter, 2005], section 1.1. We will first briefly repeat characteristics, commonalities and differences of these coarse service classes from section 1.1 to further illustrate the concept of 'information service'. We will then continue to discuss how information services and especially information retrieval in SN and MSN may profit from context awareness.

9.1.1 Flavors of Services in SN and MSN

As has been pointed out in section 1.1, **general communication services** support communication of all sorts in SN and MSN: communication of textual or media content, 1:1, 1:n or n:m communication, direct or indirect communication, etc. Since most interaction in SN and MSN involves communication and communication may be regarded the main purpose of SN and MSN, general communication services encompass all other types of services. E.g. information services may be regarded as supporting indirect 1:n or n:m communication. As a more special class, the class of **direct communication services** involving email, chat, SMS etc. may be distinguished. As has been discussed in subsection 7.3.2), context may beneficially be incorporated into direct communication services (see also ∗[Groh and Hillebrand, 2004] for a discussion on including spatial context).

In section 7.2, **awareness services** were introduced as services that aim at, mostly pro-actively but also on request / interactively, satisfying *conscious and predominantly unconscious information needs* (see subsection 9.1.2) in view of *states and events of persons of a social network* associated with a common social networking platform or, in case of decentralized SN or MSN, the sub-network induced e.g. by a limited path length to the current user. As discussed in section 7.2, states often correspond to (social) context elements (e.g. the nodes and edges of a social network) and events often correspond to changes in the (social) context (as in awareness services based on visualizing social network dynamics (== the dynamics of long-term social context). Thus awareness services often inform about contexts themselves, which is often naturally done in a context-aware way (e.g. only visualizing the dynamics of those nodes and edges that correspond to 'friends'). Regarding social context in this way but also regarding spatial end especially temporal context (e.g. by focusing on **current** events and states) conveys relevance in view of the information needs of the user.

News services may be distinguished from awareness services, in that they are targeted at informing about *events (rather than states)* linked to people also *outside the social network* of a user and also *unspecific groups* of people. Thus in SN and MSN, awareness services are more prominent than true news services, although some awareness services in SN / MSN environments are also sometimes labeled as 'news-service'. Similar to awareness services, news-services conceptually operate usually on a pro-active basis. Furthermore they also usually satisfy unconscious information needs and usually do not require formulating explicit queries. As in case of awareness services, context should be properly regarded to convey and improve relevance for the user.

Contrary to (and also in generalization of) awareness services, **information services** may be characterized as aiming at satisfying general unconscious and *predominantly conscious information needs* with the help of large information spaces. These information needs are not restricted to events and states linked to actors of a social network. In information services, conscious information needs are usually expressed and formalized in form of a *query*, thus acting mostly request-based , as especially in *information retrieval*, but proactive variants also exist (as in *information filtering*, where filters take the place of queries [Belkin and Croft, 1992]). As we will discuss in this chapter, context-awareness is also very important for information services.

While the boundaries of these service classes may **overlap**, all of these services may profit from using social **context** and / or spatio-temporal context. Furthermore, an interesting motive that appears in the above discussion is the **distinction between conscious and unconscious information need**. We will now briefly discuss interrelations between this motive and context and how these interrelations may be used to devise new forms of information retrieval especially relevant to SN and MSN.

9.1.2 Context and Unconscious Information Needs

In [Mizzaro, 1998], the problem of adequately characterizing **relevance in information retrieval** (IR) is investigated. Building on a large amount of previous work (see also [Mizzaro, 1997]), the author characterizes relevance on lattice points in a **four dimensional schema**. One 'axis' of the lattice corresponds to the **results** of IR: {surrogate, document, information}, where surrogates are meta-information and / or short excerpts of a document and information corresponds to the abstract information which an author possesses and encodes in a document. The second axis corresponds to **qualifications of information needs** that a user of IR has in view of a 'problematic situation' [Belkin et al., 1982a], [Belkin et al., 1982b], [Mizzaro, 1998]: {query, request, perceived information need (PIN), real information need (RIN)}. The query is a formalization of a request which, in turn, is a natural language expression of a PIN. The PIN is the information need that a user subjectively *perceives* in the problematic situation. The RIN may e.g. be defined via the entirety of information that is 'objectively' relevant for the solution of the problem, thus *extensionally defining* the 'problem' in the 'problematic situation' *through* the RIN. 'Objectively' may e.g. be determined by the intersection or union of the assessed RIN by the fictional set of all human experts for the problem. The third axis of this lattice is comprised of **points in time** of various steps in the IR process, and the fourth axis is comprised of the **aspects** in view of which relevance of the results should be judged: $\mathcal{P}(\{\text{topic,task,context}\})$, where $\mathcal{P}$ denotes the power set. While relevance in view of a topic or a task is clear, context in [Mizzaro, 1998] denotes all other aspects in view of which the relevance of an IR result can be judged (e.g. whether it has already been seen, whether it is in an unknown language etc.). During the IR process the user then consumes or partly consumes the results, uses his assessment of relevance judgments, corrects his PIN, formulates a new query and so on, giving rise to a **circular IR process** (see e.g. [Belkin, 1993, p. 3, figure 1]). A user will explore the space of information relevant to the RIN by repeated executions of the aforementioned IR cycle, iteratively re-shaping his PIN, and enlarging the set of acquired information.

Our notion of *conscious information need* corresponds to *perceived information need* (PIN) in [Mizzaro, 1998] and our notion of *unconscious information need* encompasses the *real information need* (RIN) in [Mizzaro, 1998] In IR, the term unconscious information need is justified because the user is not consciously aware of information needs in RIN $\setminus$ PIN in a problematic situation. However, our notion of *unconscious information need* also encompasses *an unspecific readiness to accept 'interesting' information.* Unless artificially defining some 'background problematic situations', **ongoing readiness to accept welcomed information that does *not* correspond to a 'problematic situation'** (and thus not to a RIN or PIN) is not represented in the schema of IR relevance, because this case is simply not covered by the concept of *information retrieval*, where a problematic situation induces a concrete information need which in turn finally induces a query. Examples for such a form of *unconscious information need* correspond to e.g. a user reading 'something interesting' on a news-feed or is being told 'something interesting' by a friend, etc. Thus information may be delivered to a user that the user has no a priori *perceived* information need for, and which the user has not explicitly asked for via a query or filter, but that he / she nevertheless judges as 'interesting'. This kind of information is usually pro-actively delivered by awareness services, or news services, or by direct communication services. We have seen in chapter 7 and also in chapter 10 and in the discussion of controlling information flows in chapter 8 (see especially ∗[Groh and Birnkammerer, 2011]▶ and •[Birnkammerer, 2010]) that context and especially social context may be used to provide a **relevance bracket** for this 'interesting information' that is delivered to a user by such services by e.g.

- narrowing the visualizations of social network dynamics to the network neighborhood or spatio-temporal neighborhood of a user,
- using social filtering to deliver horizon broadening recommendations,
- or use social contexts to specify suitable audiences for certain information.

It is important to note that in contrast to the more technical definition of contextual relevance in [Mizzaro, 1998] mentioned above in connection with information retrieval, the **contextual relevance bracket** is a means to anticipate or **induce relevance via context** in these proactive services.

As we will further discuss in the next sections, **incorporation of context**, especially of social and spatio-temporal context, can **also be beneficial for information retrieval** e.g. by aiding the user in exploring the space of relevant information items / in expanding the PIN, especially in relation to problems for which the RIN is hard to determine. This aid can be achieved by seeding the IR cycle with new motives especially beyond the PIN while providing a certain contextual bracket for relevance (in contrast to e.g. randomly choosing the seeds) as Figure 9.1 illustrates. In contrast to well defined problems, which may exhibit a natural saturation effect

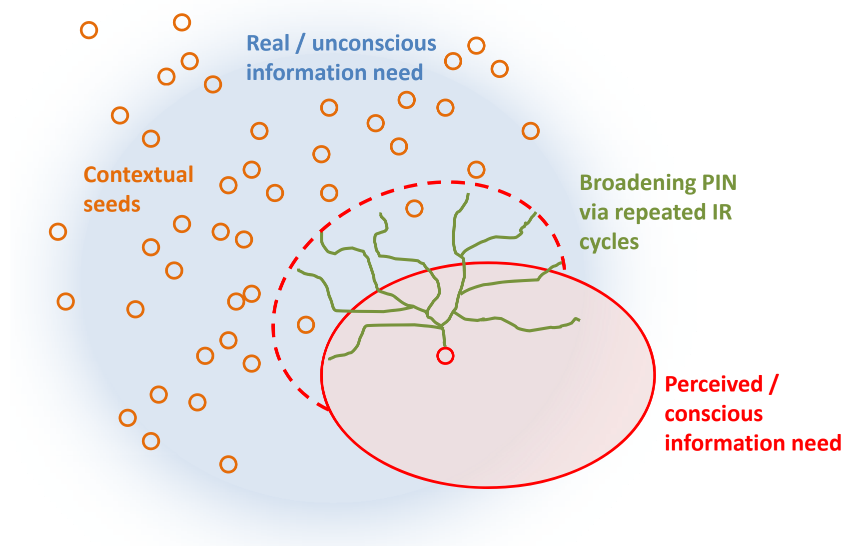


Figure 9.1: Defining unconscious information need

in view of new information, insights, competence gains, or perspectives appearing after new IR cycles and thus PIN≈RIN after 'sufficiently' many IR cycles, the 'problematic situations' for which the RIN is hard to determine might not exhibit this saturation effect, either because the problem's definition is not precise enough or because the space of information items relevant to the RIN is very large.

Traditional **Context-Sensitive Information Retrieval** is usually focused on using types of context such as query histories or implicit feedback on the results to a query (e.g. via click-analysis or eye-tracking) to improve relevance of the immediately retrieved results in view of a given query (see e.g. [Shen et al., 2005]). However it is usually limited to the PIN expressed in the query, because more general contextual brackets (e.g. induced by social context) that would be able to deliver the contextual seeds mentioned before are missing or not regarded. E.g. including seeds from the information spaces of other competent people determined via (besides the query) also taking social context into consideration, may improve the exploration of the RIN, especially in those cases where the boundaries of the RIN are hard to determine precisely.

9.1.3 Human IR

If **long-term social contexts** in the form of **social networks** are used to provide **contextual brackets** for information retrieval services in SN / MSN, it is important to review the basic results of **decentralized routing and searching** in these networks.

In 1967, **Milgram's experiment** [Milgram, 1967] showed that decentralized routing in social networks is possible and that the path lengths involved were small (on average about 6), which gave rise to the notion of **six degrees of separation** (see e.g. [Watts, 2003]). Watts and Strogatz [Watts and Strogatz, 1998] were able to provide a network model for such **Small World networks**, which did not only explain their short mean average path length (which was easy to reproduce with random graphs with a sufficiently large edge-probability p (see e.g. [Bollobás and Riordan, 2005])) but also their high clustering coefficient, a crucial property of social networks, which was also found in other types of networks [Watts and Strogatz, 1998]. The **Watts-Strogatz model** is based on a toroidally, regularly linked graph, where edges are randomly redirected with a certain probability. These constructive elements generate the local cluster structure and short mean average path length. [Watts and Strogatz, 1998]. In the same time frame, **Barabasi and Albert** [Barabási and Albert, 1999],[Albert and Barabási, 2002] were able to suggest a model that explained another interesting probability of real world networks (e.g. the link-network of the WWW) that was not incorporated into the Watts-Strogatz model, namely that the probability $P(k)$ of a node having k neighbors follows a power law $P(k) \sim k^{-\gamma}$ (thus those networks are called **scale free networks**). This was accomplished by a **preferential attachment** (the 'rich get richer') generative graph model, where the probability of a new node in the graph model being linked to an existing node is proportional to the degree of the existing node. Motivated by the expected limitations of node degrees in natural networks, investigations regarding the *cut-off of the long-tail of the power law distribution* were able to refine these models further (see e.g. [Jin and Bestavros, 2006]).

While all these models were able to explain the basic *structure of social networks*, the actual explanation of the Milgram experiment, the question of how **decentral-**

ized routing *can actually be accomplished*, was investigated by **Kleinberg** [Kleinberg, 2000b]. In his variant of the Small World model, starting from a regularly linked network on a grid, the random distant re-connections of a node a to a node b were established with a probability $d(a, b)^{-\alpha}$. He was able to show that for α corresponding to the dimension of the grid, a decentralized (local knowledge only) routing algorithm, always choosing the node located closest to the target node as the next node, is sufficient to produce short expected delivery times, polynomial in $O(log(n))$, where n is the number of nodes in the network. Refinements of this model in view of more realistic **geographic distributions of friendship relations** on the earth's surface were investigated by [Liben-Nowell et al., 2005], suggesting a different geographic connection probability distribution and empirically finding a different value for α, but confirming that the simple greedy local routing algorithm still leads to efficient delivery. This confirms that for **efficient decentralized geographic routing in social networks**, the nodes of the network need to be **spatially embedded** (each actor needs to have a location, which we assume to correspond to the current center of life location (determined e.g. via the most visited location over the last m months)) and each forwarding actor needs to have a **cognitive model of this spatio-temporal context** (or other types of context (see [Watts et al., 2002])) to select the next node. [Killworth and Bernard, 1979] confirmed that actors also used **other contexts** such as long-term social context (e.g. choosing good friends or family members) or individual contexts of the actors (e.g. occupation) to select the next node.

Parallels exist between using general context information for decentralized routing and the way **social information retrieval** is accomplished in **human societies**, which in turn has obvious **commonalities with SN / MSN**. In '**Human IR**', a question formalizing a PIN is 'routed' to persons which presumably dispose of the required information in their (not necessarily properly explicated) information spaces. The resulting routes need to be 'socially resilient' enough (e.g. in the sense of Granovetter's strong ties [Granovetter, 1973]) to support the actors en-route agreeing to process the query and to support routing the retrieved information back to the questioner. As reviewed in [Wilson, 2000], **human information seeking behavior** often uses e.g. social context to determine actors who could be asked, especially if the problem situation and the PIN is poorly defined ([Wilson, 2000, p.51]). Actors facing an informational problem will, besides the PIN ($\widehat{=}$ WHAT), evaluate **all types of contexts**, their interrelations and their relations to the PIN, in order to render their PIN more precise, expand their PIN towards the RIN and ultimately collect enough information to solve their problem (see ∗[Groh and Straub, 2010]▶ for a more elaborate discussion). (For the discussion, types of contexts will be represented by other interrogative pronouns such as WHO (pointing to social context), WHERE and WHEN (pointing to spatio-temporal context)). *Vice versa*, the asked persons will also use contextual knowledge to select appropriate information for the questioner, which may also include information that is not strictly relevant to the query but relevant to the PIN or even RIN of the questioner. Thus relevance may also be induced by the asked actor **via contextual knowledge**. As an example consider the question "How do I search for certain terms while I browse a text-document with UNIX 'more' ?". As an *expert*, a person might answer "Use the '/' character and enter the term". As an *expert* and friend the answer may include "Besides: use 'less' instead of 'more'! It has a number of advantages". As an *expert and* close friend the answer may include "Besides: I give You the advice to quit using UNIX! A Mac will suit Your needs and the needs of Your wife much better. It provides more comfortable means to view and search text-files while still retaining 'less' and 'more' if desired", using social context and the questioner's individual context.

In terms of **long-term social context**, **Human IR 'uses'** the main **characteristics of small world networks** to **search** in the complex network of distributed information spaces and context-elements for the right information: actors are able to reach experts (and their information spaces) via short expected path lengths and the highly clustered structure ensures that each actor has a large number of routing options. If he / she itself is not an expert, the probability that someone in the local cluster is, is high. Suitable interdependent contextual metrics (Semantic (WHAT), social (WHO) or spatio-temporal (WHERE + WHEN)) allow efficiently **navigating the space**.

9.2 An Alternative Information Retrieval Approach for Decentralized SN and MSN *

The question now arises, how we can employ these considerations and the considerations of the preceding section to **construct an alternative information retrieval service for SN / MSN**. While the complex socio-psychological mechanics of amalgamating and evaluating the interdependencies of WHO ↔ WHERE ↔ WHAT ↔ WHEN in Human IR in view of searching the distributed information spaces in a context sensitive way are too intricate to model directly, **spatio-temporal embedding may act as a reference point** and a means to naturally encode these interdependencies between the various forms of context for a respective IT model:

A **social spatio-temporal small world** may be defined as a social network, where the actor-nodes are *spatio-temporally embedded* into space-time via their current center of life (compare previous section). The relations correspond to directed long-term social relations of various types (compare chapter 4). We have seen that spatial distance metrics (and via using a current time-frame thus also spatio-temporal distance metrics) allow efficient decentralized routing. We assume that spatio-temporal distance metrics can thus also serve as one key means for a successful search for information in the social spatio-temporal small world part of the complex network of distributed information spaces and context-elements described in the previous section. 'Successful' implies that the information found is relevant in view of a user's RIN especially in those cases where the RIN is hard to demarcate (see discussion in subsection 9.1.2). Another argument for using spatio-temporal distance metrics as a means to naturally encode interdependencies between the various forms of context is that the studies of Kleinberg [Kleinberg, 2000a] and Liben-Nowell [Liben-Nowell et al., 2005] imply that in a social spatio-temporal small world, **spatio-temporal closeness is probabilistically correlated with social closeness**.

A **semantic spatio-temporal small world** may be defined as a network of information items (e.g. documents) that are *spatio-temporally embedded* into space-time via a *three step process of alternatives*:

- (a): the information item's meta-data contains an **explicit spatio-temporal embedding** (e.g. spatially via GML encoded GPS coordinates [OGC, 2011a]),
- or, if (a) does not apply, (b): the information item contains an **implicit spatio-temporal embedding** (e.g. explicated spatially via geo-parsing (see e.g. [Larson, 1996] [Jones and Purves, 2008]) and subsequent geo-coding (see e.g. [Jones and Purves, 2008]) of the found named entities (see e.g. [Nadeau and Sekine, 2007]).)
- or, if (b) does not apply, (c): the information item is spatio-temporally embedded in the **same spatio-temporal location(s) as the actor** whose information space this item is associated with.

The **first mode of edges** of this network are the links indicating semantic relatedness of the items (e.g. HTTP links). The corresponding network is a small world [Jin and Bestavros, 2006]. The **second mode of edges** relates items, whose 'owners' are linked in the social spatio-temporal small world, which also gives rise to a small-world network. Studies by Brent Hecht [Hecht and Raubal, 2008], [Hecht and Schöning, 2008], [Hecht and Moxley, 2009], [Hecht and Gergle, 2010] and others (e.g. [Lieberman and Lin, 2009]) imply that in a semantic spatio-temporal small world, **spatio-temporal closeness is probabilistically correlated with semantic closeness** to a certain extend, which is also expressed as a statistical tendency in (so-called) Tobler's first law of Geography: "everything is related to everything else, but near things are more related than distant things" [Tobler, 1970].

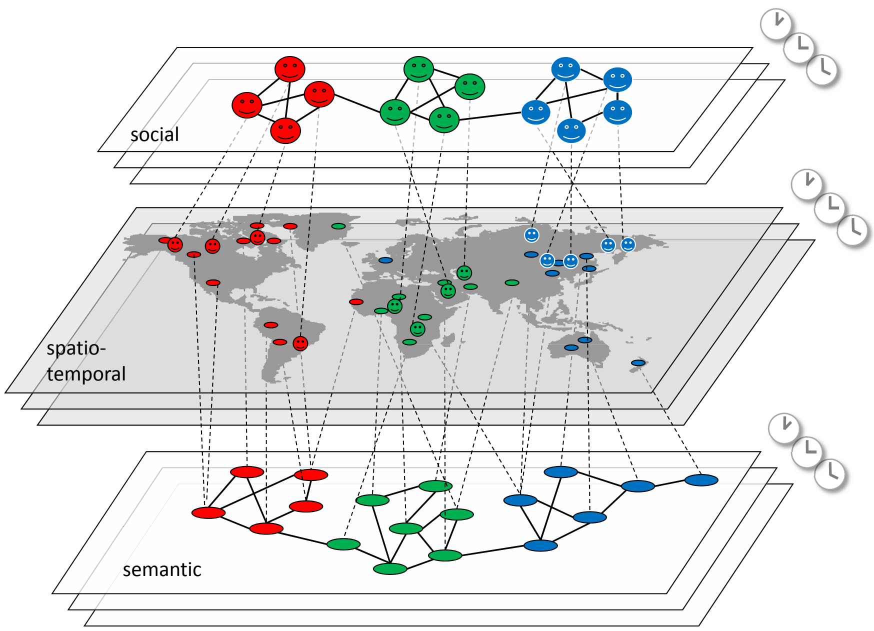


Figure 9.2: (Source: after ∗[Groh and Straub, 2010]) Spatio-temporal embedding of small worlds: how spatio-temporal embedding maintains social and semantic closeness properties as a statistical tendency

Figure 9.2 visualizes social and semantic spatio-temporal small worlds and illustrates the maintenance of social and semantic closeness via spatio-temporal embedding.

Using a transitive argumentation, **social closeness is also probabilistically correlated with semantic closeness** using spatio-temporal closeness as a binding element. The correlation between social closeness and semantic / topical closeness is also supported by other studies such as [Angelova et al., 2009] and indirectly by ∗[Groh and Ehmig, 2007]▶.

Thus in view of decentralized search of relevant information in the complex network of distributed information spaces and context-elements which is characteristic of SN / MSN, we assume that social spatio-temporal small worlds and semantic spatio-temporal small worlds may act as a simple model of this complex network of context elements and spatio-temporal metrics may aid the decentralized search because of implicitly representing interrelations between social and semantic relatedness.

Based on these considerations and models and the principles of Human IR, the **study** ∗[Groh and Straub, 2010]▶, proposed a new **context-aware, agent-based, federated approach to information retrieval in decentralized SN / MSN** in order to investigate limits and chances of using spatio-temporal embedding and its implicit 'conservation' of semantic and social context as a contextual bracket. Besides the discussion of the last sections, the design decisions in this study were supported by a number of observations such as the ever growing availability of context in SN and especially MSN, the importance of the paradigm of Distributed Social Networking (see chapter 3 and chapter 1), the problems that the Hidden Web especially in connection with access protected SN / MSN information spaces generates for traditional search engines [He et al., 2007], or the obvious parallels that searching in SN / MSN has to Human IR.

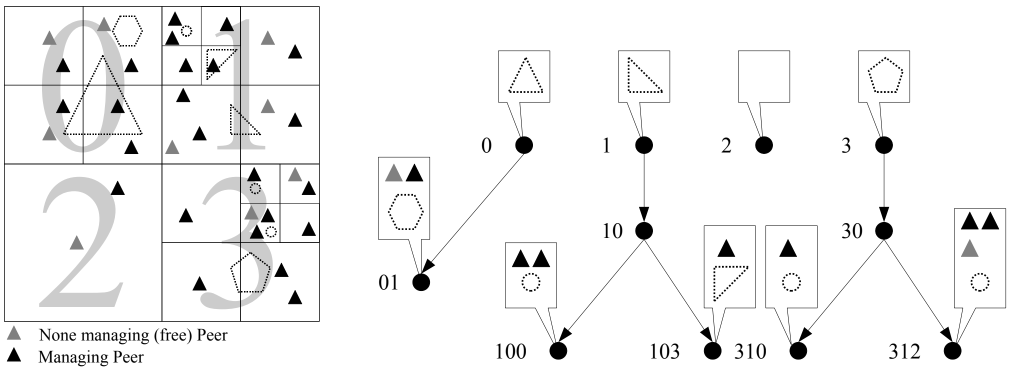
The **architecture** of ∗[Groh and Straub, 2010]▶ is based on *personal information agents* associated with *spatio-temporally embedded social actors* (users, companies, SN-platforms etc.), which contextually decide upon the execution of another actor's query in relation to the asked actor's information space (compare chapter 8). The agents are able to answer these queries in a context sensitive way, using techniques from Context-Sensitive IR and their expertise on their own information spaces. Each actor maintains socio-semantic links to other spatio-temporally embedded actors in form of topic specific *expert-links*, thus implementing a special form of social spatio-temporal small world. Furthermore, each actor publishes a selection of his / her expert-links and a set of spatio-temporally embedded *expertises*, summarizing content fields from the actor's information space (thus contributing to a special form of a semantic spatio-temporal small world). The spatio-temporal embedding of expert-links and expertises ('*knowledge flags*') follows the three step process discussed above. These knowledge flags are published in a decentralized *spatio-temporal Peer-to-Peer index*. If an actor issues a query which cannot be answered from his own information space, a social search is performed using the actor's expert links. If this search also fails, the spatial index is queried using the spatio-temporal embedding of the query, with the embedding following the three step process: e.g. if the query does not contain a spatio-temporal reference, the spatio-temporal reference of the questioner (see subsection 9.1.3) is used. The search delivers a number of knowledge flags which the questioner's agent then further evaluates by asking the related other agents. The system thus combines elements of social search (via expert-links), semantic search (local IR-systems) and spatio-temporal search (implying social and semantic contexts to a certain extent as explained above).

Compared to e.g. Peer-to-Peer (P2P) IR systems, were e.g. an index is distributed over the passively protocol-executing peers in a P2P network (see e.g. [Tang and Dwarkadas, 2004] for a hybrid document- / index-distribution approach), and thus in most cases basically 'merely' distributes a conventional IR system over a P2P network, this architecture uses the actor's agent's local IR systems to locally decide upon relevance. The agents are thus able to take into account the (e.g. social) context of the query and the querying agent / its user, thus being able to optimize contextual relevance and decide upon access (e.g. see the techniques discussed in chapter 8 (especially in ∗[Groh and Birnkammerer, 2011]▶) to control information flows, ensure privacy or even employ information markets). Furthermore, they are able to proactively keep their published knowledge flags up-to-date.

The small world structure of the networks involved ensures that the expert-links, the comparatively coarse semantic mapping of the agent's information spaces in form of the expertises, and with the comparatively coarse implicit conserving of semantic and social contexts via spatio-temporal embedding is sufficient to deliver enough contextual seeds to reach enough competent agents which can then either employ their local IR systems to deliver contextually relevant items or use the private parts of their expert link list to further forward the query if the questioner's context is matching (e.g. if the corresponding user is a friend) resembling Human IR.

9.2.1 Implementation and Test

In a study •[Koster, 2010], a realization and partial implementation of the previously described architecture was developed. Several types of P2P architectures (overlay network, key schema etc.) were evaluated in view of technically maintaining the spatio-temporally embedded knowledge flags (whose spatial embedding corresponds e.g. to a polygon in 2D space) and agent positions in a distributed spatio-temporal index. E.g. SONAR (Structured Overlay Network with Arbitrary Range Queries) [Schütt et al., 2008], a variant of d-dimensional Content Addressable Network (CAN) with an adapted local routing table, P2P-R-Trees [Mondal et al., 2005], a distributed variant of R-Trees [Guttman, 1984] or Distributed Quad-Trees (DQTs) [Tanin et al., 2005] were evaluated and found to be suitable, in principle, for our purposes despite certain disadvantages in view of the proposed system architecture (e.g. insufficient support for arbitrary range queries (e.g. in DQTs) or too many involved nodes when querying across responsibility boundaries (e.g. in P2P-R-Trees (where information is only stored in the leaves of the tree), SONAR)) (see •[Koster, 2010] for a more in depth discussion). Since no public domain implementations of these approaches were available, a more simple concept, specifically tailored to the needs of the architecture, based on a distributed Quad-Tree [Samet, 1984] as spatio-temporal index (the Quad-Tree can be extended to three dimensions to include the temporal dimension [Meagher, 1982]) was developed, implemented, and functionally evaluated. Knowledge flags are spatially embedded via points or polygons (e.g. a document about Munich may be spatially embedded via a point-like spatial reference or polygon corresponding to an approximation of the city's administrative boundary) and agents (peers) are spatially embedded using the center of life of their corresponding users and / or their current location. The tree does not only maintain such references at the leafs (as some of the other aforementioned techniques) which has advantages when the respective polygonal spatial references are large (e.g. an expertise corresponding to Europe as a whole) and thus alleviates the second disadvantage of the other approaches discussed above. The depth of the tree was limited to 18 in the implementation, which spatially roughly corresponds to the size of a block of houses. Routing, querying, join and leave operations as well as splits (in case the number of objects in a quadrant becomes too large) and the general distribution of responsibilities among peers are efficiently possible and described in more detail in •[Koster, 2010]. All spatially embedded knowledge flags matching a query associated



(a) Graphical representation (b) Tree representation

Figure 9.3: (figure taken from •[Koster, 2010]): An example of a Quad-Tree with 8 spatial polygonal embeddings of 8 objects (e.g. knowledge flags) within a rectangular region and 33 peers (agents) also spatially located in this region. Each quadrant has a managing peer. In the corresponding tree, each item geometry and each peer-location corresponds to a path encoded by a simple hash function and thus a one-to-one mapping of path and geometry is possible

with a spatial geometry are retrieved by the system and the querying agent can then decide upon contacting the corresponding agents, which in turn can then employ their local IR systems to answer the query by retrieving matching information items as described in ∗[Groh and Straub, 2010]▶.

In order to test and partially evaluate the spatio-temporal P2P index and its compliance with the principal steps of the IR process of the architecture, a test-corpus of approximately 650000 German and English language Wikipedia [wik, 2012d] articles with explicit spatial embedding as information items, together with gazetteer services for the spatial geometries and a Small-World generator for the social network of expert links were used. We used Brent Hecht's Wikapidia API [Hecht and Gergle, 2010], which allows accessing the article's topical categories and link-structure, and spatial embedding / spatial point references.

A subset of the articles of the data-set was spatially embedded with polygon-references with the help of some adaptations to the API, additional data on point-like spatial embeddings of Wikipedia articles from Wikipedia World Project [wik, 2012e] and DBPedia [Bizer et al., 2009] and polygonal geometries from the GADM database of Global Administrative Areas [gad, 2011]. Furthermore a simple geo-parsing approach via matching article categories and GADM entries using the Jaro-Winkler metric [Winkler, 1999] with a similarity threshold of 0.9 implemented via the SimMetrics open source library [Chapman and Ciravegna, 2011], and subsequent plausibility checks comparing point-like and polygon spatial embeddings was used for that purpose.

Of the 738741 English and German Wikipedia articles with a spatial reference (507347 with a unique spatial reference / embedding), 686974 had a point-like, 31472 a rectangular envelope (Minimum Bounding Rectangle (MBR) like, and 20285 a polygonal embedding. Additionally, 640703 MBRs of spatial references from the ESRI World and USA Gazetter from ArcGIS version 9.3 [arc, 2011] were used to complement the polygonal and MBR references of the Wikipedia data-set in order contribute to testing and evaluating the performance of the distributed spatial index when using a large number of non-point-like spatial references. Furthermore, in order to also include spatio-*temporal* data, 242741 biographic Wikipedia articles of men and women were included into the data-set, using place and time of birth as spatio-temporal reference.

In order to simulate information spaces and expertises and assign them to agents, the data-set was randomly partitioned into n partitions and each partition was spatially clustered into m clusters with standard K-Means (see e.g. [Bishop, 2006]) using the point-like spatial embeddings. The clusters were then randomly assigned to p agents and expertises were created from the resulting information spaces using the process described in ∗[Groh and Straub, 2010]▶, approximated via another K-Means clustering on the information space. The agents were then spatially embedded themselves via the centroid of the largest expertise cluster. For creating the expert-link social network (without the potential multi-graph edges of real topical expert links), a modified Kleinberg model [Kleinberg, 2000b] (using the KleinbergSmallWorldGenerator class from the JUNG graph library [O'Madadhain et al., 2003]) using the peer's 2D locations instead of locations fixed to the Kleinberg-grid was employed.

The resulting geometries were then spatially indexed using the distributed Quad-Tree approach discussed above, with agents as peers. Heuristically determining realistic values for p, n and m, using 2D KML visualizations of locations and Quad-Tree regions, various properties of the distributed Quad-Tree approach and its compliance with the elements and process steps of the architecture of ∗[Groh and Straub, 2010]▶ were investigated. E.g. allowing partial splits (in < 4 regions) when the maximum number of managed items for a peer is exceeded proved to be more effective for avoiding overcrowded nodes than the standard approach •[Koster, 2010, p.48ff]. As expected the small world topology of the expert-link network significantly reduces the number of hops compared to a random network in a simulated routing experiment •[Koster, 2010, p.51f]. This shows that in case of a multi-step IR process, other experts can be efficiently reached. The simulation shows that the approach exhibits a sufficient performance and is indeed compatible with the elements (knowledge flags, expertise generation, expert-link-topology etc.) and process steps of the architecture.

9.3 Evaluating Alternative IR Principles Based on Human IR

Clearly the study just discussed contains many artificial elements, which restricts its evaluative value to the distributed spatio-temporal index and its basic compliance with the architecture. Unfortunately, a full implementation and real world evaluation of the architecture is out of scope of the overall project, but would be the next step following the usual Design Science methodology [Hevner et al., 2004]. Despite not disposing of a full implementation and evaluation scenario (involving the necessary large number of actors and sub-systems), another evaluation step that can be taken is to evaluate the suitability of the principles guiding the architecture's IR process inspired by Human IR, using social search, semantic search and spatio-temporal search and here specially the suitability of spatio-temporal embedding as a contextual bracket for this type of IR, implying social and semantic contexts to a certain extent as explained above. For this evaluation, a data-set is required that contains real association of users and information items as well as realistic locations of users and explicit spatio-temporal references of their information items, as well as a social network exhibiting characteristics of the expert-link network proposed in the architecture. The micro-blogging service Twitter [twi, 2012] with his network of followers, significant share of mobile usage and thus a large share of explicit spatial embeddings, and the free availability of the data is a suitable evaluation ground. We will now briefly discuss some results of this evaluation.

9.3.1 Evaluation Study

A dataset from Twitter was downloaded using the Twitter API [twi, 2012] whose basic properties are described in Table 9.1. The Tweets and Re-Tweets which were non-English (which was decided using the approach described in [Cavnar and Trenkle, 1994], employing an ML classifier using language specific n-gram statistics) were discarded. The remaining (Re-)Tweets were Porter-stemmed [Porter, 1980] and stop-words were removed. Of the Re-Tweets, only the additional content without 're-citing' the original Tweet was regarded.

An undirected social network between the users was induced by establishing an edge if at least one @Reply or @Mention [twi, 2012] (roughly corresponding to a direct message) was exchanged between the respective users. Of this social network, the largest connected component was chosen, and the rest of the users and their Tweets and Re-Tweets discarded. Users were spatially embedded via the geo-location of their last available explicitly geo-located (Re-)Tweet. (Re-)Tweets not explicitly spatially embedded (via geo-coordinates) were embedded with a simple geo-parsing approach, analyzing the strings denoting the location and subsequently using the MetaCarta geo-coding service [met, 2011]. If this process failed, the geo-location of the Wikipedia articles corresponding to the tags of the respective (Re-)Tweet, were used, using the Wikapidia API (see previous section). If that fails, the location of the authoring user was used. Locations were subjected to very small (uniform distribution in [-0.1,0.1] decimal degrees) random deviations to avoid mapping many entities to the exact same location which would result in overcrowding peers with

Download time-frame	June, 25th - July 10th, 2010
Downloaded items	Anonymized user-ids, user geo-locations , Tweets, Re-Tweets, and their meta-data (tweed-Re-tweet, user-(tweet & Re-tweet)-relations, geo-locations, time-stamps, etc.), user-user 'direct messaging' (@Mentions, @Replys) relations.
# Re-Tweets (original data-set)	2304080
# Tweets (original data-set)	41669049
# Tweets + # Re-Tweets (original data-set)	43973129
# Tweets + # Re-Tweets (explicitly geo-coded)	9725514
# Tweets + # Re-Tweets (finally considered (explicitly geo-coded and associated with largest connected component of social network))	3323803
# Users (orginal data-set)	6887632
# Users (explicitly geo-coded)	670271
# Users (finally considered (explicitly geo-coded and in largest connected component of social network))	160690

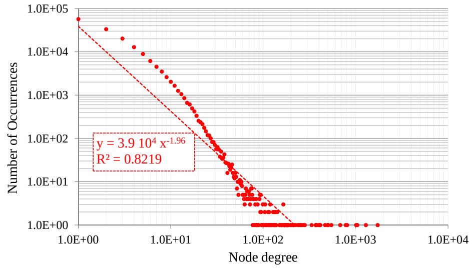
Table 9.1: Basic properties of the Twitter evaluation data set

respect to the spatio-temporal index (compare subsection 9.2.1), which was used in the evaluation environment for the experiments.

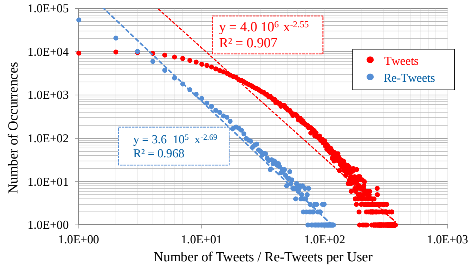
9.3.2 Studying Interrelations between Spatio-Temporal, Social and Semantic Contexts

The **social network**'s mean average path length was 6.92 (a random graph with the same number of nodes, which was computed with the help of the JUNG framework [O'Madadhain et al., 2003] yielded a value of 8.96), and the average clustering coefficient [Watts and Strogatz, 1998] of the social network was 0.046 (corresponding random graph: 0.000014). We see that although the average clustering coefficient on SN platforms is usually higher by a factor of > 4 (e.g. [Wilson et al., 2009]report an average 0.164 for their early 2009 crawl of several sub-networks of Facebook with an overall number of nodes of $\approx 10^6$). The numbers indicate that the present network can still be regarded as having small world properties.

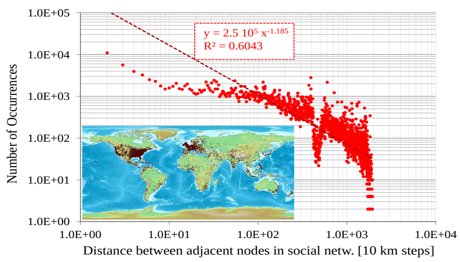
Figure 9.4 shows statistical properties of the dataset and correlation effects that support the mutual implication of social, semantic and spatial closeness which represents a basis for the proposed IR architecture. **Sub-Figure 9.4(a)** shows the degree distribution of social network which roughly follows a power law. This fact and the deviations from the exact power law distribution coincide with the findings in [Newman, 2003] [Liben-Nowell et al., 2005]. Together with the previously discussed values for the mean average path length and clustering coefficient shows that



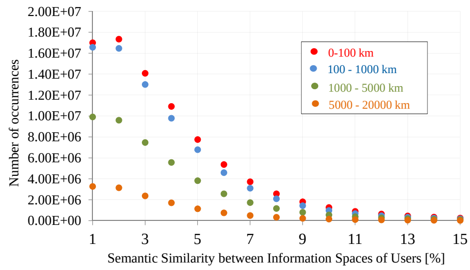
(a) Degree distribution of social network



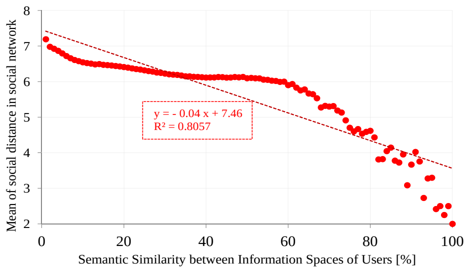
(b) Distribution of number of (Re-)Tweets per user



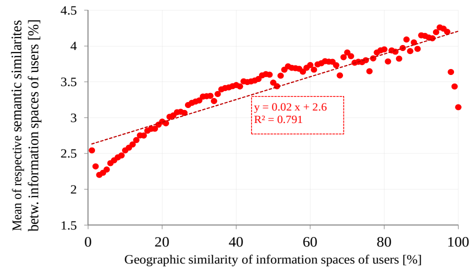
(c) Distribution of distance between adjacent nodes in the social network



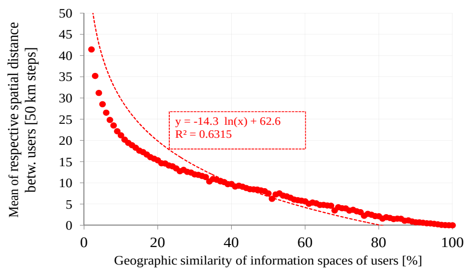
(d) Correlation between spatial distance and semantic similarity of information spaces



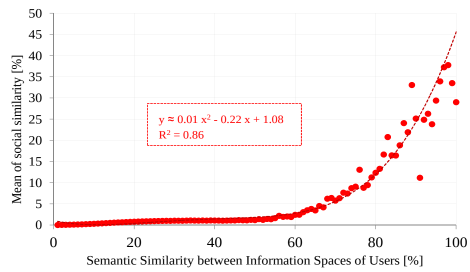
(e) Correlation between network distance and semantic similarity of information spaces



(f) Correlation between geographic and semantic similarity of information spaces



(g) Correlation between geographic similarity of information spaces and spatial distance of corresponding users



(h) Correlation between semantic similarity of information spaces social similarity (via friend sets)

Figure 9.4: General properties of the dataset and mutual implication of social, semantic and spatial closeness using different measures (compare discussion in the text). Wherever a curve fit is provided (e.g. a power law, linear or logarithmic function), standard regression [Pruscha, 2005] is used where $R^2 = 1 - \sum_i (y_i - f(x_i, \beta))^2 / \sum_i (y_i - \bar{y})^2$ is the coefficient of determination

the social network of actors in the data-set can indeed be assumed to be a realistic small world social network.

Sub-Figure 9.4(b) shows a distribution of the number of Tweets and Re-Tweets per user which, in our experiment simulate the information spaces of the users. While the Re-Tweet distribution follows a power law, the distribution of the number of Tweets shows deviations from the power-law distribution, while the R^2-value of fitting an exponential function $y(x) = ae^{-bx}$ is significantly lower, supporting that a pure exponential fit is less appropriate. Functions of the type $y(x) = \beta x^{-\alpha} + ae^{-bx}$, which induce an exponential cutoff of the power-law's long tail, qualitatively show a better congruence with the distribution and intuitively correspond to the reasonable assumption that extremely large sizes of information spaces of users in SN and MSN platforms are very rare.

Sub-Figure 9.4(c) shows the distribution of spatial (geodesic) distance between adjacent nodes (actors with a direct social relation) in the social network. Equivalence classes of geodesic distances are determined in steps of 10 km. Due to the spherical topology of earth's surface (with a maximum circumference of roughly 40000 km at the Equator), the maximum class of spatial distances encompasses all geodesic distances between 19990 km and 20000km. As reasonably expected, the distribution shows two users with a smaller spatial distance have a higher probability of being socially connected, where the distribution roughly follows a power law. This confirms other study's results, such as [Liben-Nowell et al., 2005, p.11625] and supports the assumption that social closeness and spatial closeness mutually imply each other to a certain extent. As the diagram depicted in the left corner of the diagram shows, the geographic distribution of the users concentrates on the densely populated areas of North America and Europe. The dip of the curve around $\approx 5000km$ may be explained by the relative geometric dimensions of the Atlantic ocean and the North American and European continent.

Sub-Figure 9.4(d) shows the correlation between the spatial distance of pairs of users (this time counted in classes of 50 km steps) and the semantic similarity of their information spaces (counted in equivalence classes of 1 %). The semantic similarity of information spaces was computed as the Tanimoto coefficient [Lipkus, 1999] of the multi-set of term-frequency vectors of the respective sets of information items. Other alternatives would have e.g. been to use Rocchio centroids [Joachims, 1997]. As an implementation, we used Lucene [luc, 2011]. Of a matrix containing the absolute frequency of occurrences for a combination of a geodesic distance class and class of semantic similarity of information spaces we computed the average absolute frequencies for the four new equivalence classes $[0, 100\text{km}]$, $[100, 1000\text{km}]$, $[1000, 5000\text{km}]$, and $[5000, 20000\text{km}]$. The four qualitatively Gaussian curves show that for larger distances the semantic similarity of the information spaces of the users is smaller than for smaller distances. This supports the connection between semantic relatedness and geographic relatedness. Qualitatively similar results have been obtained by [Hecht and Raubal, 2008] although the measures used were different.

Sub-Figure 9.4(e) depicts a correlation between the semantic similarity of information spaces of users (computed as in sub-figure 9.4(d)) and their average path distance in the social network. (Technically: of a matrix containing the absolute frequency of occurrences for a combination of a class of semantic similarities between

$[x, x+1]\%$ and a path distance in the social network, we computed for each class of semantic similarities between $[x, x+1]\%$ the average over all path distances between 0 and 25). The result shows that the more similar the information spaces the smaller is the average social distance between the respective users. This supports the correlation between social closeness and semantic closeness.

Sub-Figure 9.4(f) shows a correlation between the geographic similarity of information spaces of users and their semantic similarity. While semantic similarity was computed in the same way as in 9.4(e) and 9.4(d), the geographic similarity of information spaces of users was computed in the following way: In order to compute a spatial relevance density for the information space of a user, a point-like spatial reference $\mu = (\mu_1, \mu_2)$ of an information item was transformed into a Gaussian density contribution $\mathcal{N}(\mu, \sigma)(x)$ with diagonal sigma corresponding to a 500 km circle, cut off at $|x - \mu| = 500$ km with the help of ArcGis [arc, 2011]. All contributions (which properly respected the spherical geometry of earth's surface) were added to yield a user u_i's spatial relevance density $\rho_i(x)$. The geographic similarity $\mathrm{sim}(u_i, u_j)$ of the information spaces of two users u_i and u_j was computed via a Jaccard-like measure:

$$\mathrm{sim}(u_i, u_j) = \int \mathrm{d}^2 x \frac{\min(\rho_i(x), \rho_j(x))}{\max(\int \mathrm{d}^2 x \rho_i(x), \int \mathrm{d}^2 x \rho_j(x))} \tag{9.1}$$

Although most of the information spaces had a similarity of 0 (this large contribution was left out of the diagram) the values show a trend that the closer the geographic similarity of information spaces, the larger the semantic similarity. Although the slope of this trend is rather small, this finding supports the correlation between geographic reference of information spaces and their semantic similarity.

Relating this geographic similarity of information spaces to the spatial geodesic distance between users as shown in **sub-figure 9.4(f)**, yields a logarithmic trend supporting the reasonable connection that spatial closeness of users also implies similarity in the spatial references of their information spaces.

Sub-Figure 9.4(h) relates the social similarity between users computed as the Jaccard-index of the sets of friends of two users and the respective average semantic similarity of information spaces (where the semantic similarity of information spaces is computed as in sub-figures 9.4(d), 9.4(e), and 9.4(f). We see a power law relating the two quantities: the more socially similar two users are, the more similar are their friend-sets and vice versa. This supports the connection between social and semantic contexts.

These preliminary results are an excellent ground for future research, investigating the connections between social, spatio-temporal and semantic contexts.

9.3.3 Information Retrieval Experiments

The results just discussed show that the dataset can be viewed as a dataset **realistically** including and relating social, spatial and semantic elements. They **support the basic findings** of subsection 9.1.2 and subsection 9.1.3 and the **grounds** for the IR approach discussed in section 9.2. In order to **evaluate the basic suitability of these connections for IR**, IR experiments were conducted with the data-set.

As **queries**, Tweets were used. In the absence of real user assessments of relevance to be used as **ground truth** for the experiments, two **implicit assessments of relevance** were used as ground truths: As a **first** assessment of relevance, the **Re-Tweets** of the query Tweet were regarded as relevant. This assessment of relevance is intended to represent relevance with respect of the **conscious information need** of users. As a **second** assessment of relevance, all Tweets and Re-Tweets of users **following** (see [twi, 2012]) the author of the query Tweet were regarded as relevant. This assessment of relevance is intended to represent relevance with respect to the **unconscious information needs** of users containing the contextual seeds discussed in subsection 9.1.2 and subsection 9.1.3.

In order to compare semantic search, social search and spatial search (excluding temporal aspects for reasons of simplicity) as a contextual bracket implicitly relating social and semantic contexts, **seven types of retrieval processes** were tested on the data-set. For each type of retrieval, the 50 best results (according to the IR model of the respective type) are retrieved and analyzed with the **first (I)** and **second (II)** 'ground truth' assessment of relevance by computing the usual confusion matrix (TP, FP, TN, and FN) and from that precision P and recall R [Manning et al., 2008, p155f.]. If less than 50 items could be retrieved, either the missing ones are padded with random items from the respective pre-filtering (e.g. geographic or social) (**variant A**) before computing the measures to ensure comparability, or the measures are computed as is (**variant B**).

Type 1 [Sem]: semantic search (standard IR): Use Lucene [luc, 2011] to compute a global IR index (over all information items of the dataset) and decide upon the 50 best matches to the query Tweet using Lucene's ranking.

Type 2 [Soc]: social search (social pre-filtering and subsequent semantic filtering): Retrieve all information items authored by friends and friends of friends of the query Tweet's author, compute a local IR index on these items and decide upon the 50 best matches to the query Tweet using the local index. This type of search is roughly associated with the expert-link-based type of social search with subsequent evaluation using a local IR system in the architecture.

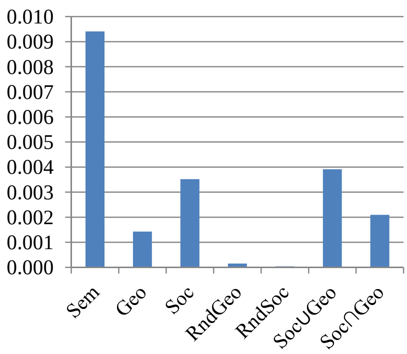
Type 3 [Geo]: geographic search (geographic pre-filtering and subsequent semantic filtering): Using the implementation of the distributed Quad-Tree (discussed in subsection 9.2.1) and an octagonal query geometry centered around the query Tweet's spatial point reference of 'radius' between 500 km and 20 km depending on the depth of the tree in this region (corresponding to the density of information items), the spatially matching items were retrieved. On this set of items the semantically 50 best were determined as in the case of social search. This type of search is roughly associated with the spatio-temporal search of the architecture on Expertises with a subsequent employment of local IR.

Type 4 [Soc∪Geo]: social-geographic search ∪ (using the union $X \cup Y$ of the results of geographic X and social pre-filtering Y and subsequent semantic filtering with Lucene as in type 2 and 3). This type is roughly associated with the spatio-temporal search of the architecture on all knowledge flags (Expertises and Expert-Links) with subsequent local IR.

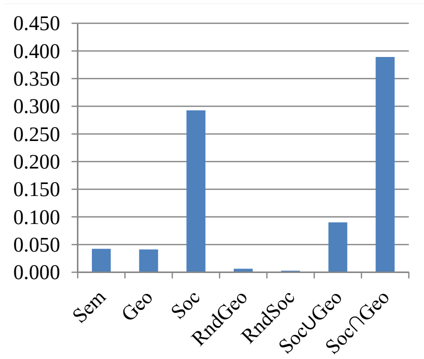
Type 5 [Soc∩Geo]: social-geographic search ∩ (using the intersection $X \cap Y$ of the results of geographic X and social pre-filtering Y and subsequent semantic filtering). This type of search is performed for reference purposes.

Type 6 [RndGeo]: random pre-filtering geographic (randomly select as many items from the dataset as a geographic pre-filtering would deliver and perform subsequent semantic filtering). This type of search is performed for reference purposes to further investigate the impact of geographic pre-filtering and thus the role of spatial context as a contextual bracket.

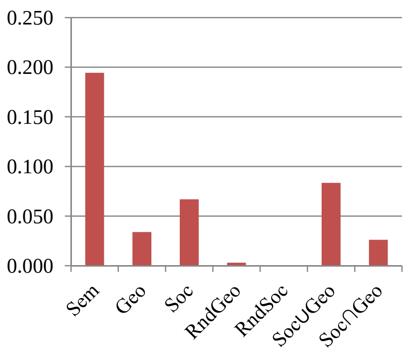
Type 7 [RndSoc]: random pre-filtering social (randomly select as many items from the dataset as a social pre-filtering would deliver and perform subsequent semantic filtering). This type of search is performed for reference purposes to further investigate the impact of social pre-filtering.



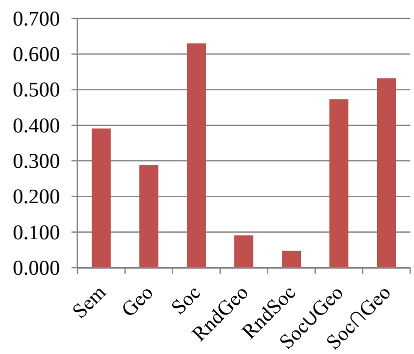
(a) Precision I



(b) Precision II



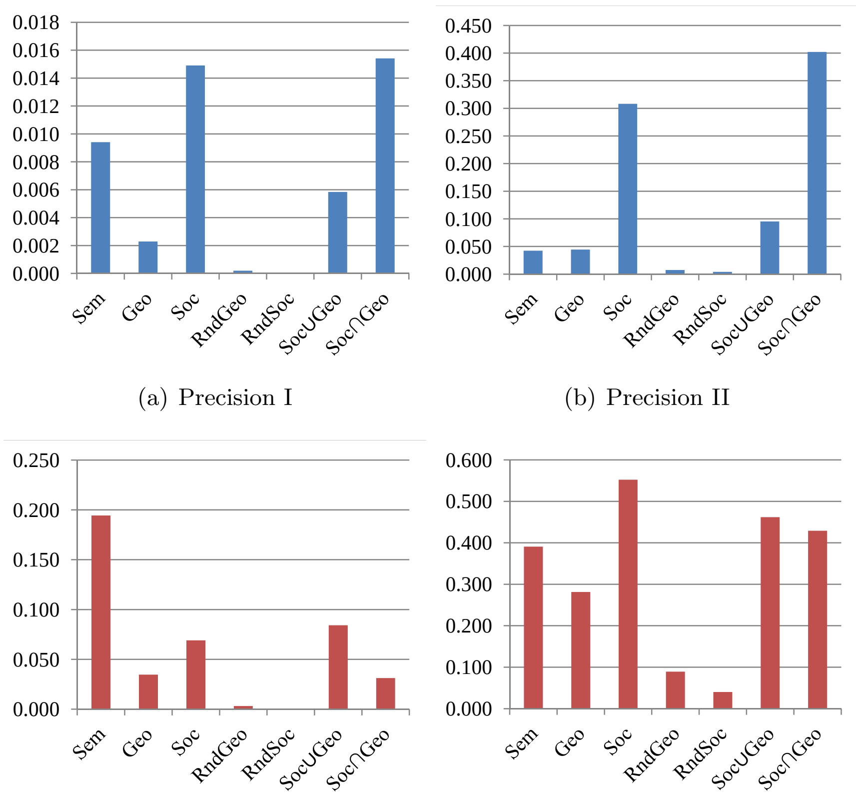
(c) Recall I



(d) Recall II

Figure 9.5: Precision and Recall, variant A

Figure 9.5 shows the precision and recall values of variant A. The while for I, the first way of ground truth relevance assessment, the conventional purely semantic search performs best by far (in precision as well as recall), social search is most successful for II, the second way of ground truth relevance assessment and geographic search is still comparable to semantic search. If the assumption that II corresponds to contributing to satisfying unconscious information needs via contextual seeds is indeed substantial, this result supports the proposed IR approach. In view of the role of spatial context as a context bracket implying semantic context to a certain degree, the comparison of the performance of geographic search (Geo) compared to random pre-filtering geographic (RndGeo) shows that indeed, Geo is significantly better than RndGeo. In other words, while Sem may use the whole set of information items to choose the 50 best (via the global index), Geo must choose from the considerably smaller set resulting from geographic pre-filtering and still delivers acceptable relative performance compared to a random pre-filtering. Indexing the whole set of information items may not be desirable for SN and MSN environments due to privacy considerations. Because of the connections between geographic closeness and social closeness, we can thus, in a realistic SN and MSN setting, expect that Geo may effectively draw from a locally richer set of relevant items and thus deliver even better overall performance than Sem.



(a) Precision I (b) Precision II

(c) Recall I (d) Recall II

Figure 9.6: Precision and Recall, variant B

Figure 9.5 shows the precision and recall values of variant B, where a, due to the restrictive pre-filtering, insufficient number of retrieved items is not padded by random items (which induces a pessimistic evaluation for the contextual search variants). Here, as a consequence, social search is best also for assessment I with respect to precision.

While these **overall results** may already be interpreted as giving **support** to the proposed architecture and its ground assumptions, the evaluation environment may still not take advantage of several of the benefits of the architecture (such as the power of local agent IR systems). Thus, one might expect that the approach is indeed able to deliver useful contextual seeds especially in view of unconscious information needs and thus is a new alternative IR concept for SN and MSN environments.

Nevertheless, the introduced study is only a starting point for a large body of **future work** on connecting social, semantic and spatio-temporal contexts for new and useful forms of IR.

9.4 Challenges and Opportunities for Future Research

As has been mentioned above, a full implementation and real world evaluation of the architecture would be the next step following the usual Design Science methodology [Hevner et al., 2004]. A special focus has to be put on evaluating the usefulness of the results obtained by the suggested alternative IR methods in terms of the extended notions of information need discussed above. Suitable concepts of extended versions of precision and recall will have to be constructed for the respective evaluations. Furthermore, more variants of combining spatial, social and semantic retrieval criteria need to be evaluated in relation to the individual and social short term and long term context of the querying user.

▷▷▷ Skip related publications and continue with next chapter ▷▷▷

Included Publications:

Groh, G. and Straub, F. (2010). An Architecture for an Alternative, Multi-Agent-Based Information Retrieval Approach with Spatio-Temporal Primary Classification Criterion. *GIS.Science Journal, 02/2010.*

Chapter 10

Social Recommender Systems

The chapter's focus are Social Recommender Systems. In a first part, the term Social Recommender Systems and the concepts and variants behind the term and general ways to incorporate social context into recommender systems are discussed. A second section is devoted to Social Filtering which makes use of social context in a variant of Collaborative Filtering. We then discuss the use of social context for person recommenders. The next section is devoted to team recommender systems, where social context is also used to a certain extend but where the main focus is on recommending teams as a social entity. Thus team recommender systems strictly spoken may be subsumed under social recommender systems but may only partly be subsumed under services using social context. A final part deals with social context in recommender systems for personal information management (PIM)
Own publications related to this chapter: ∗[Groh, 2007]▸, ∗[Groh and Ehmig, 2007]▸, ∗[Groh et al., 2011c]▸, ∗[Brocco and Groh, 2009b]▸, ∗[Brocco et al., 2010a]▸, ∗[Brocco et al., 2010b]▸, ∗[Birnkammerer et al., 2009], ∗[Wörndl and Groh, 2007], ∗[Wörndl and Groh, 2009]▸, ∗[Mühe et al., 2009], ∗[Woerndl et al., 2009], ∗[Groh et al., 2011a]▸.
Supervised theses related to this chapter: •[Ehmig, 2007], •[Birnkammerer, 2008], •[Kern, 2009], •[Kleemann, 2010], •[Lichtenberg, 2010b], •[Hammami, 2010], •[Köllhofer, 2011].

10.1 Variants of Social Recommender Systems *

The **term Social Recommender Systems** may refer to **various distinct concepts**, which are reviewed and conceptually separated in ∗[Groh et al., 2011a]▸.

First of all, the **subject** of a recommender system may be social entities in general. One example are recommender systems for teams (see section 10.4) which e.g. can be useful in Open Innovation environments such as Social Networking-based Open-Innovation platforms (see chapter 11) where the number of possible configurations for co-inventors can be large and confusing. Another example are person recommenders, which may include systems for expert finding and matchmaking services, e.g. for dating or for finding friends or like-minded people (see section 10.3). Here 'person' may refer to various roles of persons as well.

A **second** classification aspect may be whether **social context** is used for making or improving recommendations. Social filtering systems which replace a similar-voting-based neighborhood with a social context (see section 10.2) are an example of using social context for recommender systems.

A **third**, but less important aspect may be the **audience** of the recommender system, especially whether recommendations for single persons are made (the usual case) or whether recommendations for groups of persons are made (see e.g. ∗[Birnkammerer et al., 2009]).

In Social Recommender Systems, only a single aspect may be present or two or all of the aspects are combined. E.g. in a study ∗[Mühe et al., 2009], short term social context, in the form of a special social situation of a group of users simultaneously and in a co-located way interacting via mobile devices and a large screen (e.g. during a visit to a trade fair booth), is used to generate recommendations to the whole group.

Concepts, distinctions and related work of Social Recommender Systems are reviewed in the first part of ∗[Groh et al., 2011a]▶.

10.2 Social Filtering *

In Social Filtering, social contexts are used as a replacement or augmentation of the recommendation neighborhood of classic Collaborative Filtering. In classic Collaborative Filtering [Resnick et al., 1994], [Herlocker et al., 2004], a utility score for an item I and a target user A is usually predicted by statistically combining the utility scores (e.g. ratings) for this item I from a neighborhood of users, who have a sufficiently high similarity to A with respect to utility scores for other items (e.g. a similar rating vector). Thus the coherence in recommendation neighborhood is measured in terms of utility similarity.

One of the **first studies on Social Recommender Systems**, ∗[Groh and Ehmig, 2007]▶, investigated limits and chances of replacing a recommendation neighborhood on the basis of utility coherence with a **recommendation neighborhood on the basis of social context coherence**. In this case, a long-term social context, the network of 'friends' and 'friends' of 'friends' of a SN platform was used. While coherence in terms of utility has been shown to be useful by many studies [Herlocker et al., 2004], coherence in terms of shared social context has its own advantages and may produce variants of recommender systems that complement the spectrum for certain classes of items. E.g. a **horizon broadening effect** may occur, in that these systems may recommend items that completely fall outside the usual utility spectrum of a user. However, the social context raises the probability that such horizon broadening recommendations are indeed useful for a user considerably compared to a random recommendation, because of the coherence of the social context (e.g. the set of friends). E.g. some usually strictly jazz-oriented user may be recommended a heavy metal club because some of his / her new friends are solely into this type of music. While recommendation neighborhoods based on similarity in taste-utility may not have produced this result, the result may nevertheless be useful for the user, because of the social reasons. He / she may thus get to know the clubs that his / her friends like and may have a social advantage from broadening. Summarizing in a very reduced and pointed form, Social Filtering recommenders operate on the heuristic ‘I like what the people I like like’ whereas conventional Collaborative Filtering operates on the heuristic ‘I like what the people that are like me like’.

The study ∗[Groh and Ehmig, 2007]▶ showed that especially for **strongly taste related items** and items that additionally are typically used socially, such as clubs and bars, the approach can best play out its strengths and outperform Collaborative Filtering. These findings can be supported by sociological theories on the interrelations and mutual influences of social contexts and taste, as e.g. proposed by Bordieu in view of associations between taste and common social status / common social positions (seen as long-term social context) [Bourdieu, 1984] or, similarly, by Simmel in relation to fashion [Simmel, 1957]. Since the function of socialized taste can be to express social segregation and status [Bourdieu, 1984, p.7], the horizon broadening effects of Social Filtering may sometimes also to the contrary lead to a fixation of narrow horizons if the social contexts in question are too fixed or too uniform.

To further investigate the chances and limitations of the approach, **another study** •[Birnkammerer, 2008] investigated the suitability of Social Filtering for the class of more **matter of fact oriented domains**, where utility can be rationally argued about, or **interest-based domains**, as interest structurally differs from taste e.g. via a stronger cognitive involvement. In these domains the approach is expected to perform less well. As an example recommendations of posts in a large discussion board were chosen. Indeed, the results (although slightly flawed because of structural issues with the data-set) show that Collaborative Filtering performs substantially better in these cases. The second part of ∗[Groh et al., 2011a]▶ compares the two studies and further discusses these issues.

10.2.1 Challenges and Opportunities for Future Research

It may be interesting to investigate recommendation neighborhoods on the basis of **short-term social contexts** such as Social Situations (compare e.g. [Tokarchuk et al., 2009] for a roughly related work). A restaurant or movie recommender that is able to amalgamate the views of persons, which are currently socially interacting may better be able to respect all interests and avoid domination effects by single ‘opinion leaders’ in the group.

Furthermore, it is interesting to further investigate for which class of items a Social Filtering approach can play out its advantages best. This might also contribute to determining how Social Filtering approaches could be used best as a service or service-element in SN / MSN.

10.3 Recommending Persons *

Person recommender systems on the basis of long-term social context are standard services in most SN platforms [Chen et al., 2009]. Variants may include random recommendations from the set of ‘friends’ of ‘friends’ or recommendations based on dense subnetworks, e.g. recommending users that often share membership in the same cliques, plexes, LS-sets (see [Kosub, 2005] for a review on dense subgraph prototypes) or graph clusters (see e.g. [Gaertler, 2005], [Newman, 2006] on graph clustering and community detection). Shared memberships in self declared groups (see ∗[Groh and Rappel, 2009]▶) may also be a basis for recommending persons. Furthermore, people may be recommended that have the same or a higher degree of centrality (see [Koschützki et al., 2005] for a review of centrality measures) or that share a typical pattern of linkage with other users (see [Lerner, 2005] for a review on role assignments).

In a study ∗[Groh et al., 2011c]▶, the use of very simple long-term social contexts for person recommendations was investigated and compared to interest-based person recommendations in order to compare the social approach to person recommendations to a ‘content-based’ recommender approach.

10.3.1 Challenges and Opportunities for Future Research

The alternatives for more sophisticated person recommenders on the basis of more advanced network analysis method as discussed above are interesting to investigate and to compare. Care must be taken to use methods that can be handled from a complexity point of view, but e.g. person recommenders based on shared clique membership would e.g. not necessarily have to consider all shared cliques. Thus approximations or techniques enumerating dense subnetworks with polynomial time delay (see [Kosub, 2005]) might be sufficient. Current graph clustering techniques have been shown to be applicable to large networks [Newman, 2006] and thus may also be good candidates.

In a small study •[Hammami, 2010], an MSN platform mainly targeted for **matchmaking** was developed. Matchmaking (see [Groh and Schlichter, 2005]) is largely synonymous to person recommending. The basic concept was based on creating awareness with respect to sharing spatio-temporal contexts (which may be viewed as a very simple and not very expressive form of short-term social context) with other users via ‘checking in’ to locations and related awareness components. Thus the system can be viewed as a simple form of person recommender on the basis of short-term shared spatio-temporal / simple social context. This is very similar to other platforms such as [pla, 2012], however, the application of the study was more explicitly oriented towards actual dating. Although the study largely failed to investigate possible influences of long-term social context as was planned, the potential use of social networks as long-term **social context for dating applications** remains an interesting field of study. Elements of building of trust and estimations of security may be conveyed by recommending persons as ‘safe’ if they have a minimum feedback (e.g. PageRank) centrality measure [Koschützki et al., 2005] in the network of acquaintances or in a network of directed security approval relations (in the fashion of a Web of Trust [Khare and Rifkin, 1997]). These measures may be more personalized by limiting the set of acquaintances or security approvers to the personal network of a user. Aside of dating, recommending persons on the basis of finding central nodes in webs of trust or webs of recommendations may generally be an interesting field of study (see [Golbeck et al., 2003] [Jamali and Ester, 2009], [Lathia et al., 2008] for related approaches).

10.4 Team Recommender Systems *

In a **study**, ∗[Brocco and Groh, 2009b]▶, ∗[Brocco et al., 2010a]▶, a **meta-model for team recommendations** was developed, on the basis of which a number of subsequent successful studies investigating certain optimization variants (such as e.g. using case-based reasoning (see [Brocco, 2011])) were realized. The main intended use case were Open Innovation environments (see chapter 11).

Team recommendation or, more generally, the problem of **recommending sets of items, whose synergetic utility exceeds the sum of utilities of its constituents** is a **hard problem**. Seen as a recommendation problem, it may best be characterized as a content-based recommendation problem (see ∗[Groh et al., 2011a]▶), because the number of known subjective estimations of the utility function (e.g. via ratings by various users) is usually very low (often zero) compared to the combinatorially huge size of the space of possible recommended objects (sets of items) and thus collaborative or social filtering approaches cannot be applied. It may also be viewed as a complex general optimization problem, although the underlying utility function and solution space appear to be too complex to be reasonably treated by usual optimization techniques, or as a constraint solving problem (see [Brocco, 2011]).

Contributions to estimating and **formulating aspects of the synergetic utility function** often come from fields such as human resources, sociology and socio-psychology (see ∗[Brocco et al., 2010a]▶) but these models often are of a qualitative nature only, which makes it hard to translate them into components of a formal, algorithmically processable model. Thus, the meta model constructed in ∗[Brocco and Groh, 2009b]▶ identified classes of influence variables of the synergetic utility function and a general framework, using analytic and heuristic mappings to approximate the synergetic utility function on the basis of these variables.

The meta model can then be used to formulate an **instance of a concrete synergetic utility function**, which is tailored to the needs of a **specific use case** (via choosing appropriate variable instances, heuristics etc.) In ∗[Brocco et al., 2010a]▶, the concept was qualitatively evaluated by showing that several standard qualitative models can be formulated as instances of the meta model. The resulting synergetic utility function may then be **optimized** using a number of suitable techniques such as case-based reasoning or soft constraint reasoning (see [Brocco, 2011]). The model has also been successfully applied in a team recommender service ∗[Brocco and Groh, 2010] for the Social Networking based Open-Innovation platform of the **KOPIWA project** ∗[Zeini et al., 2008]. The project aimed at investigating competences and competence development for Open Innovation and incorporated long-term social context in various ways (see chapter 11).

Social contexts are among the **important influence factors or variables** of such a synergetic utility function. A network of long-term relations (friendship-relations, dislike-relations, previous team membership relations etc.) among the candidate team members may influence the ‘quality’ of a team. In a **study** ∗[Brocco et al., 2010b]▶, the influence of these factors on team recommendation were investigated.

10.4.1 Challenges and Opportunities for Future Research

Besides the use of team recommender systems for professional teams, it may be interesting to investigate analogous systems for **recommending friendship circles** for sharing interests or other private use cases (see e.g. [Saha and Getoor, 2008] for a related approach). These systems need to incorporate criteria based on long-term social context such as analysis of the social network e.g. revealing coherent subgroups in a 'friendship' network (see first part of section 10.3), but they would also have to incorporate content-based aspects such as interest profiles etc. (see also ∗[Groh et al., 2011c]▶). Such a service could be useful for people that are new in a city and want to build up their social network. Special forms of advertisement targeting are another variant. However, in contrast to the professional case, where **publication of related long-term social contexts** (as in Open Innovation networks) is mostly in the interest of the users, this may ultimately not be the case if used for friendship circle recommendations in the private use case, if such a service draws unwanted interest to subnetworks with a high Social Capital. Thus new mechanisms for endorsement of the recommendation on behalf of the recommended group must be devised. This may not only apply to recommending groups but also to recommending single persons. In case of groups, voting mechanisms may be used, where votes may be weighted with a continuous membership degree of a voter in the group in question, derived from the social network graph. In essence, variations of such mechanisms are already a normal part of social interaction, e.g. when introducing somebody new into a friendship circle, members will subtly 'vote' on the acceptability of that person via social signals or even via explicit comments. As with all explications of social mechanisms, entities and contexts in Social Networking, new unexpected positive use-cases and usage cultures may develop from such a service.

10.5 Recommender Systems for Personal Information Management *

Personal Information Management (PIM) applications support the user in managing the personal information space. In a study ∗[Wörndl and Groh, 2009]▶, (see also ∗[Mühe et al., 2009], ∗[Woerndl et al., 2009]), the use of social context for mobile semantic desktops as a means of mobile PIM system using Semantic Web formalisms were investigated. Short-term social context (approximated by people in spatio-temporal proximity) was used to select other users, the public part of whose information spaces were included in content-based recommendation processes. Long-term social context (the social network) was used to limit the circle of users who are principally considered for this incorporation.

10.5.1 Challenges and Opportunities for Future Research

Proactive sharing of information with other users on the basis of long-term or short-term social contexts is an interesting subject of studies. While on the one hand, such services may contribute to information overflow, they may, on the other hand, contribute to broadening horizons (compare section 10.2) (The relevance and potential of social context for non-proactive information services has already been discussed in chapter 9). Such a service has been discussed and evaluated in a survey in •[Birnkammerer, 2010] as an interesting use case for privacy management and control of information flows in SN and MSN.

▷ ▷ ▷ Skip related publications and continue with next chapter ▷ ▷ ▷

Included Publications:

Groh, G. and Ehmig, C. (2007). Recommendations in Taste Related Domains: Collaborative Filtering vs. Social Filtering. *Proc. Group07, Sunibel Island, USA, Nov 2007.*

Groh, G., Birnkammerer, S., and Köllhofer, V. (2011a). Social Recommender Systems. *in Jose J. Pazos Arias et al (Eds.): "Recommender Systems", Springer, Intelligent Systems Reference Library, Volume 32.*

Groh, G., Brocco, M., and Kleemann, A. (2011c). Interest-Based vs. Social Person-Recommenders in Social Networking Platforms. *Arxiv.org.* http://arxiv.org/abs/1107.5654 (checked May 2012).

Brocco, M. and Groh, G. (2009b). A Meta Model for Team Recommendations in Open Innovation Networks. *Short Paper, Proc. Third ACM Conference on Recommender Systems (RecSys 09), NY, USA.*

Brocco, M., Groh, G., and Forster, F. (2010a). A Meta Model for Team Recommendations. *Proc. SocInfo2010, Laxenburg, Austria.*

Brocco, M., Groh, G., and Kern:, C. (2010b). On the Influence of Social Factors on Team Recommendations. *Second International Workshop on Modeling, Managing and Mining of Evolving Social Networks (M3SN), Co-located with IEEE ICDE 2010, Long Beach, USA.*

Wörndl, W. and Groh, G. (2009). A Social Item Filtering Approach for a Mobile Semantic Desktop Application. *Proc. AAAI 2009 Spring Symposium on Social Semantic Web (SSW), Stanford, CA.*

Chapter 11

Supporting Creativity and Open Innovation

This chapter discusses, where and how social context may be used to generate or improve services in connection with IT support for Open Innovation processes. The first deals with with contextual awareness services and service elements for Social Networking based Open Innovation platforms. Examples are visualizations of multi-modal networks of innovators, organizations, and innovation artifacts and service elements for reputation modeling in OI communities. The second part deals with contextual IT support for creativity, which is an important element in early stages of OI processes. Examples are measurement and usage of short term social contexts around co-located collaborative UI environments such as multi-touch tables. A special use case is collaborative music composition.

Own publications related to this chapter: ∗[Zeini et al., 2008], ∗[Brocco and Groh, 2009b], ∗[Reinhardt et al., 2010], ∗[Friess et al., 2010b]▶, ∗[Brocco and Groh, 2009a], ∗[Schmucker et al., 2009], ∗[Reinhardt et al., 2009], ∗[Frieß et al., 2012]▶, ∗[Reinhardt et al., 2012], ∗[Groh et al., 2011b]▶, ∗[Kammergruber et al., 2011], ∗[Reinhardt et al., 2011]▶, ∗[Brocco et al., 2011], ∗[Brocco and Groh, 2010], ∗[Schmucker et al., 2010], ∗[Friess et al., 2009], ∗[Friess et al., 2010c], ∗[Friess et al., 2010a]▶, ∗[Frieß et al., 2010], ∗[Klügel et al., 2011]▶, ∗[Friess et al., 2012b]▶, ∗[Friess et al., 2012a, (submitted)]▶

Supervised theses related to this chapter: •[Kaiser, 2009], •[Klügel, 2010], •[Kleinhans, 2010], •[Kleinhans, 2011]

11.1 IT-Support for Open Innovation Processes

Open Innovation (OI) is a **new paradigm for innovation processes and innovation culture** [Chesbrough, 2003] [Von Hippel, 2005] that is characterized by opening up innovation processes by integrating customers, freelancers and other companies into the innovation process (see also ∗[Zeini et al., 2008], ∗[Reinhardt et al., 2010], ∗[Reinhardt et al., 2012], ∗[Groh et al., 2011b]▶, ∗[Reinhardt et al., 2011]▶, ∗[Brocco et al., 2011]). In traditional **closed innovation**, "[...] *firms adhered to the following philosophy:* Successful innovation requires control. *In other words, companies must generate their own ideas that they would then develop, manufacture, market, distribute and service themselves* [...]. *This approach calls for self-reliance: If you* *want something done right, you've got to do it yourself*" [Chesbrough, 2006, p.36]. In contrast to that, **Open Innovation** is characterized by companies including other players especially into their innovation and product development processes. The reasons, why such a strategy can be successful despite possibly losing control, or market momentum, or despite the danger of competitors profiting from own contributions, are manifold. One aspect is the growing research, technological, and business complexity and dynamics in relation to many modern products or services, which is hard to control by a single company. Thus new ideas, innovations, and research results are constantly produced outside the company, which may be highly relevant in view of a product or the company as a whole. Thus a company may synergeticly profit from collaboration with the other players [Von Hippel, 2005].

The **challenges and capabilities of IT support for Open Innovation** are manifold, and include techniques and paradigms of classic CSCW (see [Borghoff and Schlichter, 2000]), Social Software (see ∗[Reinhardt et al., 2010]), or creativity support (see section 11.2) to back up communication, awareness, and collaboration of the actors in all stages of the innovation processes. Here, social context plays a key role and involvement of social context for OI support will be discussed in this section and the next section.

Two **projects** aimed at investigating special aspects of OI and IT support for OI. In the **KOPIWA** project ('Kompetenzentwicklung und Prozessunterstützung in Open Innovation-Netzwerken der IT-Branche durch Wissensmodellierung und Analyse' (which translates to 'Development of Competencies and Process-Support in Open Innovation Networks in the IT sector via Knowledge-Modeling and Analysis')) ∗[Zeini et al., 2008], [kop, 2011] (see also ∗[Brocco and Groh, 2009a], ∗[Schmucker et al., 2009], ∗[Groh et al., 2011b]▸, ∗[Kammergruber et al., 2011], ∗[Brocco et al., 2011], ∗[Brocco and Groh, 2010], ∗[Schmucker et al., 2010]), it was the goal to support users in monitoring and developing skills and competencies necessary for certain fields required to successfully participate in Open Innovation.

The **Open-I** project ('Open Innovation im Unternehmen' (which translates to 'Company-Internal Open Innovation') ∗[Reinhardt et al., 2010], [ope, 2011] (see also ∗[Friess et al., 2010b]▸ , ∗[Reinhardt et al., 2009], ∗[Frieß et al., 2012]▸, ∗[Reinhardt et al., 2012], ∗[Reinhardt et al., 2011]▸) was targeted at investigating how the paradigms of OI and the general possibilities to support OI manifest themselves in the case of OI *within* large companies, which are composed of so many different organization units that analogous problems to an ensemble of companies engaged in OI may occur.

In both projects, IT support was centered around **Open Innovation platforms** based on concepts from Social Software and Social Networking which were tested and evaluated in case studies with several industry partners (in case of KOPIWA, several medium sized German IT companies with focuses on mobile applications, serious games [Stone, 2005] and learning software were involved, and in case of Open-I, a company running one of the largest German airports and a large IT company specializing in software for lawyers, tax-, and business accountants were involved). We will now discuss, how social context may be used in the services and service elements of these platforms.

11.1.1 Social Networking Based Open Innovation Platforms and Services

From an abstract point of view, an Open Innovation setting may be associated with an **Open Innovation network**, a **multi-modal network**, modeling the **general context** of Open Innovation processes and its elements. Nodes may correspond to organizations (e.g. companies), persons (customers, employees etc.), OI-(sub-)projects, groups of inventors, skills and competencies, or ideas. Edges may correspond to social ties, 'involvement-in' relations, 'prerequisite-for' relations etc. A large distributed information space is associated with this context network, containing documents, sketches, photos and other innovation artifacts. OI processes or steps of OI processes govern the dynamics of this context network and the associated distributed information space, and vice versa: the network's dynamics influences OI processes and process steps and acts as context for these processes and process steps. Examples of process steps or dynamical changes in the context network may include: OI projects going trough several stages ∗[Reinhardt et al., 2012], actors joining or leaving the network, actors changing their associations with other players, new skills become relevant for certain fields etc. The context network thus contains many elements which correspond to long- and medium-term **social context**. Since context aware services and service elements support users in their OI processes in view of awareness, communication and collaboration in the context modeled by this network, social context is intimately linked with these services and service elements.

11.1.1.1 Open-I *

The **Open-I platform** and corresponding evaluation studies are discussed in ∗[Reinhardt et al., 2010], ∗[Reinhardt et al., 2012], and ∗[Reinhardt et al., 2011]▶. Building on the paradigm of a Social Networking platform, it contains services and service elements asynchronously supporting all phases of an OI process. A typical example of **using medium-term and long-term social context** is a social network visualization in an awareness service of the OI platform which is called NetStream ∗[Friess et al., 2010b]▶. The social network acts as a context for all stages of the OI process as e.g. for initially selecting OI partners, or during convergent and divergent phases of creativity support for idea generation. As usual, nodes correspond to actors and edges model social ties. Actors are usually persons but other platforms (see the discussion in relation to the KOPIWA platform below) may as well also use organizations as a further mode. Social ties are modeled as self-declared bi-directional 'friendship'-type relations but may also correspond to 'co-invention' type of relations induced from statistics of the common activities during the stages of the OI process (e.g. common participations in an IdeaStream session supporting creativity in early idea generating stages of the OI process (see ∗[Frieß et al., 2012]▶, and section 11.2). The NetStream application is a network visualization which makes use of Shortest-Path-Betweenness centrality [Koschützki et al., 2005] in various aspects of the visualization such as node diameter, coloring etc.. This centrality measure was chosen because it is well suited to model the importance of a node in a network which e.g. is closely associated the flow of information along shortest paths ∗[Friess et al., 2010b]▶. The application also offers other views on the multi-mode OI network, e.g. showing the association of users and ideas or the association of users with innovation groups ∗[Frieß et al., 2012]▶. ∗[Frieß et al., 2012]▶ also shortly discusses the role of **short term social contexts** in early stages of the OI process, which is discussed in more detail in section 11.2.

11.1.1.2 KOPIWA *

The KOPIWA platform is also a Social Networking based OI platform (see ∗[Brocco and Groh, 2010], ∗[Groh et al., 2011b]▶). Since the focus of the project is different compared to Open-I, the platform's character also differs from the Open-I platform. The Open-I platform supports the management of various phases of OI-processes more directly, while the KOPIWA platform offers a number of higher level services for the management and meta management of OI processes. One bundle of services aims at managing skills and competencies for the various fields in which Open Innovation processes are suited as e.g. ontology-based matching between job-offers and applicant profiles (see [Ziebarth et al., 2010], [Ziebarth et al., 2009], [Hoppe et al., 2010]) or trend-spotting [Massolle et al., 2011]. Other services support team recommendation (see ∗[Brocco and Groh, 2010], section 10.4).

Long-term social context in the form of social networks is used to enhance services in various ways. Broker nodes between dense sub-networks can be identified by social network analysis [Zeini and Hoppe, 2010b]. E.g. if the detected dense sub-networks [Zeini and Hoppe, 2010a] can be associated with certain innovation topics, broker nodes may correspond to actors that are involved in many such topics [Zeini and Hoppe, 2010b]. It can be interesting to use these analysis results for awareness or information services structuring the complex network and conveying important information to other innovators, which may then influence and act as contexts for their strategic or tactical actions in their OI processes.

The **Fame Mirror** ∗[Groh et al., 2011b]▶ is another service of the KOPIWA platform mostly targeted at awareness in relation to various aspects of the OI-network. Elements (nodes) of this context network on which the Fame Mirror operates and which are subject of the awareness it conveys via visualization and search options are basically innovations, topic tags for innovations, competence tags for innovations, statistics of user actions on the platform, and ratings of a user's performance in an innovation in five different categories. Edges correspond to user involvement in innovations, associations of tags and innovations etc. The ratings for an actor and the statistics of his / her community-enhancing social actions are amalgamized into a **fame value** for this actor, via several heuristics e.g. weighting a rating with the fame of the rater. One service element of the fame mirror are **multi-context visualizations of local subnetworks** of this network (e.g. a visualization of an innovation and all its involved actors together with a tag cloud characterizing the innovation which differentiates between competence and topic tags, or an analogous actor centric view. Another service element visualizes the **dynamics of actor fames** in three different fashions, targeted to several motivation-psychological types of persons (see ∗[Groh et al., 2011b]▶). These service elements support awareness with respect to important competence- or topic-trends or the implicit dynamics of an innovation. Persons with a high fame may be preferably included into new innovation projects and the visualizations of fame may contribute to actor motivation. Furthermore, in an OI setting it is important to account for an actor's contributions in terms of transparency and fairness, which the Fame Mirror also contributes to.

The Fame Mirror makes direct use of the co-inventor relations between users as simple forms of **medium-term social context** in its visualizations. It also makes use of social contexts in an **indirect** way. The assessment of an actor A's performance in relation to a certain innovation in a certain category by actor B may be viewed as a qualification of the professional social context (a qualification of the co-inventor-relation) between A and B or as a qualification of their implicit personal social context (long-term social context (over the course of several innovations) as well as medium-term social context (over the course of one innovation)). Thus, the fame mirror also contributes to explicating / modeling social contexts in a special way via ratings. Furthermore, the relation of the fame values of the actors may influence the social contexts involving these actors in view of status, envy, perception of fairness etc. Thus the Fame Mirror also shapes social context.

11.1.2 Challenges and Opportunities for Future Research

Perspectives in view of supporting Open Innovation processes with IT services and platforms are too manifold to discuss here and also involve other disciplines such as research on human motivational psychology or research from business science regarding process management, controlling, organizational development etc. As the previous discussion showed, possibilities of using social context in OI support platforms and services are also manifold: One key aspect of OI support that was featured in the previous discussion was contributing to **awareness** in view of all sorts of contexts elements and their relations modeled in the OI network (see also chapter 7). Awareness in view of social contexts may, in most cases, correspond to **professional social context** (co-innovator relations, co-employee relations etc.) but may also involve social contexts with a stronger emotional involvement, due to the emotional quality of creativity (see section 11.2). As has been discussed, in case of Open Innovation, the context elements and their relations form a very complex multi-modal network. Awareness services using dynamic social contexts (involving actors and their relations) thus will in most cases have to involve other context elements and relations as well in order to optimize usefulness in view of awareness. As an example consider the Fame-Mirror which uses actors as well as innovations or competence or topic tags in its visualizations.

Key challenges in this field include **visualizations that can cope with the complexity of the network and its dynamics** while still not overburdening the user and at the same time maximizing awareness and overview. Which type of visualization involving social context is right for which task or which conscious or unconscious information need in context with an OI process should be investigated on the basis of a number of further case studies, which, due to the enormous complexity and multi-facetedness involved, should be conducted by **linking into existing OI communities** or groups and their current set of tools. As became apparent in Open-I as well as KOPIWA artificially setting up case studies and designing platforms and services from scratch, will, in general, be very difficult.

Furthermore, it is interesting to further investigate heuristics that are able to capture and **measure quantity and quality of contributions** of users in Social Networking-based OI platforms. Innovation processes may lead to large revenues or valuable patents being generated, and thus involving other actors may potentially lead to conflicts regarding the book-keeping of who contributed what and thus is eligible for what share of the potential revenues, patents etc. From a business strategy perspective, it may, for similar reasons, be necessary to also investigate suitable (context aware) **privacy concepts** for such platforms or services, where the decision of what to open to which co-inventors may be important, even in an *Open* Innovation setting.

11.2 Situative Creativity Support *

One important phase of OI processes are the **early stages** (see ∗[Reinhardt et al., 2011]▶), where, besides other tasks such as information gathering, actors **create ideas** in view of a given coarse problem or coarse frame and in a certain context, whose long-term and medium-term elements may be modeled by an OI network discussed above ∗[Frieß et al., 2012]▶. The created ideas may then be further refined, rated, selected, reviewed, or further developed in other process steps ∗[Reinhardt et al., 2011]▶. Since an OI process typically does not follow a linear workflow ∗[Reinhardt et al., 2011]▶, idea generation phases may occur multiple times throughout the stages of the OI process.

Idea generation may be supported by **IT-based creativity support systems** (see ∗[Friess et al., 2012b]▶). Such systems support the generation of ideas via generic creativity techniques [VanGundy, 1988], which in most cases incorporate divergent phases (where ideas are created) and convergent phases (where ideas are rated, unified, classified, clustered etc.). A web-based creativity support system, IdeaStream [Forster, 2010], was further developed and integrated into the Open-I web-platform ∗[Reinhardt et al., 2011]▶ ∗[Friess et al., 2012b]▶ (see also (see subsubsection 11.1.1.1), in order to allow users to initiate 'creativity sessions' at any time in the OI process if a certain problem requires new ideas. Typically, creativity sessions occur especially during the early stages of the OI process as has been discussed above.

Long-term social contexts but especially **short-term social contexts** may have a substantial influence on the divergent and convergent phases of idea generation. Long lasting personal preferences and friendships as well as antipathies but also short-term group effects have the potential to influence quality and quantity of the produced ideas (see ∗[Frieß et al., 2012]▶ ∗[Friess et al., 2010a]▶). E.g. the distributed interaction governing a web-based system such as Ideastream may alleviate some of the negative effects of social context such as Social Loafing ∗[Friess et al., 2010a]▶.

In the **study** ∗[Friess et al., 2010a]▶, the **influences of short term social contexts on the quality and quantity of ideas** was indirectly investigated by providing one group of users of the study with certain means of electronic communication during the creativity session and not providing these means to the other group. Communication may be viewed as a means in which an otherwise latent short term social context may exert influence on users and become manifest. The general **influences of social context on creativity support systems** are discussed in ∗[Frieß et al., 2012]▶ and ∗[Friess et al., 2012b]▶.

Since there is multiple evidence that short term social context indeed has an influence on creativity ∗[Friess et al., 2012b]▶, the advantages of user interface paradigms that support face to face interaction such as **multi-touch tables**, may contribute to combining the positive effects of social context and especially short-term social context with the advantages of IT support. Several quantitative studies on the implications of individual context and social context for creativity support using multi-touch tables, mobile devices and combinations of multi-touch tables and mobile devices are discussed in ∗[Frieß et al., 2012]▶ ∗[Friess et al., 2012b]▶.

Systems for **collaborative music composition** using table top user interfaces are a special case of creativity support where short term social context may have a strong influence. An example system is discussed in ∗[Klügel et al., 2011]▶ and ∗[Frieß et al., 2010]. These systems mediate between distributed asynchronous music composition (e.g. by alternating between exchanging tracks and sounds (e.g. via email) and each musician contributing and combining) and classic synchronous improvisation which usually has a tight preexisting musical frame or context (as e.g. improvising together over a jazz standard.).

All these creativity support systems just discussed often only make **indirect use of social context**. Their UI- and other system-concepts anticipate social context and incorporate general features of social context (as e.g. in the table-metaphor or multi-touch tables). But these systems only in a limited way make **direct use** of explicitly detected and modeled social context. The study ∗[Friess et al., 2012a, (submitted)]▶ investigated, how short term social contexts around table-top systems may be explicitly detected and modeled. Knowing that e.g. a Social Situation in the vicinity of such a system is currently instantiated, the system may react by inviting the involved actors to resume a previously interrupted creativity session. The explicit modeling of long-term social contexts (e.g. the friendship relations of users in a company social network) may allow such systems to further fine-tune their behavior (e.g. by offering or not offering certain users certain spots or territories on the table).

11.2.1 Challenges and Opportunities for Future Research

Detection, explicit modeling and incorporation of short term social context may foster situative creativity support, where (as described in ∗[Frieß et al., 2012]▶) a number of user interfaces should be available, which allow users to participate in the creative processes in a coherent way in many different situations. Especially in company-internal OI processes, creative user participation could be supported by situatively appropriate invitations as described above.

Adapted social signal processing techniques (see chapter 5) are required that measure those elements of short-term social context that are useful for the respective creativity support application. In the case of collaborative music composition, adapted techniques of facial emotion detection (see [Truong et al., 2007]) or emotion detection from dance movements may contribute to optimally provide matching musical elements for the collaborators or to fine-tune gesture-based instrumental UIs (see also [Blaine and Fels, 2003]). Considering and adapting to the emotional contexts of all collaborators and the emotional quality of the collaborative Social Situation might be crucial factor for collaborative music composition systems.

▷▷▷ Skip related publications and continue with next chapter ▷▷▷

Included Publications:

Frieß, M. R., Groh, G., Reinhardt, M., Forster, F., and Schlichter, J. (2012). Context-Aware Creativity Support for Corporate Open Innovation. *International Journal of Knowledge-Based Organizations.*

Reinhardt, M., Frieß, R., Groh, G., and Amberg, M. (2011). Fostering Process and Context Support through Social Networking Services on an Open Innovation Platform. *in Hoppe et al (Eds.): IT Support for Open Innovation, Eul-Verlag, Germany.*

Friess, R., Groh, G., and Reinhardt, M. (2010b). Supporting Open Innovation Communities by an Interactive Network Visualization. *Proc. Web-Based Communities 2010 (WBS2010), Freiburg, Germany.*

Groh, G., Brocco, M., and Asikin, Y. A. (2011b). Contribution Awareness and Fame in Open Innovation Networks. *in Hoppe et al (Eds.): IT Support for Open Innovation, Eul-Verlag, Germany.*

Friess, R., Groh, G., Kluegel, N., and Kleinhans, M. (2012b). A Tabletop Application Environment for Generic Creativity Techniques. *International Journal of Computer Information Systems and Industrial Management Applications.*, 4:55–65. (Invited journal contribution based on *Rene Friess, Martin Kleinhans, Florian Forster, Florian Echtler, Georg Groh: "A Tabletop Interface For Generic Creativity Techniques", Proc. Interfaces and Human Computer Interaction 2010 (IHCI2010) Freiburg, Germany, July 2010*, http://mirlabs.ujn.edu.cn/ijcisim (checked May 2012)).

Friess, R., Groh, G., Kluegel, N., and Kleinhans, M. (2012a). An Analysis Framework for Quantitatively Characterizing Collaboration in Tabletop Based CSCW Environments. *International Journal of Computer Information Systems and Industrial Management Applications*, 4:341–351. http://mirlabs.ujn.edu.cn/ijcisim (checked May 2012).

Friess, R., Forster, F., Brocco, M., and Groh, G. (2010a). On the Impact of Chat Communication on Computer-Supported Idea Generation Processes. *First Intl. Conf. on Computational Creativity 2010 (ICCC10), Lissabon, Portugal.*

Klügel, N., Frieß, R., Groh, G., and Echtler, F. (2011). An Approach to Collaborative Music Composition. *Proc. NIME2011, Oslo, Norway.*

Conclusions

In this thesis we investigated the multi-faceted research question of how suitable forms of context may be measured and induced for use in new or improved services for Social Networking and especially Mobile Social Networking and how these new or improved forms of context-aware services may be designed. In order to distinguish this scenario, in Part I we defined and characterized important concepts from Contextual-, Mobile-, and Decentralized Social Networking using a range of different methods and focusing on different detailed aspects. We then in Part II focused on the acquisition and derivation of useful and expressive variants of social contexts as especially interesting types of context for Social Networking. This involved the development of suitable models for social context and the investigation of methods of how these models may be instantiated using sensor data (low level context elements) and other context elements of various degrees of abstraction. On the one hand we focused on the semantically rich characterization of social relations as a typical form of long-term social contexts e.g. using NLP-based methods for sentiment analysis. On the other hand we also investigated Mobile Social Signal Processing methods for deriving short-term social contexts on the basis of geometry of interaction and audio. One key form of basic short-term social contexts discussed were Social Situations, which were characterizations of the boundaries of social interaction situations in terms of the participating persons and in terms of spatial and temporal boundaries. We furthermore investigated how personal social agents may combine such social context elements on various levels of abstraction and were able to show that a combination of several low level data sources allowed for a more precise assessment of Social Situation contexts. The third part discussed new and improved context aware Social Networking service concepts, using social contexts such as those discussed in Part II as well as other forms of context interesting for Social Networking. We investigated special forms of awareness services, new forms of social information retrieval, social recommender systems, context aware privacy concepts and services and platforms supporting Open Innovation and creative processes. Evaluations and partial evaluations of the proposed concepts were able to demonstrate their potential.

In each chapter we provided sections discussing challenges for future research, pointing to unsolved or partly solved problems as part of the larger research agenda of Contextual Social Networking and to new questions and ideas which have not yet been covered in detail. Several of the problems that have not been fully solved are still subject to ongoing research. These include e.g. the adaptation and extension of the models for Social Situations to moving interaction scenarios, the adaptation in terms of the integration of temporal information, in terms of integrating other contexts (e.g. the overall social 'density' or the cultural implications of the surroundings), or in terms of the precise mobile measurement of interaction geometry as an important prerequisite.

Many of the results presented here may have or gain significance beyond Social Networking and Social Media, as e.g. formal models for social interaction on all temporal scales and methods for their instantiation may prove to be useful for e.g. general context-aware services and interfaces, crime-prevention, or understanding of higher-level human social behavior. However, as partly discussed in chapter 8, it is not fully clear if an ever extending 'computerization' of social life with a growing number of sensors and with an increasingly accurate modeling and explication of social behavior and social relations is only beneficial. We will have to carefully monitor the dangers such a technology may bring along. These dangers are not only limited to possible compromises of privacy (in terms of social contexts or other information in Social Networking) and adverse use of this information against users, but also encompass more subtle consequences such as a possible emotional and cognitive overload of users not being or feeling able to deal with the chances and demands of this 'brave new world'. Thus when designing new forms of services or investigating methods for acquiring new forms of context, one is obliged to never lose sight of the fact that the well-being and support of human beings still has to be the center of all engineering efforts.

List of Publications

Publications included in this thesis are marked with a **(*)** symbol.

Theses

- Georg Groh: "Husimidichte und Phasenraumentropien für zweidimensionale Quantensysteme mit gemischt-regulär-chaotischer klassischer Dynamik" (Husimi-Density and Phase-Space Entropies for two-dimensional Quantum-Systems with Mixed Regular-Chaotic Classical Dynamics), Diploma-thesis in theoretical Physics, University of Kaiserslautern, Germany, 153 pages, Jan.1997
- Georg Groh: "Applying Text Classification Methods to the Mapping of Simple Extensional Ontologies for Community Information Management", Diploma thesis in Computer Science / Informatics, University of Kaiserslautern / Technische Universität München (TUM), Germany, 115 pages, Feb. 2001
- Georg Groh "Ad-Hoc-Groups in Mobile Communities – Detection, Modeling and Applications", PhD-thesis in Computer Science / Informatics, Technische Universität München (TUM), Germany, 254 pages, Feb. 2005

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- Martin S. Lacher, Georg Groh: "Facilitating the exchange of explicit knowledge through ontology mappings", Proc. 14th International FLAIRS conference, AAAI Press, S.305-309, Key West, USA, Mai 2001
- Christian Hillebrand, Georg Groh, Michael Koch: "Mobile Communities - Extending Online Communities into the Real World (Long Version)", Proc. Multikonferenz Wirtschaftsinformatik 2002 (MKWI2002) - Mobile and Collaborative Business, Nürnberg, Germany, 2002
- Michael Koch, Georg Groh, Christian Hillebrand: "Mobile Communities - Extending Online Communities into the Real World (Short Version)", Proc. Americas Conf. on Information Systems (AMCIS2002), Dallas, USA, Aug. 2002.

- Oliver Brakel, Georg Groh, Christian Hillebrand, Andreas Tasch: "Privacy-Einstellungen bei Lokalisierungsdiensten" (Privacy Settings in Location-Based Services) Proc. MKWI04, Essen, Germany, March 2004
- Wolfgang Woerndl, Georg Groh, Karlheinz Toni: "Semantic Blogging Agents: Weblogs and Personalization in the Semantic Web", Proc. AAAI Spring Symposium on Computational Approaches to Analyzing Weblogs, Stanford, USA, March 2006

(*) Georg Groh: "Groups and Group Instantiations – Detection Modeling and Applications" Proc. AAAI International Conference on Weblogs and Social Media (ICWSM07), Boulder, Co, USA, March 2007

- Ruth Cobos, Clarissa Falge, Georg Groh: "Sistema multiagente para el mantenimiento de las áreas de conocimiento que ofrece el sistema de gestión de conocimiento" (A Multi-Agent System for the Maintenance of Areas of Expertise in a Knowledge Management System), Proc. DESMA07, Saragossa, Spain, September 2007

(*) Georg Groh, Christian Ehmig: "Recommendations in Taste Related Domains: Collaborative Filtering vs. Social Filtering", Proc. ACM Group07, Sunibel Island, USA, Nov 2007

- Andreas Nauerz, Georg Groh: "Implicit Social Network Construction and Expert User Determination in Web Portals", Proc. AAAI Spring Symposium on Social Information Processing, Stanford University, USA, 2008
- Sam Zeini, Nils Malzahn, H. Ulrich Hoppe, Joachim Hafkesbrink, Ulrich Mill, Georg Groh, Thomas Schauf, Roland Westermaier, Oliver Pfeiffer, Hartmut Scholl: "Ansätze zur softwareunterstützten Kompetenzentwicklung in innovationsgetriebenen Berufen der Digitalen Wirtschaft. Virtuelle Organisationen und Neue Medien 2008" (Approaches for Software-Supported Development of Competencies in Innovation-Driven Professions in Digital Economy), Proc. GeNeMe 2008, pp. 229-240, Dresden, Germany, 2008
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- Rene Friess, Martin Kleinhans, Florian Forster, Florian Echtler, Georg Groh: "A Multi-Touch Tabletop-Interface for Applying Collaborative Creativity Techniques", Video, ACM Intl. Conf. on Interactive Tabletops and Surfaces 2009 (Tabletop09), Banff, Canada, Nov 2009

(*) Michele Brocco, Georg Groh: "A Meta Model for Team Recommendations in Open Innovation Networks", Short Paper, Proc. Third ACM Conference on Recommender Systems (RecSys 09), Oct 2009, NY, USA

- Rene Friess, Florian Forster, Michele Brocco, Georg Groh: "On the Impact of Chat Communication on Computer-Supported Idea Generation Processes“, First Intl. Conf. on Computational Creativity 2010 (ICCC10), Lissabon, Portugal, Jan. 2010

(*) Michael Reinhardt, Rene Friess, Georg Groh, Michael Amberg: "Web 2.0 driven Open Innovation Networks - A Social Network Approach to support the Innovation Context within Companies", Proc. MKWI 2010, Göttingen, Germany, Feb. 2010

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- (*) Piotr Kozikowski and Georg Groh: "Inferring Profile Elements from Publicly Available Social Network Data", Proc. IEEE Socialcom2011, Boston, USA

Refereed Workshop Publications

- Martin S. Lacher, Georg Groh: "Enabling personal perspectives on heterogeneous information spaces", Proc. IEEE 10th Intl. Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE 2001), MIT, Cambridge, USA, 20-22. Jun. 2001.
- Georg Groh: "Modelling Ad-Hoc-Groups in Communities" , Proc. International Workshop "Virtual Communities & Mobility", 27-28. TU-München, June 2003
- Wolfgang Woerndl, Georg Groh: "A proposal for an agent-based architecture for context-aware personalization in the Semantic Web", Proc. IJCAI-05 Workshop Multi-Agent Information Retrieval and Recommender Systems, Edinburgh, UK, 2005.
- Clarissa Falge, Ruth Cobos, Georg Groh: "Classification and Ontology Maintenance in Agent-based Knowledge Management Frameworks: A Prototypical Approach" Proc. Intl. Workshop on Social Media Analysis, IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology (WI-IAT 07), November 2007
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- Bastian Seehaus: "Social Marketing in Mobile Peer to Peer Networks", WS 2008 / 2009
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Abbreviations

- **AJAX**: Asynchronous JavaScript and XML
- **ASP**: Active Server Pages
- **BIC**: Bayesian Information Criterion
- **CSCW**: Computer Supported Cooperative Work
- **CSN**: Contextual Social Networking
- **CSS**: Community Support System, Cascading Style Sheet
- **DBN**: Dynamic Bayesian Network
- **DOM**: Document Object Model
- **DSN**: Decentralized Social Networking
- **EM**: Expectation Maximization
- **FOAF**: Friend Of A Friend
- **GML**: Geographic Markup Language
- **GMM**: Gaussian Mixture Model
- **HMM**: Hidden Markov Model
- **JSON**: JavaScript Object Notation
- **JSP**: Java Server Pages
- **MAE**: Mean Absolute Error
- **ML**: Machine Learning, Maximum Likelihood
- **MSN**: Mobile Social Networking
- **MSSP**: Mobile Social Signal Processing
- **MVC**: Model View Controller
- **NLP**: Natural Language Processing

- **OI**: Open Innovation
- **OWL**: Ontology Web Language
- **PCA**: Principal Component Analysís
- **POS**: Part of Speech
- **RDF(S)**: Resource Description Framework (Schema)
- **RIA**: Rich Internet Application
- **SIOC**: Semantically-Interlinked Online Communities
- **SKOS**: Simple Knowledge Organization System
- **SN**: Social Networking
- **SOAP**: Simple Object Access Protocol
- **SPARQL**: SPARQL Protocol and PDF Query Language
- **SS**: Social Situation
- **SSP**: Social Signal Processing
- **SVM**: Support Vector Machine
- **RM**: Reality Mining
- **RSS**: RDF Site Summary / Real Simple Syndication
- **UDDI**: Universal Description Discovery and Integration
- **XACML**: eXtensible Access Control Markup Language
- **XSLT**: eXtensible Stylesheet Language Transformations
- ***SN**: Decentralized, Mobile, and Contextual Social Networking

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