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Observing and Analyzing Clinicians' Information and Communication Behaviour:

An Approach to Requirements Engineering for Mobile Health Information Systems

Thesis for the degree of doctor scientiarum

Trondheim, October 2007

Norwegian University of Science and Technology
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NTNU

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Norwegian University of Science and Technology

Thesis for the degree of Doctor Scientiarum

Faculty of Information Technology, Mathematics and Electrical Engineering
Department of Computer and Information Science

ISBN 978-82-471-4848-8 (printed ver.)
ISBN 978-82-471-4851-8 (electronic ver.)
ISSN 1503-8181

Theses at NTNU, 2007:220

Printed by Tapir Uttrykk

To my family

Abstract

Advanced information systems have great potential for supporting clinicians in their patient-centered work. In order to meet the specific information and communication needs of healthcare professionals during a wide range of situations, there is an increased focus on developing context-aware user interfaces for pervasive health information systems. However, the high information and communication intensity, the nature of clinical work, and the complexity of healthcare organizations make the system design process, and especially the requirements engineering (RE) phase, particularly challenging.

This thesis addresses how *structured observation* can be used as a technique for elicitation and analysis of requirements for mobile electronic patient record (EPR) systems. The thesis explores how important properties of clinical situations can be captured through observation of actors, processes, and systems.

The contributions of the thesis consist of two main components:

- An iteratively developed method for structured, focused observation and analysis of clinicians' information and communication behaviour
- Exploration of how the observational data can be analyzed with varying foci and perspectives, and how the results of the processed data may be used as input to the requirements engineering process

The approach has been developed and refined during several observational studies performed in different hospital wards. The development process and the observational studies are presented in the eight papers which constitute the main part of this thesis.

Medical students are found to be particularly suited for performing the observations due to their domain knowledge and natural presence as apprentices in hospital wards. As future users of the information systems they can also function as mediators between the end users and the system developers, both during the data collection and the analysis phases of the studies.

The recorded observational data consists of sequences of events or *communicative acts*. When analyzing the data, it is possible to produce patient, process, or actor trajectories. In the thesis it is suggested how this can be used to inform implementation of clinical guidelines. Examples of how communicative patterns of actors and roles can be visualized and directions for how this can be used in the RE process are also given.

Contents

Preface

This thesis is submitted to the Norwegian University of Science and Technology (NTNU) in partial fulfillment of the requirements for the degree *Doctor Scientiarum*. The work has been conducted at the Department of Computer and Information Science (IDI), NTNU, under supervision of Associate Professor Øystein Nytrø.

This has been a long and winding road. I started my PhD studies at IDI in May, 1999, in the Group of Artificial Intelligence and Learning with Professor Agnar Aamodt and Assistant Professor Asbjørn Thomassen as my supervisors. The research area was in the intersection of Human Computer Interaction and Artificial Intelligence, with specific focus on User Modeling and Intelligent User Interfaces but without any specific application area. In 2000 I was on leave, hence I was still in my initial research phase when I in 2001 was asked to join the MOBEL (Mobile electronic patient record) project, an interdisciplinary project in the Strategic Area of Medical Technology at NTNU, as one of four PhD students. This was a welcome opportunity for me to enter the field of health informatics, which I found very interesting. Due to my most important deliveries during these years (Sigrid; born January 2000, Edvard; born June 2002, and Haakon; born September 2004), research progress has been delayed for some years. During this period, my primary research focus has shifted from AI and intelligent user interfaces to development of methods for requirements elicitation and analysis, but the underlying focus on designing context-aware and flexible user interfaces for mobile health information systems remained the same as when I joined the MOBEL project.

Acknowledgments

The work presented in this thesis has been conducted as part of the MOBEL project, funded by the NTNU Innovation Fund for Business and Industry (Næringslivets Idéfond for NTNU).

I would like to express my gratitude to all those who contributed in some way to

this thesis. First of all, thank you to my supervisor Øystein Nytrø, for guidance, cooperation, inspiration and enthusiasm, and for support and patience, especially during my periods of leave and part-time work.

Thanks for valuable advice and cooperation to my co-advisor Amund Tveit, who unfortunately (for me) was hired by Google long before my thesis was finished.

Thanks also to my original supervisors Agnar Aamodt and Asbjørn Thomassen at Division of Intelligent Systems, IDI, for admitting me in the group and for approving my transition into the health informatics research field and the MOBEL project.

Thanks to my colleagues and friends at IDI for providing a nice working environment. In particular, thanks to the administrative and technical staff for always being helpful.

Thanks are also due to all my colleagues at NSEP (The Norwegian Centre for EHR Research) and especially to Arild Faxvaag, Line Melby, Gry Seland, Yngve Dahl, Thomas Brox Røst, and Ole Edsberg, for interesting and inspiring discussions and cooperation. Special thanks to Line, Thomas, and Ole, for helpful suggestions and comments during the final stage of writing this thesis. I am also grateful to the POCMAP (Point-Of-Care Multi-Aware clinical Pilot) project funded by the Research Council of Norway's VERDIKT (ICT – Core Competence and Growth) program, for giving me the opportunity to finish the thesis while I have been working in the project.

My sincere thanks go to the staff at the hospital wards where the field studies were conducted, and to the medical students who performed most of the data collection.

Warm thanks also to my former office-mates Elisabeth Bayegan and Xin Tong, and to my colleague Hege Knotten, for friendship, encouragement, and pleasant chats.

Thanks to my family for continuous love and support; to my parents Gullaug and Jan H. Dybdahl and to my parents-in-law Grete and Tore Sørby for numerous occasions of babysitting and practical help, and to my father and my sisters Marit and Brit for providing me insight into the hospital world.

Finally, thank you to my husband Knut for patience, help, and support, and to our marvellous children Sigrid, Edvard, and Haakon, for unconditional, unlimited love and joy.

Inger Dybdahl Sørby
October 19, 2007

Part I

Research Overview and Summary

Chapter 1

Introduction

> Perhaps, the way a clinician uses an EHR system in a hospital environment is comparable to a cadenza in a piano or violin concert, or to an improvisation in a jazz concert.
> *J. H. van Bemmel, 2006*

Electronic health record (EHR) systems and other clinical information systems have great potential for supporting clinicians in their patient-centered work. During the last decades, efforts have been made in developing and implementing such systems, but in contrast to primary care, where the introduction of EHRs has been very successful, several major challenges still remain in the hospital sector.

Traditional user-centered design methods are often based on communicating with 'representative' users, but for clinical information systems, the users consist of clinicians with varying backgrounds, experiences, ideas, and knowledge, treating patients with complex and often unique case histories. This complexity and heterogeneity in clinical patient care imply a need for clinical information systems that permit a lot of freedom for the clinicians to implement their own working styles and ideas [van Bemmel 2006].

When designing systems for these users, it is essential to comprehend and to be able to document both the variability in the users' information and communication needs and the context within which the systems are going to be used. This thesis addresses one approach to these challenges by presenting a framework for structured observation of clinical work.

In order to provide the setting and define the scope of the thesis, Section 1.1 to Section 1.4 of this chapter will explain and elaborate on the different parts of the thesis title. Section 1.5 briefly introduces the main contribution of this thesis; a framework for performing focused, structured observation of clinicians'

communication and information behaviour in hospital wards. Section 1.6 lists the publications resulting from the research leading to this thesis, and Section 1.7 gives an overview of the structure and the chapters in the thesis.

1.1 Clinicians' Information and Communication Behaviour

The underlying objectives of the research leading to this thesis have been to design user interfaces for mobile information systems that support the information and communication needs of healthcare personnel in their patient-centered work in hospital wards. The prospective users are any healthcare professionals directly involved in patient care. In the title as well as throughout the thesis, the term 'clinician' is used as a collective term in the same way as Coiera [2003] denotes clinicians as 'physicians, nurses, and other allied healthcare professionals working with hospital patients'.

One of the main purposes of an information system is to support communication between different actors in a work practice [Cronholm and Goldkuhl 2005]. Due to the nature of clinical work, the variety of the actors involved, and the high information and communication intensity in hospital wards, the information systems used in these settings should also enable each individual clinician easy access to and navigation in relevant information according to the current situation and context of use. With this challenge as a point of departure, the work presented in this thesis has focused on exploring a method for identifying and recording knowledge about actors, roles, situations, procedures, information, communicative acts, and other rich context information in real hospital ward situations, with the ultimate goal of eliciting and producing requirements to context-aware user interfaces for clinicians.

1.2 Mobile Health Information Systems

Clinicians' work is to a high extent characterized by mobility. They often move from preparations and pre-rounds meetings in offices and meeting rooms, via patient rounds in several different locations to examination rooms, more meetings, office work, drug adminstration, and other bedside activities. Moreover, the clinicians' work processes can also be described as 'mobile' as they are often interrupted and changed due to e.g. phone calls and emergency or other unplanned events in the wards.

Most electronic health record systems do not support these processes and the rapid context changes that occur in a hospital ward setting, and since they are

often available only on stationary computers, a number of paper-based information systems (e.g. the patient chart and the patient overview list) are still extensively used by clinicians. Mobile devices such as handheld computers offer information access at the point of care, and could thus to a certain extent replace the paper-based systems, but the limited screen size and input possibilities place strong demands on the presentation and navigation of the information.

1.3 Requirements Engineering

Several of the most common reasons for failure in system development projects are related to insufficient requirements engineering (RE)[Matulevicius 2005]. Requirements elicitation is the first and perhaps the most difficult step in the RE process, particularly when designing complex, sociotechnical[1] systems such as clinical information systems. The design process must be user-centered (i.e. focus on the health care workers and their information needs in various contexts). User-centered design include a lot of different techniques for requirements elicitation, such as questionnaires and surveys, interviews, analysis of existing documentation, workshops, and drama improvisation techniques. However, these techniques often lead to use-cases and scenarios that are generalized and do not capture the variations and the different contexts of use. Hence, there has been an increased focus on performing field studies (i.e. observational studies) when designing sociotechnical systems.

1.4 Observing and Analyzing

Observational studies are frequently used within the social sciences, and during the last decades computer science researchers have also acknowledged such methods as useful for understanding the complexity of organizations and the various information needs of different users. However, these methods are normally very time consuming. Moreover, the unstructured, detailed field notes and transcriptions are often difficult to transform into formal requirements and design decisions. Performing *structured observation* is one way of dealing with these obstacles. The technique is derived from the ethnographic technique participant observation, and can be defined as 'the planned watching and recording of behavior and/or events as they occur within a well-known/predefined environment'.

This thesis presents the development and exploration of a method for performing structured observation of clinicians' information and communication behaviour.

[1] A sociotechnical system is defined as a complex inter-relationship of people and technology, including hardware, software, data, physical surroundings, people, procedures, laws and regulations [Maté and Silva 2005]

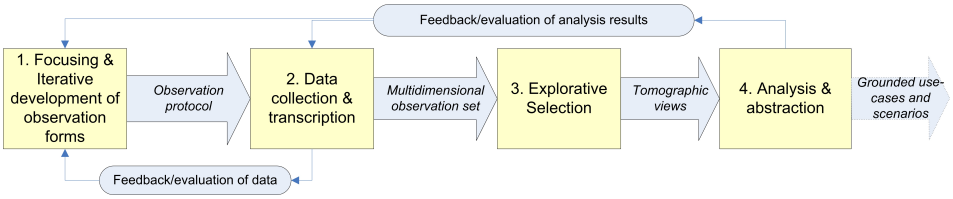

Figure 1.1: Method application process

The method is based on manual observation of clinicians in hospital wards in their daily, patient-centered work such as pre-rounds meetings, patient rounds, and discharge. The field data is recorded by means of note-taking forms, which can be adapted according to current focus of interest. The observation forms include fields with pre-defined codes with primary emphasis on information sources and information types, but the forms also include free-text fields, which enables recording of context information such as situation or event trigger, reason for admission, illness history, the purpose of the act being performed, and the outcome of the act. This rich context data allows for further investigation of findings in the initial analysis.

1.5 A Method for Structured Observation

As a response to the challenges described in the previous sections, the main research contributions of this thesis is a proposed method for structured observation of clinicians' information and communication behaviour. The approach was taken as an attempt to achieve domain knowledge and collecting field data in an efficient and non-intrusive manner.

The approach consists of four stages as illustrated in Fig. 1.1. The first stage establishes different dimensions of observations, followed by a process of focusing and refinement of observation forms/protocols. The second stage includes data collection and transcription, and finally iterative exploration and analysis of the recorded data is performed.

The approach was originally developed to be used in the initial stages of the requirements engineering (RE) process as a means for developing *grounded* scenarios and use-cases, but it can also be applied after the introduction of new information systems in order to explore any changes in clinicians' information and communication behaviour.

The approach is described in detail in Paper G and briefly discussed in Sect. 3.7.

1.6 Publications

The research activities and the results are described in a number of scientific papers that have been published in journals, books, and/or presented at international workshops and conferences:

***** Sørby, I. D., Melby, L. and Nytrø, Ø. (2002). Characterising Cooperation In The Ward: A Framework for Producing Requirements to Mobile Electronic Healthcare Records. Proceedings of the Second International Conference on the Management of Healthcare and Medical Technology: The Hospital of The Future. Chicago, Illinois, USA.

A Sørby, I. D., Melby, L. and Nytrø, Ø. (2006). "Characterizing cooperation in the ward: framework for producing requirements to mobile electronic healthcare records." Int. Journal of Healthcare Technology and Management 7(6), pp. 506–521.

B Dahl, Y., Sørby, I.D. and Nytrø, Ø. (2004). Context in care - Requirements for mobile context-aware patient charts. Medinfo 2004 — Proceedings of the 11th World Congress on Medical Informatics. M. Fieschi, E. Coiera and Y.-C. J. Li (eds.). Studies in Health Technology and Informatics 107, pp. 597–601. Amsterdam, IOS Press.

C Sørby, I. D., Melby, L. and Seland, G. (2005). Using scenarios and drama improvisation for identifying and analysing requirements for mobile electronic patient records. Requirements engineering for socio-technical systems. J. L. Maté and A. Silva, pp. 266–283. Hershey, Information Science Publishing.

***** Sørby, I. D., Nytrø, Ø. and Tveit, A. (2004). Physicians' Use of Information Sources in the Discharge of Patients with Coronary Heart Diseases. Proceedings of the second HelsIT Conference at the Healthcare Informatics week in Trondheim. Trondheim, Norway, 2004.

D Sørby, I. D. and Ø. Nytrø (2006). "Does the EPR support the discharge process? A study on physicians' use of clinical information systems during discharge of patients with coronary heart disease." Health Information Management Journal 34(4), pp. 112–119.

***** Sørby, I. D., Nytrø, Ø., Tveit, A. and Vedvik, E. (2005). Physicians' Use of Clinical Information Systems in the Discharge Process: An Observational Study. Connecting Medical Informatics and Bio-Informatics - Proceedings of MIE 2005. R. Engelbrecht, A. Geissbuhler, C. Lovis and G. Mihalas (eds.). Studies in Health Technology and Informatics 116, pp. 843–848. Amsterdam, IOS Press.

E Sørby, I. D., Nytrø, Ø. and Røst, T. B. (2006). Empirical Grounding of Guideline Implementation in Cooperative Clinical Care Situations. AI Techniques in Healthcare: Evidence-based Guidelines and Protocols (workshop at ECAI 2006), Riva del Garda, Italy.

F Sørby, I. D. and Nytrø, Ø. (2007). A Study on Clinicians' Information Systems Usage in Patient-Centered Situations — Preliminary Results (Poster). Medinfo 2007 (The 12th World Congress on Health (Medical) Informatics). Brisbane, Australia, 20.–24. August, 2007.

G Sørby, I. D. and Nytrø, Ø. (2007). Towards a Tomographic Framework for Structured Observation of Communicative Behaviour in Hospital Wards. Proceedings of REFSQ 2007. P. Sawyer, B. Paech and P. Heymans (eds.). LNCS 4542, pp. 262–276 Springer-Verlag Berlin Heidelberg.

H Sørby, I. D. and Nytrø, Ø. (2007). Analysis of Communicative Behaviour: Profiling Roles and Activities. Information Technology in Health Care 2007. Proceedings of the 3rd International Conference on Information Technology in Health Care: Socio-technical Approaches. J.I. Westbrook, E. Coiera, J.L. Callen and J. Aarts (eds.). Studies in Health Technology and Informatics 130, pp. 111–120. Amsterdam:IOS Press.

The eight papers denoted A–H constitute the foundation of this thesis. These papers are included by permission in their original formats in **Part II**.

1.7 Thesis Structure

The thesis consists of two main parts. The structure is as follows:

Part I Research Overview and Summary

- **Chapter 1** gives a brief introduction to the problem domain and the main themes addressed in the thesis
- **Chapter 2** describes the research process and the research approach taken
- **Chapter 3** provides a synopsis of the research papers included in Part II of the thesis
- **Chapter 4** contains a summary of the main results and contributions, addresses some challenges, and outlines some directions for future research.

Part II Papers

- **Paper A** presents a framework for high-level characterization of varying information-intensive, complex, cooperative care situations in hospital wards. Example scenarios from a hospital ward are presented and characterized by means of the framework.

Paper B proposes how observational studies and drama improvisation can be used as a means to identify and analyze requirements for mobile electronic patient records.

Paper C discusses how contextual information can be utilized for easier navigation in health information systems and provides an example ward scenario with interruptions and possible future care trajectories.

Paper D presents the results of an observational study focusing on information use in one specific situation (patient discharge) with multiple system actors (4-5 different information systems) but few human actor roles.

Paper E explains how situational properties can be elicited from field data based on the perspective of one actor role (a physician) over longer periods of time, and argues for how this can be used in empirically grounding of clinical guidelines.

Paper F presents preliminary results of an extensive observational study performed in two hospital wards during a two-month period.

Paper G summarizes the results of four observational studies in hospital wards and explains the development of a framework for focused ('tomographic'), structured observation and analysis of information and communication behaviour in hospital wards.

Paper H proposes how field data recorded via structured observation in hospital wards can be expressed as sequences of *communicative acts* and suggests how the resulting analysis can be visualized as communicative acts profiles.

Bibliography includes all references cited in Part I and in the papers.

Chapter 2

Research Process and Contributions

This chapter briefly explains the research process, the methodological approach, and the theoretical landscape of the research presented in the thesis. The main contributions of each paper included in the thesis are summarized in the final section of the chapter.

2.1 The MOBEL project: An Optimistic Approach

The research presented in this thesis has been conducted as part of the MOBEL (Mobile Electronic Patient Records) project. MOBEL was established in 2000 as an interdisciplinary project with participants from Department of Sociology and Political Science, Department of Linguistics, Department of Electronics and Telecommunication, Department of Computer and Information Science, and Faculty of Medicine at NTNU. The problem area of the project was communication and information needs in hospital wards, and the aim of the project was to create a conceptual design of a context– and procedure–aware, multimodal (e.g. combined text and speech) interface to a mobile, electronic patient record system; i.e. a mobile, electronic patient chart (MEPC). In addition to being an ordering/booking- and recording tool as a replacement for the paper-based patient chart, the objective was to improve coordination and communication of healthcare workers in hospital wards, minimize errors and enhance efficiency, and thereby improving quality of patient care.

However, no explicit or formal requirements to the MEPC were defined as the project started. Hence, the initial focus was to explore the hospital ward in order

to identify possible usage areas/scenarios and requirements for a MEPC.

2.2 Research Focus: From Solving to Understanding

There are two divergent main approaches to development of new technological solutions; *Technology driven* approaches, and *Problem driven* approaches. The first approach is concerned with determining what kind of problems that will be solved by using a certain new technology, while the problem driven approach explores how to solve a particular problem [Coiera 2003].

To a large extent, 'medical informatics has been dominated by concern with the technology and has developed solutions that have to search for problems' [Smith 1996]. This has led to a lot of unsuccessful projects in the healthcare sector and information systems that do not address the real needs of the users. These experiences imply that the problem driven approach seems more appropriate for designing healthcare information systems. However, solving a problem presupposes *understanding* the problem, which is a major and non-trivial challenge for system developers of such systems.

2.3 Methodological Approach

In the MOBEL project, several different approaches to understanding the problem — or the users' needs — were undertaken (see Paper B [Sørby et al. 2005a]) as the first step in the requirements engineering phase. In order to get a general understanding of the domain and a view of how the paper-based patient chart was used in the hospital wards, an initial observational study was carried out in 2002. The study is presented in Paper A [Sørby et al. 2006a], and the main focus of the study was to identify scenarios that would improve, change, or become superfluous by introducing a mobile electronic patient chart. The data was recorded by free-text notes that was abstracted into 'representative' scenarios. Due to the discontinuous research process (explained in the Preface), the study was not followed up as intended. However, when analyzing and evaluating the study, a need for more focused and structured observation was identified. Since the goal of the project was to develop user interfaces that support clinicians in their daily, patient-centered work — not as traditional decision support systems, but rather as enabling easy and efficient access to relevant information and process support — it was decided to perform a second observational study, focusing on a well-defined and limited patient care process. In order to be able record more detailed process and context knowledge than in the first study, medical students were used as observers due to their domain and terminology knowledge. The study focused on the discharge

process and was performed at the Department of Cardiology (presented in Paper D). The approach was developed and improved in a number of other studies, and finally, the studies were summarized in Paper G and a framework for structured observation was presented.

Two of the latest papers (Paper E and Paper H) give examples of how observational data recorded by means of the approach can be analyzed and viewed as *actor trajectories* (i.e. sequences of communicative acts). Paper E proposes how this can be used in empirical grounding of guideline validation and implementation, while Paper H gives an example of how profiles of the communicative behaviour of different actors/roles or other groups of actors can be visualized by means of radar graphs. These papers include interesting, but preliminary approaches/ideas, and hence the main contributions of this thesis is the proposed approach to focused, structured observation of clinicians' information and communication behaviour.

2.4 Theoretical Landscape

The work has been inspired by and influenced by research in several theoretical fields, such as Requirements Engineering, Computer Supported Cooperative Work (CSCW), Ethnography, Human Computer Interaction (HCI), and Speech Act Theory. Implicitly, the research has been framed within a *socio-technical perspective*[Westbrook et al. 2007]; i.e. acknowledging the importance of the human, social, and organizational contexts within which information systems operate.

There is an increased tendency to perform observational studies both in the HCI, Requirements Engineering and Socio-technical health informatics research communities. A lot of different approaches are taken, and various tools and techniques are used. Our approach is particularly related to the Communication Observation Method (COM) [Spencer et al. 2002], but our method requires structured observation as means of data collection, and is bent towards producing system requirements. One of the benefits of our approach is the ability to filter out sensitive and person-identifying data during the data collection, thus reducing the need for post-processing the data to make it anonymous before leaving the hospital.

2.5 Research Themes and Contributions of the Papers

An overview of the publications listed in Section 1.6 in relation to time period of writing and main research focus is given in Fig. 2.1. The figure indicates three different research themes that have been the main focus in the different papers: Methods development, Empirical studies, and Applications/Analysis and

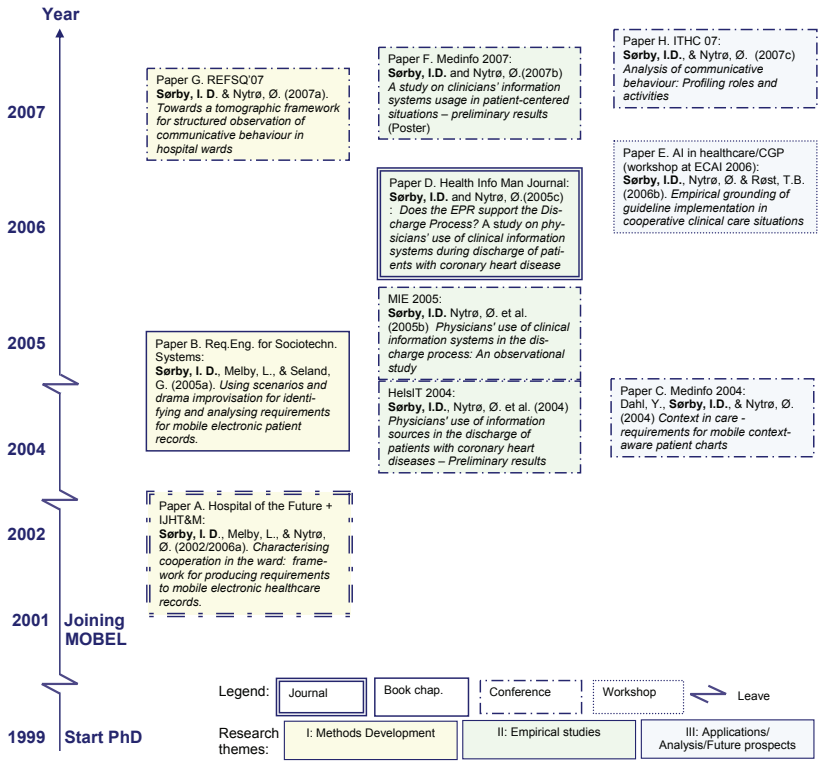

Figure 2.1: Overview of publications. The y-axis indicate time period of writing, the border styles correspond to different publication types, while the fill colors indicate primary research focus.

implications for RE. However, the empirical studies constitute a basis for both the papers mainly focusing on development of methods and the Applications/Analysis papers (apart from Paper C), hence there is considerable overlap between both research foci and contributions of some of the papers. This is illustrated in Figure 2.2.

The main contributions of each of the papers included in Part II of this thesis are summarized in Table 2.1. The papers are summarized in more detail in Chapter 3.

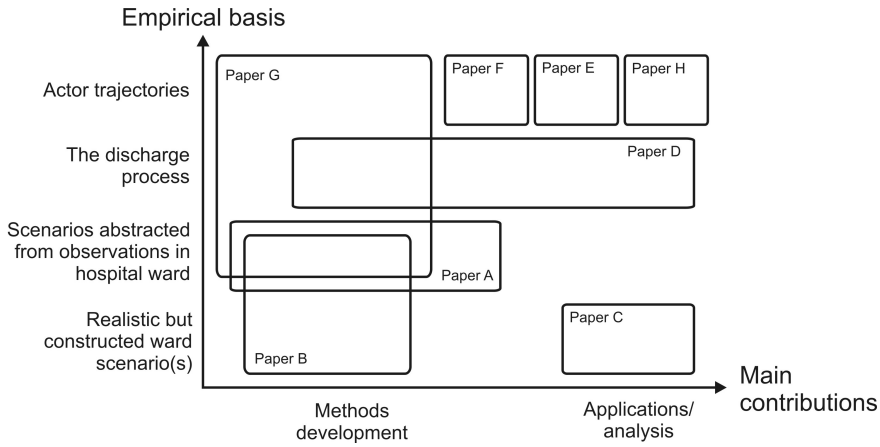

Figure 2.2: Illustration of main contributions and empirical basis for Paper A – H.

Table 2.1: Summary of empirical basis and contributions of the papers

	Empirical basis	Contributions	Approach
A	Scenarios abstracted from observations	Framework for high-level characterization of scenarios	Iterative observations, scenario abstractions and characterizations
B	Scenarios abstracted from observations and realistic, constructed scenarios	Presentation of two complementary approaches to requirements elicitation for mobile EPR systems	Framework for high-level characterization of scenarios + Drama improvisation workshops
C	Realistic, constructed scenario	Examples of requirements for context models, design methods, and system properties for mobile clinical information systems	Analysis of example scenario
D	Observational study (the discharge process)	Analysis of observational data	Iteration of observational framework
E	Observational study (actor trajectories)	Example analysis of actor trajectories and arguments for empirical grounding of clinical guidelines implementation	Conceptual framework and example actor trajectory analysis
F	Observational study (actor trajectories)	Summary and initial analysis of observational data	Iteration of observational framework + Survey
G	Scenarios, observed discharge processes, observed actor trajectories	Framework for focused, structured observation and recording of clinicians' communication behaviour	Summarization of iterative development of four observational studies
H	Observational study (actor trajectories)	Example analysis of trajectories and visualization of communicative acts profiles	Examples of communicative acts profiles created by means of radar graphs

Chapter 3

Paper Summaries

This chapter gives a summary of the papers included in Part II of the thesis. For each paper the original abstract is presented along with the main objectives and contributions, publishing and authorship details, and finally some retrospective comments.

3.1 Paper A: Characterizing Cooperation in the Ward: Framework for producing requirements to mobile electronic healthcare records

3.1.1 Main Objectives

- To characterize hospital ward scenarios obtained from observational studies in order to produce requirements to a mobile, electronic patient chart (MEPC)
- To identify scenarios that would benefit from a MEPC, and to identify scenarios where a MEPC would not be useful

3.1.2 Details

Authors of the paper: Inger Dybdahl Sørby, Line Melby, and Øystein Nytrø.

This paper was originally written in 2002 and presented at the Second International Conference on the Management of Healthcare and Medical Technology: The Hospital of the Future [Sørby et al. 2002]. The paper was subsequently selected

for publication in the International Journal of Healthcare Technology and Management, and it was finally published in 2006.

A shorter version of the paper is also published as part of the book chapter "Using scenarios and drama improvisation for identifying and analysing requirements for mobile electronic patient records" [Sørby et al. 2005a] in Requirements engineering for socio-technical systems, edited by Maté and Silva. The chapter is included in the thesis as Paper B.

Author contributions: The observational studies presented in the paper were performed by Sørby and Melby. All three authors participated in developing the framework and in analyzing and discussing the results. Sørby wrote the main parts of the paper, and all three authors participated in commenting and refining the paper.

3.1.3 Abstract

We present a framework for characterizing hospital scenarios involving the patient chart. The paper-based chart is regarded as simple, efficient, and handy for mobile use by patient-care teams. However, the chart is available in only one physical place at a time, and it needs to be manually synchronized with the electronic healthcare record (EHR). The framework presented in this paper has been developed for use in non-participatory, observational studies performed at the University Hospital of Trondheim, conducted as a part of the MOBEL (MOBile ELectronic patient chart) project at NTNU. We have developed the framework iteratively; repeatedly observing groups in the ward, characterizing observations in the framework, and changing attributes and outcome values. This paper presents our latest framework, a representative choice of scenarios, and their characterization. We conclude with a discussion of results so far, the method, and the utility in the development of the MEPC.

3.1.4 Main Results/Contributions

- A framework for high-level characterization of varying information-intensive, complex, cooperative hospital ward scenarios
- Descriptive hospital ward scenarios abstracted from non-participatory observational studies

3.1.5 Retrospective

The paper was written during spring 2002, and due to various reasons, the planned follow-up studies were not carried out. Hence, clustering analysis of scenarios char-

acterized by means of the framework has not been conducted. Still, the proposed framework seems promising in classifying scenarios and for producing high level requirements for mobile hospital information systems. The scenarios abstracted from the observations provided useful, initial insight into some of the daily patient-centered work of clinicians. However, the recorded situations were detached and included considerable variations which could not be captured by the proposed characterization framework.

3.2 Paper B: Using scenarios and drama improvisation for identifying and analysing requirements for mobile electronic patient records

3.2.1 Main Objectives

- To present two different approaches to requirements elicitation and analysis for mobile electronic patient records conducted as part of the MOBEL project
- To compare and discuss the approaches in relation to requirements engineering for sociotechnical systems

3.2.2 Details

Authors of the chapter: Inger Dybdahl Sørby, Line Melby, and Gry Seland.

This chapter appears in *Requirements Engineering for Sociotechnical Systems* edited by J. L. Maté and A. Silva. Hershey: Information Science Publishing, 2005, pp. 266–283.

Author contributions: The chapter was planned and discussed by all three authors. Sørby and Melby wrote the main parts of the chapter. All three authors participated in commenting and refining the chapter.

3.2.3 Abstract

This chapter presents two different techniques for elicitation and analysis of requirements for a mobile electronic patient record (EPR) to be used in hospital wards. Both techniques are based on human-centered and participatory design principles. The first technique uses observational studies as a basis for identifying and analyzing requirements for a mobile EPR. The observations are structured and systematized through a framework. The second technique is named 'Creative system development through drama improvisation', and it enables users (in this

case healthcare professionals) to contribute to the requirements engineering (RE) process by acting out everyday work situations in one-day workshops. Both techniques presented in this chapter focus on user requirements elicitation, and we believe that they are promising and complementary contributions to more traditional requirements elicitation and analysis methods, not only for hospital information systems but for a wide variety of complex, sociotechnical systems.

3.2.4 Main Results/Contributions

- A presentation of two complementary approaches to requirements elicitation for mobile EPR systems
- Suggestion of how these two approaches may complement each other in the initial requirements engineering phase of clinical or other sociotechnical systems

3.2.5 Retrospective

This chapter was written in 2003/2004, as a synthesis of two different approaches to requirements engineering performed in the MOBEL project. The first part of the chapter presents the characterization framework also presented in Paper A (see section 3.1), while the second part of the chapter presents the 'Creative system development through drama improvisation' approach developed by Gry Seland and Dag Svanæs [Svanæs and Seland 2004]. The last part of the chapter summarizes the two approaches and concludes that the techniques are complementary contributions to existing RE methods. The characterization framework can be applied in the initial phase of a system development project, and relevant situations and scenarios can subsequently be used as input to and explored in the drama improvisation approach.

3.3 Paper C: Context in care - Requirements for mobile context-aware patient charts

3.3.1 Main Objectives

- To explore some aspects of the rich 'context space' of clinical ward activities
- To develop requirements for design methods, context models, and system properties of a mobile, electronic patient chart

3.3.2 Details

Authors of the paper: Yngve Dahl, Inger Dybdahl Sørby and Øystein Nytrø.

The paper was presented at *Medinfo 2004 - The 11th World Congress On Medical Informatics*, San Francisco, USA, August, 2004.

Published in Studies in Health Technology and Informatics, Vol. 107, pp. 597–601, IOS Press, 2004.

Author contributions: Sørby provided the example scenario. Dahl wrote the main parts of the paper. All three authors participated in planning the paper, discussions, and in writing and refining the paper.

3.3.3 Abstract

The hospital ward is a highly dynamic work environment, in which health care personnel rapidly switch from one task to another. The process is partly planned, and partly driven by events and interrupts. A mobile electronic patient chart (MEPC) will be an important tool for supporting order entry and accessing, communicating, and recording clinical information. The users need to switch from one context to another with minimal delay and effort. Context-awareness, the ability to sense relevant situational information, can allow the user interface of the MEPC to adapt to various situations. In this paper, we present a future scenario from the coronary care unit. This scenario is analyzed and discussed in order to develop requirements for design methods, context models, and system properties of the MEPC.

3.3.4 Main Results/Contributions

- A set of requirements for context models, design method, and system properties for mobile clinical information systems

3.3.5 Retrospective

This paper presents an example scenario from a hospital ward, and discusses how context information can be utilized for easier navigation in a prospective mobile health information system (i.e. a mobile electronic patient chart). Illustrated by the example scenario, the paper presents requirements for context models, design, and system properties. The paper can be considered a position paper. The example scenario was constructed in cooperation with a physician, and is regarded as realistic.

3.4 Paper D: Does the EPR support the discharge process? A study on physicians' use of clinical information systems during discharge of patients with coronary heart disease

3.4.1 Main Objectives

- To categorize and measure the usage of different information sources and types in a well-defined stage of clinical work, with a particular focus on the electronic patient record (EPR)

3.4.2 Details

Authors of the paper: Inger Dybdahl Sørby and Øystein Nytrø.

Published in *Health Information Management Journal*, Vol. 34, no. 4, pp. 112–119, 2005.

The observational study is also described in a paper presented at MIE 2005 (The XIXth International Congress of the European Federation for Medical Informatics) [Sørby et al. 2005b] and in a paper presented at the Second HelsIT Conference at the Healthcare Informatics week in Trondheim, 2004 [Sørby et al. 2004].

Author contributions: Both authors participated in planning and designing the study, and in analyzing and discussing the results. Sørby wrote the main parts of the paper.

3.4.3 Abstract

This paper presents a study conducted at a Norwegian university hospital during the period March - September 2004. The purpose of the study was to categorize and measure the usage of different information sources and types in a well-defined stage of clinical work, with a particular focus on the electronic patient record (EPR). The study included observations of nine cardiologists' work during 52 discharge processes, and a supplementary survey distributed among every physician at the Department of cardiology. The results from the study clearly indicate that there is a large potential for improved EPR systems that support the physicians in their work regarding discharge of patients.

3.4.4 Main Results/Contributions

- The study showed that the paper-based information sources were preferred as primary sources during the discharge of patients, while electronic sources (i.e. the EPR) often were chosen as secondary sources and human sources as a third choice.

- The survey responses differed from the observational data as the physicians reported more use of electronic information sources and less use of the paper-based patient chart than observed in the field study.

3.4.5 Retrospective

This paper presents the results of a study focusing on information systems usage in situations related to patient discharge. This was our first attempt to perform structured observation, and the data was collected by two medical students. The analysis presented in the paper focus on how the different information sources, categorized as paper-based, electronic, or human, were used to retrieve various information types needed for the discharge report. One of the intentions behind the study was to investigate whether it was possible to identify common patterns in the information systems usage of the physicians who were followed. The resulting analysis showed that even if the physicians worked in the same hospital ward, there were considerable variations in working style and in the efforts regarding the discharge of patients. The recorded data were not immediately suited for further analysis, as they did not contain any context or background information to explain the differences, but the study verified that there is a need for flexible clinical information systems that can support different needs and working patterns of the individual clinicians. The paper also presents results from a survey, and discusses why the results differ from the observational study. The survey results indicate that the physicians use the EPR more and the patient chart less than what was observed, but as discussed in the paper, these results can be related to the design of the survey and the physicians' personal interpretations of the questions. This is also the main reason why using surveys as a means of measure or evaluate the use of information systems is difficult.

3.5 Paper E: Empirical Grounding of Guideline Implementation in Cooperative Clinical Care Situations

3.5.1 Main Objectives

- To discuss how methodical observations of clinical care situations and trajectories of care activities can be used to study and improve guideline *implementation*, the process of transforming a guideline into a plan for clinical work

3.5.2 Details

Authors of the paper: Inger Dybdahl Sørby, Øystein Nytrø, and Thomas Brox Røst

The paper was presented at the workshop *AI Techniques in Healthcare: Evidence-based Guidelines and Protocols* held in conjunction with The 17th European Conference on Artificial Intelligence (ECAI 2006), Riva del Garda, Italy, 29th August, 2006.

Author contributions: The paper was planned and discussed by all three authors. Nytrø developed the conceptual framework illustrated in Figure 1 in the paper while Sørby provided the examples. All three authors participated in commenting and refining the paper.

3.5.3 Abstract

Clinical practice guidelines and protocols are designed in order to fulfill the goals of evidence-based medicine (EBM) and to achieve best practice in care and treatment. These idealized decision process models present a highly abstract view of actual clinical practice. In this paper, we discuss how methodical observations of clinical care situations and trajectories of care activities can be used to study and improve guideline *implementation*, the process of transforming a guideline into a plan for clinical work. This is a step towards an ideal empirically grounded guideline lifecycle. We present a framework and concepts for representing observable attributes of situations, actors and action trajectories. The example data that are presented in the paper are taken from an observational study at a local hospital.

3.5.4 Results/Contributions

- Examples of characterization of care situations and trajectory acts from observational study
- Discussion of the potential impact of structured observations of clinical care situations on guideline implementation, validation, and design

3.5.5 Retrospective

This paper argues for empirically grounding of clinical guidelines. The paper presents how situational properties can be elicited from the perspective of one actor role (a physician) over longer periods of time. In the paper it is briefly discussed how empirical data obtained from structured observation can be used to inform guideline design, validation, and implementation in order to provide input to plan-based user interfaces to the EHR. This is considered as interesting, future work.

3.6 Paper F: A Study of Clinicians' Information Systems Usage in Patient-Centered Situations - Preliminary Results

3.6.1 Main Objectives

- To identify and capture clinicians' information and communication behaviour
- To further develop a method for performing structured observation of clinicians' patient-centered work

3.6.2 Details

Authors of the paper: Inger Dybdahl Sørby and Øystein Nytrø.

This paper was accepted for poster presentation at Medinfo 2007 - The 12th International Health (Medical) Informatics Congress, Brisbane, Australia, 20-24 August, 2007.

Author contributions: The paper was planned and discussed by both authors. Sørby wrote the main parts of the paper.

3.6.3 Abstract

This paper presents preliminary results from an observational study performed at a Norwegian university hospital. The purpose of the study was to identify and capture clinicians' information and communication behaviour and also to further develop a method for performing structured observation of clinicians' patient-centered work. One fifth-year medical student spent 20 days in two different hospital wards, following seven physicians from one to seven days each. The observer recorded data from several ward situations such as pre-rounds meetings, ward rounds, and discharge situations. The data was recorded by means of an observation form consisting of a mixture of codes and free-text fields.

3.6.4 Main Results/Contributions

- 325 situations consisting of 1557 communicative acts were observed during the study
- 33% of the acts recorded at Dept. of Cardiology were related to medications, and these acts involved 9 different information sources
- The number of acts per observed situation type varied considerably, e.g. from 1 to 16 in the pre-rounds situations recorded from Dept. of Cardiology

3.6.5 Retrospective

This paper was written to summarize the results of a field study conducted in 2005. The recorded data has not been thoroughly analyzed, but an example analysis approach is presented in Paper H [Sørby and Nytrø 2007c], see Sect. 3.8. The data was also used as empirical basis for Paper E [Sørby et al. 2006a], and it is one of the four studies that are summarized in Paper G [Sørby and Nytrø 2007b].

A considerable amount of data was recorded during the study. The medical student who performed the observations was able to record a lot of information regarding the context of the situations, in addition to the information types and sources used, which is considered valuable in the further analysis of the data.

3.7 Paper G: Towards a Tomographic Framework for Structured Observation of Communicative Behaviour in Hospital Wards

3.7.1 Main Objectives

- To summarize the iterative development of four observational studies performed during the period 2002-2005
- To present an iteratively developed framework for structured, focused observation of communication and information behaviour

3.7.2 Details

Authors of the paper: Inger Dybdahl Sørby and Øystein Nytrø.

The paper was presented at REFSQ 2007 - The international working conference on Requirements Engineering: Foundations for Software Quality, Trondheim, Norway, 11-12 June 2007.

Published in Lecture Notes in Computer Science (LNCS) 4542, Springer-Verlag 2007, pp. 262–276.

Author contributions: The paper was planned and discussed by both authors. Sørby wrote the main parts of the paper. Both authors participated in commenting and refining the paper.

3.7.3 Abstract

The research presented in this paper investigates how observation of information- and communication-intensive work in hospital wards can be used to produce requirements for mobile clinical information systems. Over a number of years, we have explored how important properties of clinical situations can be captured through structured observations of actors, processes, and systems. In the paper, we present experience from four observational studies of a total of more than 400 hours in hospital wards. Based on the observational studies, we propose a framework for structured, tomographic, observation of clinical work practice. We also briefly discuss and illustrate how the field data can be analyzed and used as input to the requirements engineering process.

3.7.4 Main Results/Contributions

- A framework for focused, structured observation of clinicians' communication and information behaviour

3.7.5 Retrospective

This paper was written to summarize the experiences of four observational studies conducted during the period 2002 to 2005. Based on the approaches taken and the lessons learned in each of the observational studies, a framework for structured observation of clinicians' information and communication behaviour is presented. The term 'tomographic' in the title is meant to illustrate how the proposed framework facilitates focused observation and analysis of recorded field data by fixing either actor, information system, or situation type and varying along the remaining dimensions. The extracted data can be compared to the two-dimensional image representing a selected layer of the body created through computerized tomography examinations.

3.8 Paper H: Analysis of Communicative Behaviour: Profiling Roles and Activities

3.8.1 Main Objectives

- To present a method for visualization of clinicians' communicative behaviour
- To suggest how these profiles can be used as input in the design of new information systems

3.8.2 Details

Authors of the paper: Inger Dybdahl Sørby and Øystein Nytrø.

The paper was presented at the Third International Conference on Information Technology in Health Care (ITHC 2007): Socio-technical approaches, Sydney, Australia, 28 – 30 August 2007.

Published in Studies in Health Technology and Informatics, Vol. 130, pp. 111–120, IOS Press, 2007.

The paper has been selected for publication in a special ITHC2007 issue of the International Journal of Medical Informatics, planned for publication in 2008.

Author contributions: The paper was planned and discussed by both authors. Sørby created the radar graphs and wrote the main parts of the paper. Both authors participated in commenting and refining the paper.

3.8.3 Abstract

In this paper, we discuss how profiles of communicative behaviour can be used to present and analyze information about role activity recorded through structured observation of specific situations. The role activities are encoded as distinctive speech acts. Example profiles resulting from the analysis of three clinicians' communicative behaviour during pre-rounds meetings and ward rounds are given. The examples are based on an observational study performed at a Norwegian university hospital. One fifth-year medical student spent 20 days in two different hospital wards, following seven physicians from one to seven days each. The observer recorded data from several ward situations such as pre-rounds meetings, ward rounds, and discharge situations. The data was recorded by means of an observation form consisting of a mixture of codes and free-text fields. The data has been post-processed by associating each event with one communicative act. The approach is an efficient and useful means for studying clinicians' information and communication patterns in hospital wards, which can serve as an important tool in the design of new clinical information systems.

3.8.4 Main Results/Contributions

- Definition of 12 communicative acts that are represented in the observational data
- Presentation of example communicative acts profiles of three different physicians in pre-rounds, ward rounds, and drug-related activities

3.8.5 Retrospective

This paper presents an approach to analysis of field data collected through structured observation performed by means of the framework presented in Paper G [Sørby and Nytrø 2007b]. The paper describes how profiles of the communicative behaviour of clinicians can be visualized by means of radar plots. This is assumed to be particularly useful in order to illustrate variations (and similarities) among individual clinicians, roles, or other groups of clinicians (e.g. residents working in different hospital wards). The proposed analysis approach needs further investigation, but seems promising and is considered as most interesting in future research.

Chapter 4

Concluding Remarks

This chapter summarizes the main results and contributions, addresses some challenges, and outlines some directions for future research.

4.1 Main Results and Contributions

The contributions of this thesis consist of two main components:

- An iteratively developed method for structured, focused observation and analysis of clinicians' information and communication behaviour
- Exploration of how the observational data can be analyzed with varying foci and perspectives, and how the results of the processed data can be used in the requirements engineering process

The main strength of the approach is that it enables efficient field data recording at appropriate abstraction levels and that requires a minimum of transcription before further analysis. The technique combines structured, pre-defined coding of field data with free-text fields, which enables both quantitative and qualitative analysis of the data. This is useful for understanding the context of the communication and information behaviour of the clinicians being observed, and leads to valuable insight which is necessary when designing new information systems. The approach can also be used after the implementation of a new system in order to compare information and communication behaviour before and after a new system has been introduced.

Regarding practical matters, the approach has also proved beneficial. Since it is possible to omit all kinds of sensitive and person-identifying data, the efforts and

bureaucracy are less comprehensive than for instance when seeking permission to perform video recordings in hospital wards.

Medical students are found to be particularly suited for performing the observations. Both clinicians and patients are used to being followed by medical students, and they are found less intrusive than system developers and computer science students. Due to their domain knowledge and their role as apprentices and future users of the information systems they can also function as mediators between the end users and the system developers, both during the data collection and the analysis phases of the studies.

4.2 Challenges

As mentioned in Section 3.2, structured observations of clinicians complement other methods, and should be used as one of several techniques for exploring requirements for new health information systems. In order to get a thorough picture of the information and communication needs of the clinicians and to validate the recorded data, the results and findings of observational studies must be presented to and discussed with clinicians during interviews, workshops, and surveys.

Field studies suffers from the risk that the participants being observed are affected by the presence of the observer(s). However, by using senior/graduate medical students as observers and emphasizing that our focus was on the clinicians' communication and information acts and not on their performance or potential mistakes, this phenomenon was hopefully minimized in our approach.

One of the unexpected challenges during the observational studies was the scepticism of some clinicians, mostly physicians. They did not mind being followed by students, but they considered observing their interactions with the current systems as useless, since their behaviour obviously was adapted to the far from optimal current user interfaces.

4.3 Directions for Future Research

The following topics appear as the most interesting (and natural) when considering various paths for further work:

Developing tools for data registration and analysis

The observational data has so far been registered in spreadsheets and manually analyzed. To enable more easy data analysis in future studies, tools for registration

and analysis of the observational data should be developed.

Requirements specification and prototyping

The research presented in this thesis has mainly focused on development of methods for structured observation of clinicians' communication and information behaviour. As presented in the first chapters in the thesis, the main motivation behind the research has been to be able to elicit and develop requirements to mobile health information systems. However, analyzing and transforming field data collected by means of the framework for structured observation into formal requirements for new systems has so far been performed only to a very limited extent in a few student prototyping projects. Hopefully, the approach can be used in the development of requirements specifications and prototypes in future projects.

User interfaces for plan-based health record systems

One of the most interesting topics of this work that has only been briefly addressed is how the observational framework can be used to support plan-based user interfaces for clinicians. The recorded observational data consists of sequences of events or *communicative acts*. In Paper E it is proposed how Clinical Guidelines can be validated and/or developed and instantiated in explicit patient care plans based on patient, process, and actor trajectories produced from empirical data collected by means of the observational framework. Continuing the work presented in the paper is considered most important and interesting for further research.

Part II

Papers

Paper A

Characterizing cooperation in the ward: framework for producing requirements to mobile electronic healthcare records

This paper appears in *International Journal of Healthcare Technology and Management*, Vol. 7, no. 6, pp. 506–521.

Int. J. Healthcare Technology and Management, Vol. 7, No. 6, 2006

Characterising cooperation in the ward: framework for producing requirements to mobile electronic healthcare records

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Abstract: We present a framework for characterising hospital scenarios involving the patient chart. The paper-based chart is regarded as simple, efficient, and handy for mobile use by patient-care teams. However, the chart is available in only one physical place at a time, and it needs to be manually synchronised with the electronic healthcare record (EHR). The framework presented in this paper has been developed for use in non-participatory, observational studies performed at the University Hospital of Trondheim, conducted as a part of the MOBEL (MOBile ELectronic patient chart) project at NTNU. We have developed the framework iteratively; repeatedly observing groups in the ward, characterising observations in the framework, and changing attributes and outcome values. This paper presents our latest framework, a representative choice of scenarios, and their characterisation. We conclude with a discussion of results so far, the method, and the utility in the development of the MEPC.

Keywords: characterising scenarios; clinical cooperation; mobile electronic healthcare records; requirements for user interfaces.

1 Introduction

An important tool for organising and recording patient care activities in today's Norwegian hospitals is the paper-based patient chart. The patient chart, also called the chart book,[1] is a binder that contains the most essential information about one or several patients in the ward, such as the most recent laboratory and test results, medication, and plans for further treatment. Even in 'paperless' hospitals, with pervasive electronic healthcare records (EHR), a chart containing printouts and informal notes is in daily use as a co-operational tool used in patient-centred work.

The interface of the chart is considered simple, efficient and handy for mobile use by patient care teams. From the users' point of view, the main problem regarding the chart is that there exists only one copy. This might lead to inefficiency in daily work and more serious consequences such as postponed decision making, as a result of lacking availability of information as the chart is needed by physicians and nurses for various purposes and often simultaneously. Another important limitation of today's patient chart that might lead to possible errors, omissions and delays is that it must be manually synchronised with the EHR. In addition, the nurses have their own documentation systems so that important information is documented in different places. This information redundancy is a latent risk if the information becomes unsynchronised or inconsistent due to misconceptions or other human errors.

The potential and need for a computerised substitute for the paper-based patient chart has been shown in several projects (Ancona et al., 2000; Bardram, 2002). Various laptop and PDA-based interfaces have been developed and tested (e.g. Ammenworth et al., 2000; Wilcox et al., 1997). However, these have been found to be cumbersome (i.e. too heavy, too small, inflexible input) and inefficient for keeping a coherent and updated view of relevant information.

2 The MOBEL project

The MOBEL (MOBile ELectronic patient chart) project at NTNU is an interdisciplinary project that aims to specify a 'Mobile Electronic Patient Chart unit' (MEPC),[2] a context and procedure–aware, multimodal (e.g. combined text and speech output) interface to the EHR. In addition to being an ordering/booking and recording tool as a replacement for the paper-based patient chart, the objective is to improve the coordination and communication of health care workers in hospitals, minimise errors, and enhance efficiency, thereby improving quality of patient care. One of the main challenges of the MEPC is to be able to present the most relevant information at any time to the various users of the system on a small screen. Another important aspect, and one main reason why many computerised healthcare information systems fail, is that such a system

should not only lead to job shifting, such as nurses or doctors taking over secretarial duties, but to the real, conceived improvement of patient-centred work (Moore, 2002).

To get a general view of how the paper-based patient chart is used in the wards today, we performed, and still do, non-participatory, qualitative observational studies at the University Hospital in Trondheim. So far, the studies have taken place in three different departments (Department of Medicine: Division of Gastroenterology, Department of Cardiology, and Department of Neurology). The purpose of the observations was to identify scenarios that would improve, change, or even become superfluous by introducing the MEPC.

As a preparation for the observational studies, a set of attributes that we considered important for structuring and formalising the observations was defined. The purpose of developing this framework was twofold, as we also wanted to use the outcome of characterising the scenarios obtained from the observations in producing requirements to the mobile, electronic patient chart.

This paper presents the framework and describes a number of representative example clinical scenarios that are characterised by means of the framework.

3 Related work

The proposed framework for characterising scenarios is inspired by and related to work in requirements engineering, computer supported collaborative work (CSCW), human–computer interaction, and sociology (e.g. Horrocks et al., 1998; Sørensen et al., 2002).

Observational studies are valuable for understanding clinical needs and to allow analysis of communication behaviour among health care workers (Coiera and Tombs, 1998; Heath and Luff, 2000; Hughes et al., 1993). This technique is used extensively by anthropologists and sociologists. Forsythe et al. (1992) have conducted an empirical study, using ethnographic techniques. They identify and interpret physicians' expressions of information needs in medicine and how to broaden our conception of 'information needs'. Schneider and Wagner (1993) have analysed the complex nature of collaboration in hospitals, especially investigating information sharing and organisation of work under different technological regimes, with special attention to the role of different types of screen-based records. Furthermore, Symon et al. (1996) also use participant observation as a basis for a discussion about how work coordination is achieved in practice and how those insights are important for CSCW design in a hospital. Marc Berg has published extensively about information systems/technology and health care, with a social scientific point of departure, and has conducted several ethnographic studies. He stresses the importance of insight into 'organisational issues' when developing and evaluating patient care systems. Designing successful systems is dependent on a thorough sociological understanding of the complex practices in which information technology is to function (Berg, 1999; Berg et al., 1998).

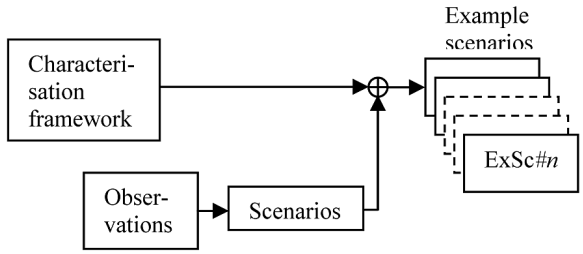
Building narrow or rich scenario descriptions of current work practice situations in order to perform requirements analysis has been one of several roles of scenarios in the system development lifecycle (Carroll, 1995) (see also Bødker and Christiansen (1997)). The term 'scenario' is here defined as the description of a process or a sequence of acts, in narrative form (Kuutti, 1995).

4 Framework outline

A complex mixture of formal procedures and informal practices, cyclicity and mobility characterises the work activities in the wards. The proposed framework tries to capture all these aspects.

Figure 1 illustrates the process of developing the framework. Initially, a set of attributes with corresponding values was defined. Next, the observational studies were performed, and based on the observations a number of example ward scenarios were extracted. Then the example scenarios were characterised by using the framework.

Figure 1 Elements in the framework development process



The framework consists of three main parts: process attributes, input attributes and outcomes (see Table 1). The main characteristics of the framework are related to the produced knowledge or information; type, amount, medium/modality, information/knowledge flow and time perspective/validity. Other characteristics include planning, delegation, and decision-making issues.

Table 1 Framework for characterising ward scenarios

Facet	*Attribute*
Process	Number of participants
	Number of roles
	Number of role levels
	Composition
	Decomposability
	Scenario nature
	Regularity
	Scheduling
	Variance of required information
	Location(s)
	Spatiality
	Temporality

Table 1 Framework for characterising ward scenarios (continued)

Facet	*Attribute*
	Information exchange
	Initiation
	Delay tolerance of scenario start
Input information	Novelty
	Recorded
	Longevity
	Medium/mode
	Scope
	Delay tolerance of input information
Outcomes	Explicit
	Shared
	Novelty
	Recorded
	Longevity
	Type of produced information
	Medium/mode
	Scope
	Delegation of responsibility
	Delegation of tasks
	Delay tolerance for outcome
	Outcome type known in advance

The attributes of the framework are described in more detail in the following sections. The possible values of each attribute are given in brackets, separated by commas.

4.1 Process attributes

Number of participants (1, 2–4, > = 5)
States the number of participants involved in the scenario. The value '2–4' typically represents a patient care team, while '> = 5' represents the ward physicians, nurses or the entire ward staff.

Number of roles (One, Two, Several)
Number of roles represented in the scenario (i.e. physician, nurse, enrolled nurse etc.).

Number of role levels (One, Two, Several)
Number of different role levels (i.e. consultant physician, house officer, etc.).

Composition (Predermined, ad hoc)
States when the composition of the scenario is decided.

Decomposability (No, Partly, Yes)
States if the scenario is decomposable, 'Yes' implies that the scenario can be decomposed into phases.

Scenario nature (Informal, Semiformal, Formal)
Denotes the level of formality of the scenario.

Regularity (Shift, Daily, Occasionally)
Indicates if the scenario takes place every shift, every (week–)day, or sporadically.

Scheduling (On the spot, In advance, Well in advance)
States to what degree the scenario is planned and scheduled in advance ('Well in advance' indicates more than one day in advance).

Variance of required information (No, Somewhat, A lot)
Indicates to what degree the amount of used information of the scenario varies.

Location(s) (Predetermined – fixed, Predetermined – varying, Multiple locations in phases, ad hoc)
States the possible location(s) of the scenario.

Spatiality (One place/face-to-face, Two places, Several places)
States if one scenario takes place one or more physical places simultaneously.

Temporality (Synchronous, Asynchronous)
States the temporal nature of the scenario.

Information exchange (One–one, One–many, Many–one, Many–many)
Indicates how many of the scenario participants who provide and receive information.

Initiation (On demand, On decision, On preconditions)
States the reason for the scenario.

Delay tolerance of scenario start (None, <1 day, <2 days, <5 days, Unknown)
States how urgent the scenario is; the values corresponds to 'urgent', 'within 24 hours', 'not urgent' or 'not known'.

4.2 Input information attributes

Novelty (To some, To all)
Indicates if the input information is new to one or more of the scenario participants.

Recorded (Personal notes, Informal local practice, Forms, Patient record, Not)
Denotes how the source(s) of the input information is recorded, such as in personal notes, forms, varying due to informal local practice, and/or in the patient records.

Longevity (None, Short term, Long term)
Denotes the lifetime of the recorded input information used in the scenario. 'None' is related to oral input information, 'Short term' is related to personal notes or other informal practices, 'Long term' indicates permanent storage in the patient record.

Medium/mode (Speech, Text, Picture, Other)
Denotes the form of the information brought into the scenario.

Scope (Some, All)
Indicates the intended receiver(s) of the input information.

Delay tolerance of input information (None, <1 day, <2 days, <5 days, Unknown)
States how soon the information is needed; the values correspond to 'urgent', 'within 24 hours', 'not urgent' or 'not known'.

4.3 Outcome attributes

Explicit (Yes, No)
States if the outcome is specific or more vague.

Shared (Yes, No)
States if the outcome is shared among several scenario participants or not.

Novelty (To some, To all)
Indicates if the output information is new to one or more of the scenario participants.

Recorded (Personal notes, Informal local practice, Forms, Patient record, Not)
Denotes how the output information is recorded, such as in personal notes, forms, varying due to informal local practice, and/or in the patient records.

Longevity (None, Short term, Long term)
Denotes the lifetime of the recorded output information used in the scenario. 'None' is related to oral output information, 'Short term' is related to personal notes or other informal practices, 'Long term' indicates permanent storage in the patient record.

Type of produced information (Constructive, Cooperation, Coordination, Socialisation, Negotiation, Motivation):

- constructive: the information is used as a decision basis or leads to some performed action
- cooperation: used as a basis for care team work
- coordination*: the practice of encouragement of working relationships between differentiable groups and/or individuals
- socialisation*: the introduction, reinforcement or modification of an organisation's culture or sub culture

- motivation*: the increase in expenditure of effort, energy and enthusiasm by members of a group
- negotiation*: a collaboration between two or more parties representing particular interests in specific outcomes where the purpose is ostensibly to achieve these outcomes through a process of discussion and compromise.

*Values from Horrocks et al. (1998).

Medium/mode (Speech, Written, Picture, Other)
Denotes the form of the produced information.

Scope (Patient, Patient Care Team Member (PCTM), Ward, Other)
Indicates the intended receiver(s) of the output information.

Delegation of responsibility (Predefined by function/role, Decided on spot, ad hoc/occasional)
Denotes to what degree potential delegation of responsibility is predefined.

Delegation of tasks (Predefined by function/role, Decided on spot, ad hoc/occasional)
Denotes to what degree potential delegation of tasks is predefined.

Delay tolerance for outcome (None, <1 day, <2 days, <5 days, Unknown)
States how soon the outcome is needed; the values correspond to 'urgent', 'within 24 hours', 'not urgent' or 'not known'.

Outcome type known in advance (Yes, No)
Indicates if the output type of the scenario is given.

4.4 Example scenarios

As an example of use, we present examples of ward scenarios and characterise them by using the framework presented in the previous section. An instance of a scenario is here defined as a time-limited process in which the cast (persons filling roles) does not change, and which has identifiable start, preconditions, end, and outcome. The scenarios are primarily based on non-participatory observations of physicians' and nurses' daily work in the hospital wards and informal interviews with nurses and physicians at the University Hospital of Trondheim during the period February to April 2002. Observable scenario attributes and subjective participant statements are used to characterise each scenario.

In the example scenarios, conferences have been divided into separate scenarios related to individual patients. A conference may also include briefing sessions and education of medical students. The morning conference is held every weekday. Every physician of the ward attends the conference if possible. The purpose of the morning conference is to share information about new patients and to discuss other patients if needed. The head physician might also give additional administrative or other general information. Two or three days a week,

medical students may also attend the conference. The conference is separated into three different scenarios:

S1a: Morning conference per new patient

The physician who was on call the previous night or another physician from the patient care team briefly informs the group about the new patient. The information is primarily taken from a photocopied paper sheet that contains extracted patient information written by hand by a nurse and distributed to the attendants of the conference or the 'in-card' displayed on a slide. The physician who informs the others might have added some notes by hand, regarding, for instance, medication or previous hospital stays. This additional information is taken from the patient journal and/or from speaking to the patient prior to the morning conference.

S1b: Morning conference per other patients

This part of the conference includes informal discussions about some of the other patients in the ward. The discussions are initiated due, for instance, to unusual test or examination results, or if the responsible physician wants some advice from the other physicians.

S1c: Morning conference, general information

The last part of the morning conference consists of general, administrative or other information given by the head physician or other attendants of the conference.

S2: Pre-rounds conference per patient

This is a scenario that was initiated by the chief physician of the patient care team because he was unable to attend the ordinary pre-rounds conference (cf. S3a–c) due to other duties. The assistant physician and the chief physician briefly discussed the patients of the care team based on the 'in-card'. The patient charts were not used and no new test results were available.

S3a: Pre-rounds conference per patient

The pre-rounds conference is held every weekday prior to the ward rounds. One or more physicians and nurses from the care team discuss the care plans of the patients based on the patient chart, possible new test and/or examination results, and supplementary information from the nurse documentation or undocumented information from the participants of the conference. The nurse has a notebook called the 'ward rounds book' in which she registers the tasks of the ward secretaries and the nurses, for instance if there has been a change in the medication of a patient or if a patient is to be discharged or moved to another ward.

S3b: Pre-rounds incident: seeking specific information about a new patient

The physician wants to know if there has recently been a specific examination of the patient (echocardiography), and the possible results of the examination. If the examination is very recent, the patient might not need to take an additional examination, or else the results of a new examination might be compared to the latest results.

The physician searches the paper-based patient journal, but does not have time to make a systematic search, and so he is not able to answer the question during the pre-rounds conference. He, therefore, orders a new examination anyway.

S3c: Pre-rounds incident: Seeking specific examination information

The physician wants to know the result of an examination (abdomen ultrasound) that was ordered previously. He is not able to find the result, and when searching the patient chart he is not able to find out if the examination has ever been ordered. He therefore instructs the nurse to call the X-ray department to find out if the examination requisition has ever been received, and decisions regarding further treatment of the patient have to be postponed until the result of the inquiry is known.

S4a: Ward rounds per patient

One or more of the physicians and nurses who participated in the pre-rounds conference visit the patient. Based on decisions made at the pre-round conference and new input (examination of patients, test results) further actions are taken, including test order, referrals, transfer and medication. The patient chart is brought along either as a 'patient chart book', a binder including all the patient charts of current interest (used at for instance the Division of Gastroenterology) or as separate units per patient kept in a trolley that is handled by the nurse. The nurse also brings the 'ward rounds book' described in S3a.

S4b: Ward rounds incident: Seeking new test results

One of the patients wants to know his haemoglobin percentage. The nurse returns to the office to check the latest laboratory answers, but it turns out that, due to a mistake, the specific test had not been ordered that morning. The consequence is that the patient has to take an additional blood sample, and the physician has to remember to check the result of the test when it becomes available.

S5: Ordering of new tests

After the ward rounds, the physician decides what additional tests are needed for each patient and notes this in the patient chart. The nurse completes the corresponding forms and sends or brings them to the appropriate receivers.

S6: Medication

One of the nurses of the patient care team uses information from the patient chart to put this particular day's medicines for the ward patients on a medicine tray. Later, the nurse who is in charge inspects the medicine tray to ensure that the medicines correspond to the recorded information in the patient chart.

Table 2 Applying the framework to the example scenarios

	Attribute	*S1a*	*S1b*	*S1c*	*S2*	*S3a*	*S3b*	*S3c*	*S4a*	*S4b*	*S5*	*S6*
Process	Numb. of part	> = 5	> = 5	> = 5	2–4	2–4	2–4	2–4	2–4	2–4	2–4	2–4
	Numb. of roles	Several	Several	Several	Two	Several	Two	Two	Several	Several	Two	Two
	# role levels	Several	Several	Several	Two	Several	Two	Two	Several	Several	Two	Two
	Composition	Predet.	Predet.	Predet. Ad–hoc	Ad–hoc	Predet.	Predet.	Predet.	Predet. Ad–hoc	Ad–hoc	Predet.	Predet.
	Decomp.	No	No	Partly	Yes	No	No	No	No	No	Yes	Yes
	Scenario nature	Semi–formal	Semi–formal	Semi–formal	Informal	Semi–formal	Informal	Informal	Informal	Informal	Informal	Informal
	Regularity	Daily	Daily	Occ.	Occ.	Daily	Occ.	Occ.	Daily	Occ.	Daily	Daily
	Scheduling	Well in advance	On the spot	Well in advance	On the spot	Well in advance	On the spot	On the spot	Well in advance	On the spot	On the spot	On the spot
	Variance of req. inform.	A lot	A lot	A lot	Some what	A lot	A lot	A lot	Some what	No	Some what	Some what
	Location(s)	Predet., fixed	Predet., fixed	Predet., fixed	Ad hoc	Predet., varying	Predet., varying	Predet., varying	Predet., varying	Multiple	Ad hoc multiple	Predet., fixed
	Spatiality	One place	One place	One place	One place	One place	One place	One place	One place	Two places	Several places	One place
	Temporality	Synch.	Synch.	Synch.	Synch.	Synch.	Synch.	Asynch.	Synch.	Asynch.	Asynch.	Asynch.
	Information exchange	One–many	One–many	One–many	Many–many	Many–many	One–many	One–many	Many–many	One–many	One–many	N/A
	Initiation	Demand	Precond.	Demand	Decision	Demand	Precond.	Precond.	Demand Precond.	Demand	Demand Precond. Decision	Demand Precond.
	Delay toler. of scen. start	None	None	None	Unknown	None	Unknown	Unknown	None	None	<1 day None	None
Information input	Novelty	To all	To all To some	To some	To all	To some	To some	To all	To all	To some	To all	To some
	Recorded	P. notes Informal Not	P. notes	P. notes	P. notes Not	P. notes Pat. rec. Forms	Pat. rec.	Pat. rec.	Pat. rec. Not	Pat. rec.	P. notes Pat. rec.	Pat. rec.

Table 2 Applying the framework to the example scenarios (continued)

	Attribute	*S1a*	*S1b*	*S1c*	*S2*	*S3a*	*S3b*	*S3c*	*S4a*	*S4b*	*S5*	*S6*
	Longevity	Short term	None	Short term	Short term	Short and long term	Long term	Long term	Short term	Long term	Short term	Short term
	Medium/mode	Speech Text	Speech	Speech	Speech Text	Speech Text	Text	Text	Speech	Text	Text	Text
	Scope	Some	Some	All	All	All	All	All	All	Some	All	All
	Delay toler. of inp. inform	None	None	Unknown	None	None	Unknown	Unknown	Unknown	None	None	None
Outcomes/ produced input	Explicit	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Shared	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Novelty	To some	To all	To some	To some	To some	To all	To all	To some	To all	To all	To some
	Recorded	P. notes Not	P. notes Not	Not	P. notes Not	All types	Not	Not	Pat. rec. Not	Pat. rec. P. notes	Forms	Pat. rec.
	Longevity	Short term	Short term	Short term	Short term	Short and Long term	N/A	N/A	Short and long term	Long term	Short term Long term	Long term
	Type of prod. information	Coord.	Constr. Coop.	Social. Motiv	Constr. Coop.	Constr. Coop. Coord.	Constr. Coord	Constr. Coord	Motiv. Constr. Coop.	Constr.	Constr.	Coop. Constr.
	Medium/mode	Text None	Text None	None	Text	Speech Text	Speech, Text	Speech	Speech Text	Speech Text	Text	Text
	Scope	PCTM	PCTM	Ward	PCTM	PCTM	PCTM	PCTM	Patient PCTM	PCTM	Other	PCTM
	Delegation of responsibility	Predef.	Predef.	Predef. On spot	On spot	Predef.	Predef.	Predef.	On spot	On spot	Predef.	Predef.
	Delegation of tasks	N/A	Predef.	Predef. On spot	On spot	Predef.	Predef.	On spot	On spot	On spot	Predef.	Predef.
	Delay toler.	N/A	N/A	Unknown	None	Unknown	Unknown	Unknown	None	None	None	None
	Outcome type known in adv.	Yes	No	No	No	Yes	No	No	No	No	Yes	Yes

4.5 Applying the framework to the scenarios

Table 2 shows the result of applying the framework to the example scenarios (denoted S1a–S6) described in the previous section. 'N/A – (Not applicable) – indicates that the attribute is irrelevant to the scenario in general or as a consequence of the value(s) of previous attributes. For some of the scenarios, several valid values apply to a number of the attributes.

5 Methodological results

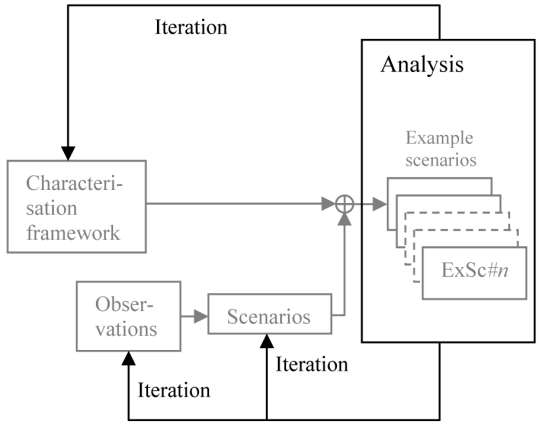
The subject of this paper is the development of a framework; a set of attributes characterising information flow in a clinical setting. However, in order to further explicate our approach, it is necessary to compare it to other approaches. There are several different ways to observe a process and record what is happening in a real situation by for example:

1. Record video and sound.
2. Writing narratives, stories describing one and one observation.
3. Abstracting narratives into scenarios, in which more than one narrative are combined into one, but with remarks about variations and exceptions.
4. Abstracting scenarios into characterising features that are applicable to many different scenarios.
5. Identifying actors, resources and actions and try to model specific, or abstract, processes.
6. Doing interviews and making models of participant knowledge.
7. Making a model of the information, and model abstract processes involving this information.

Combinations of these methods are of course possible. Studies made in order to introduce changes in organisation, or introducing software systems, often make very superficial analyses of actual behaviour. Models 5, 6 and 7 suffer from shortcomings in modelling tools, the preconceptions of the engineer and requirements based on subjective interviews of managers and selected participants. On the other hand, our goal has been to introduce a tool, the MEPC, into actual work processes, not aiming to change or replace them as such, but to augment and enhance them by giving easy access to a common EHR, improve distribution of information and support decision-making.

Our preferred method for making the MEPC is to characterise situations in which it can be beneficial, describe initial requirements to it through observation, and eventually develop the MEPC through participatory design. To that end, we forego recordings (1) and narratives (2) and look for features (4) of the process that we believe can be improved. This set of features; the attributes in a framework, has changed as a result of observing and using the framework. The actual process has been to propose attributes, observe, characterise, rethink attributes and values, recharacterise, and do new observations. This is illustrated in Figure 2.

Figure 2 Iterative framework development



So far, our experience with the framework development is that:

- A scenario is but an abstraction of many implicit narratives. The variance is considerable from observation to observation, and it is important to capture and describe this variance as part of a scenario description.
- Even if the overall information needs and communication patterns in the different wards are similar, the use of the patient chart varies a lot depending on the individual user, i.e. how experienced the user is, for how long (s)he has been working in the particular ward, and how 'familiar' the patients are.
- Seemingly unfinished or inconclusive processes are common.
- Deviations from plans, or from normal scenarios, are common.
- Variations in roles are important.

Our framework development is not yet finished, and will be further refined after we have started working on MEPC requirements and participatory design. Observations in new wards and hospitals will increase our experience. As a summary so far, we have concluded that instead of looking at scenarios as idealised observations, we should regard them as abstractions of observations with variance and failures, and carefully capture all deviations.

6 Discussion and further work

How does the framework and analysis so far help us towards making the MEPC? We have not finished our observations, and have not yet made a thorough analysis. We plan to do various clustering analyses to compare the results before embarking on the next steps in the design process.

However, preliminary results show that an MEPC would be beneficial when:

- the documented decisions and plans are direct results of consulting formalised information (from the EHR)
- the process is asynchronous or spawns multiple other processes
- the outcome must be documented
- both formal and informal information exchanges occur simultaneously.

The MEPC seems superfluous when:

- a process outcome is short–term operational knowledge, only relevant for indirectly documented, immediate actions, unless interruptions or disturbances are common
- the process primarily produces 'new common knowledge', i.e. the process aims to produce consent and understanding.

The outcome of characterising ward scenarios by using the framework presented in this paper will later be used to guide further work of the MOBEL project in specifying requirements for the actual information systems. These systems include domain models and usage models of the MEPC, and we believe that the proposed framework will serve as a constructive tool before and during system design.

Acknowledgements

We would like to thank the staff at the University Hospital of Trondheim for their cooperation. The research presented in this paper is financed by NTNU Innovation Fund for Business and Industry (www.idefondet.ntnu.no).

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Notes

[1] The patient chart (also called the 'chart book') is described in more detail in Ellingsen, G. and Monteiro, E. (2003) 'A patchwork planet: integration and cooperation in hospitals', *Computer Supported Cooperative Work (CSCW)*, Vol. 12, No. 1, pp.71–95.

[2] The project includes members from the Department of Computer and Information Science, Department of Sociology and Political Science, Department of Telecommunications, Department of Linguistics and Faculty of Medicine at NTNU.

Paper B

Using scenarios and drama improvisation for identifying and analysing requirements for mobile electronic patient records

This chapter appears in *Requirements Engineering for Sociotechnical Systems* edited by J. L. Maté and A. Silva.

Chapter XVI

Using Scenarios and Drama Improvisation for Identifying and Analysing Requirements for Mobile Electronic Patient Records

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Abstract

This chapter presents two different techniques for elicitation and analysis of requirements for a mobile electronic patient record (EPR) to be used in hospital wards. Both techniques are based on human-centred and participatory design principles. The first technique uses observational studies as a basis for identifying and analysing requirements for a mobile EPR. The observations are structured and systematised through a framework. The second technique is named "Creative system development through drama improvisation", and it enables users (in this case healthcare

professionals) to contribute to the requirements engineering (RE) process by acting out everyday work situations in one-day workshops. Both techniques presented in this chapter focus on user requirements elicitation, and we believe that they are promising and complementary contributions to more traditional requirements elicitation and analysis methods, not only for hospital information systems but for a wide variety of complex, sociotechnical systems.

Introduction

Advanced clinical information systems have great potential for systematising and structuring the large amounts of information that exist in modern hospitals. At the same time these systems may also simplify and coordinate the endless streams of communication that take place. A well-designed system has to be intuitive, effective, and flexible enough to meet the specific information and communication needs of a wide range of healthcare professionals. However, the high information intensity and the complexity of the organisation make the system design process particularly challenging. Both the social features of current work practice and the technical features of the system have to be considered when performing requirements gathering and analysis (Reddy, Pratt, Dourish, & Shabot, 2003). One approach to such sociotechnical requirements analysis is to involve users more actively in the design process through methods such as participatory design.

In this chapter we introduce and discuss two different techniques for elicitation and analysis of requirements for a mobile electronic patient record (EPR) to be used in hospital wards. Both techniques are based on human-centred and participatory design principles, and they have been developed and used as parts of the MOBEL[1] (Mobile Electronic Patient Record) project at the Norwegian University of Science and Technology (NTNU). An EPR is a computer system designed to support clinicians by providing accessibility to complete and accurate patient data. It may also include alerts, reminders, clinical decision support systems, links to medical knowledge, and other aids (Coiera, 2003; Dick, Steen, & Detmer, 1997). Numerous EPR systems exist, most of them developed for stationary computers, but also for various other devices such as handheld computers.

The first of the techniques presented in this chapter uses observational studies as a basis for identifying and analysing requirements for a mobile EPR. Observational studies are frequently used within the social sciences, and during the last decades computer science researchers have also acknowledged such methods as useful for understanding the complexity of organisations and the various information needs of different users. Yet system developers may not always be able to transform rich observations to requirements and design decisions. In this chapter we present *a framework for structuring and formalising scenarios* obtained from observational studies at a hospital ward. Further we discuss how the outcome of characterising these scenarios may be used for producing requirements to a mobile electronic patient record.

The second technique, *Creative system development through drama improvisation*, has been introduced by product designers and software engineers as a method for develop-

ing and testing ideas for functionality. However, most of them have only reported results of the method without providing any detail on how the drama sessions were actually performed. We have developed and tested a procedure for how healthcare professionals can contribute to the requirements engineering (RE) process by acting out everyday work situations at a hospital ward. The procedure description is accompanied by a presentation of the findings, including the advantages and limitations of the technique.

The next section of this chapter focuses on the hospital as a complex organisation and hence a challenging site for introducing new information and communication systems. We briefly address how traditional RE methods fall short in integrating social processes and work practices in the system development. Furthermore we discuss the tradition of user-centred design and some approaches to requirements elicitation methods for system development in complex organisations such as hospitals. This is followed by a presentation of the two different techniques used in the MOBEL project and a discussion of the advantages and disadvantages of both techniques. Finally we suggest how these methods may be used as a supplement to traditional requirements elicitation methods when developing complex sociotechnical systems.

Background

"Traditional" RE methods have previously focused on system functionality, based on the assumptions that the application domain is stable, that information is fully available and known, and that most work consists of formal, routine processes (Reddy et al., 2003). This view is about to change, as system designers are more aware of the importance of including social and organisational processes if they want their systems to be successfully adopted into complex organisations. Air traffic control, underground subway control systems, and financial systems are examples of areas where sociotechnical approaches to requirements analysis have been used successfully (Reddy et al., 2003). Nonetheless traditional requirements analysis is still predominant in the area of clinical healthcare. A great number of costly clinical systems and projects have failed (see, for example, Heath & Luff, 2000; Heath, Luff, & Svensson, 2003; Sicotte, Denis, & Lehoux, 1998), one of the most common reasons being the lack of sufficient requirements analysis. This implies the need for a more thorough requirements analysis and elicitation phase, taking into account both sociological and organisational aspects of clinical work. So far only a few researchers have reported using sociotechnical requirements analysis in this application area (Berg, 1999; Berg, Langenberg, v.d. Berg, & Kwakkernaat, 1998; Heath & Luff, 1996).

The Hospital as a Complex Organisation

Today's hospitals are highly specialised and differentiated organisations. Dedicated departments and services have required an expansion of physical facilities, reallocation of workers, and the integration of new skilled personnel into a continuously changing

division of labour. This has in turn led to the establishment of complex relationships among a multiplicity of hospital services and departments (Strauss, Fagerhaug, Suczek, & Wiener, 1997). This puts strong demands on coordination and collaboration between different specialist departments and also between the different professions in the hospital.

Scheduling, coordination, and communication in hospitals take place through a wide array of sources: electronic, paper-based, and oral. Even in "paperless" hospitals, the EPR is often supplemented by paper-based systems, and such a mixture of systems may cause several problems. A major problem with paper-based systems is that there is often only one copy of each document, and consequently it can only be used at one place and for one purpose at a time. Paper-based systems are not synchronised with the EPR, which might lead to errors and omissions. Furthermore different groups of healthcare workers have their own documentation systems, which imply that important information is stored in different places. Providing this information to all groups of health personnel, by improving accessibility, is an important task.

Replacing paper-based systems by computer systems might solve the problem of unavailability and unsynchronised information and also enhance the quality of care by providing healthcare personnel more quickly with information they currently collect from different sources.

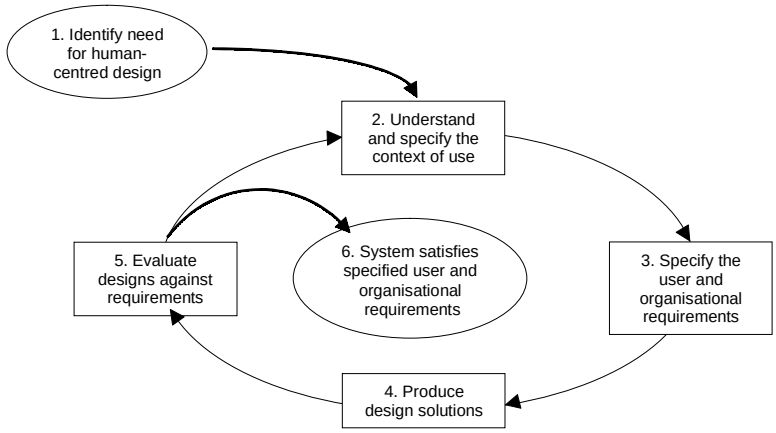
However, designing such systems brings about at least two important challenges:

1. *How to decide what kind of information health personnel need and consequently what to include in the system.* Health personnel have multiple and diverse information needs, and to be able to design a functional system, it is vital to understand their information needs in relation to different tasks and contexts.
2. *How to present the information.* Health personnel are mobile workers, and they therefore need mobile information systems. Mobile devices such as handheld computers offer information access at the point of care, but the limited screen size and poor input facilities place strong demands on the presentation and navigation of the information. The lack of good user interfaces has also been identified by several other researchers as a major impediment to the acceptance and routine use of many types of computing systems in healthcare (see, for example, Patel & Kushniruk, 1997).

Human-Centred Design

To face the challenges of designing and developing user-friendly and efficient computer applications for healthcare organisations, it is necessary to know and understand the context of use. This is one of the main activities in human-centred design, an approach to interactive system development that focuses specifically on making systems usable (EN ISO 13407, 1999). Figure 1 shows the main components of the human-centred system development cycle.

Figure 1. Human-centred design activities (from EN ISO 13407, 1999)



One of the principles of human-centred design is "*the active involvement of users and a clear understanding of user and task environments*" (EN ISO 13407, 1999, p. 2). This desire to increase and improve user participation by making users more active through acting out everyday situations is the rationale for using drama improvisation as a part of the system development process. Through establishing a common ground, or a "third space", for communication (Muller, 2002) we consider this approach useful for improving communication between system developers and prospective users of the system. This approach follows the tradition of several research projects in the Scandinavian countries, where role-play and games have been used to create common spaces between software developers and users from the early efforts in participatory design (Ehn, 1988), to more recent years (Buur & Bagger, 1999). However, few of these methods have been deployed when developing systems for such complex organisations as hospitals.

The drama improvisation method relates mainly to activities three, four, and five of the human-centred design approach (see Figure 1). To be able to gain a thorough insight and specify the context of use (activity 2), it may be crucial to perform ethnographic or observational studies. These studies are valuable for exploring the nature of a particular phenomenon and gaining detailed insight into an environment (Atkinson & Hammersley, 1994). Anthropologists and sociologists extensively use these techniques (Coiera & Tombs, 1998; Heath & Luff, 2000; Hughes, Randall, & Shapiro, 1993). There exist a great number of ethnographic studies of healthcare organisations in general and of information needs and communication behaviour among healthcare workers (see, for example, Berg, 1999; Berg et al., 1998; Forsythe, Buchanan, Osheroff, & Miller, 1992; Schneider & Wagner, 1993; Symon, Long, & Ellis, 1996). Nevertheless, a remaining challenging task is how to utilise this sociological insight in informing design.

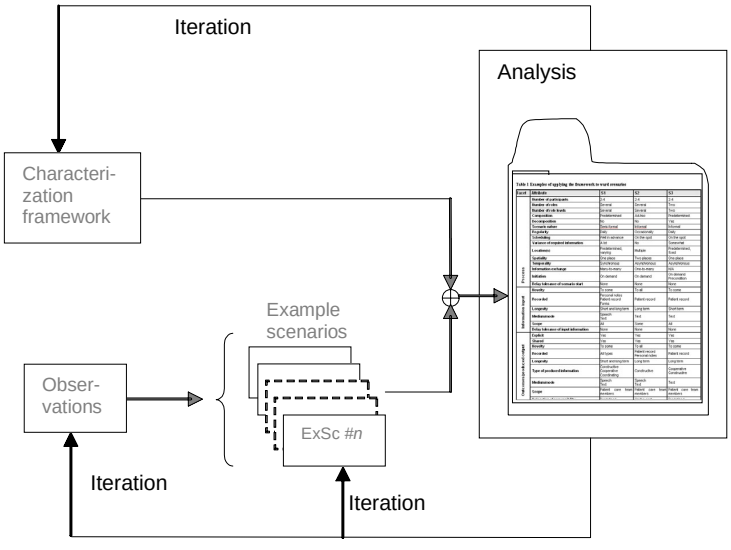
One technique for bridging some of the gap from ethnographic studies to design decisions is by building narrow or rich scenario descriptions of current work practice

situations in order to perform requirements analysis. This has been one of several roles of scenarios in the system development lifecycle (Carroll, 1995; see also Bødker & Christiansen, 1997). A scenario is a description of a process or a sequence of acts in narrative form (Kuutti, 1995). The next section gives an example of how to structure and characterise scenarios obtained from observational studies at a hospital ward.

Observational Studies: Creating a Framework for Structuring and Analysing Scenarios

To be able to produce requirements for a mobile, electronic patient record, our first challenge was to understand how both paper-based and electronic information systems were currently used on the hospital wards. Hence observational studies of physicians' and nurses' daily work in three wards at the University Hospital of Trondheim were conducted. One week was spent observing at two of the wards, while a more extensive observational study of four months was conducted in one ward. The observations were supplemented with informal interviews with the health personnel.

Figure 2. Elements of the framework development process



Framework Outline

One of the main purposes for conducting the field studies was to identify scenarios that would improve, change, or even become superfluous by introducing the mobile EPR. As preparation for the observational studies, a set of preliminary attributes that were considered important for structuring and formalising the observations was defined. We also defined a set of values corresponding to the attributes. Next the observational studies were conducted, and based on the observations a number of example ward scenarios were extracted. Subsequently the example scenarios were characterised by applying the framework. The framework has been developed iteratively as new observations, scenarios, and characterisations brought the need for changing attributes and outcome values. Figure 2 illustrates the framework development process.

The attributes were prearranged into three main parts: process attributes, input attributes, and outcomes. The process attributes were aimed at depicting the structure of the scenario, for example, if the composition of the scenario was predetermined and if the scenario was decomposable. Other process attributes involve the number of actors and roles in the scenario, dependencies and preconditions, formality level (that is, informal/semiformal/formal), information flow, location, and temporal nature of the scenario.

Process attributes:

Below are some examples of process attributes with corresponding values and explanation:

Number of participants *(1, 2-4, >=5)*

States the number of participants involved in the scenario. The value "2-4" typically represents a patient care team, while ">=5" represents the ward physicians, nurses, or the entire ward staff.

Number of roles *(One, Two, Several)*

Number of roles represented in the scenario (for example, physician, nurse, enrolled nurse, and so forth.).

Scenario nature *(Informal, Semiformal, Formal)*

Denotes the formality level of the scenario.

Regularity *(Shift, Daily, Occasionally)*

Indicates if the scenario takes place every shift, every (week-) day, or sporadically.

Scheduling *(On the spot, In advance, Well in advance)*

States to what degree the scenario is planned and scheduled in advance ("Well in advance" indicates more than one day in advance).

Input and Outcome Attributes

Attributes related to input information and outcome include type (for example, whether the information is constructive, for coordination, or motivation), variance, error, excep-

tions, medium/modality, time, and validity (for example, novelty, longevity, and delay tolerance).

Examples of input information attributes:

Recorded *(Personal notes, Informal local practice, Forms, Patient record, Not)*

Denotes how/if the source(s) of the input information is recorded, such as in personal notes, forms, varying due to informal local practice, and/or in the patient records.

Longevity *(None, Short term, Long term)*

Denotes the lifetime of the recorded input information used in the scenario. 'None' is related to oral input information, 'Short term' is related to personal notes or other informal practices, 'Long term' indicates permanent storage in the patient record.

Medium/mode *(Speech, Text, Picture, Other)*

Denotes the form of the information brought into the scenario.

Example of outcome attribute:

Type of produced information *(Constructive, Cooperation, Coordination, Socialisation, Negotiation, Motivation)*

Constructive: The information is used as a decision basis or leads to some performed action; Cooperation: Used as a basis for care team work; Coordination*: The practice of encouragement of working relationships between differentiable groups and/or individuals; Socialisation*: The introduction, reinforcement or modification of an organisation's culture or sub-culture; Motivation*: The increasing of the expenditure of effort, energy, and enthusiasm by members of a group; Negotiation*: A collaboration between two or more parties representing particular interests in specific outcomes where the purpose is ostensibly to achieve these outcomes through a process of discussion and compromise. *Values from (Horrocks, Rahmati, & Robbins-Jones, 1998)

All the attributes and the corresponding values are described in (Sørby, Melby, & Nytrø, in press).

As previously mentioned, work activities in hospital wards are characterised by a complex mixture of formal procedures and informal practices, cyclicity, and mobility, and the proposed framework tries to capture all these aspects. The selected attributes were inspired by and related to work in traditional requirements engineering, computer-supported collaborative work (CSCW), human-computer interaction, and sociology (for example, Horrocks et al., 1998; Sørensen, Wang, Le, Ramampiaro, Nygård, & Conradi, 2002).

Characterising Scenarios by Means of the Framework

In Figures 3a, 3b, and 3c three example ward scenarios are presented. An instance of a scenario is here defined as a time-limited process (for an individual patient) in which the

Figure 3a. Example scenario 1

S1: Pre-rounds conference per patient

The pre-rounds conference is held every weekday prior to the ward rounds. One or more physicians and nurses (typically the head physician, one assistant physician, and the team leader nurse) from the care team discuss the care plans of the patients based on the patient chart, possible new test and/or examination results, and supplementary information from the nurse documentation or undocumented information from the participants of the conference. The nurse has a notebook called "ward rounds book" in which he or she registers the tasks of the ward secretaries and the nurses; for instance, if there has been a change in the medications of a patient or if a patient is to be discharged or moved to another ward.

Figure 3b. Example scenario 2

S2: Ward rounds incident: Seeking new test results

One of the patients wants to know his haemoglobin percentage. The nurse returns to the office to check the latest laboratory answers, but due to a mistake the test was not ordered in the morning. The consequence is that the patient has to take an additional blood sample, and the physician has to remember to check the result of the test when it becomes available.

Figure 3c. Example scenario 3

S3: Medication - per patient

One of the nurses in the patient care team uses information from the patient chart to put today's medications for the ward patients onto a medicine tray. Later the nurse in charge inspects the medicine tray to ensure that the medicines correspond to the recorded information on the patient chart.

cast (people filling roles) does not change and that has an identifiable start, preconditions, end, and outcome.

Based on observable scenario attributes and subjective participant statements, each scenario has been characterised by applying the framework presented earlier in this section.

Table 1 shows the result of applying the framework to the example scenarios S1-S3. "N/A" (not applicable) indicates that the attribute is irrelevant to the scenario in general or as a consequence of the value(s) of previous attributes. For some of the scenarios, several valid values apply to a number of the attributes.

Findings: The Scenario Approach

The presented framework is mainly intended for structuring and sorting observations and scenarios from current work situations and establishing a vocabulary for

Table 1. Examples of applying the framework to ward scenarios

	Attribute	S1	S2	S3
Process	**Number of participants**	2-4	2-4	2-4
	Number of roles	Several	Several	Two
	Number of role levels	Several	Several	Two
	Composition	Predetermined	Ad-hoc	Predetermined
	Decomposition	No	No	Yes
	Scenario nature	Semi-formal	Informal	Formal
	Regularity	Daily	Occasionally	Daily
	Scheduling	Well in advance	On the spot	On the spot
	Variance of required information	A lot	No	Somewhat
	Location(s)	Predetermined, varying	Multiple	Predetermined, fixed
	Spatiality	One place	Two places	One place
	Temporality	Synchronous	Asynchronous	Asynchronous
	Information exchange	Many-to-many	One-to-many	One-to-many
	Initiation	On demand	On demand	On demand Precondition
	Delay tolerance of scenario start	None	None	None
Information input	**Novelty**	To some	To all	To some
	Recorded	Personal notes Patient record forms	Patient record	Patient record
	Longevity	Short & long term	Long term	Short term
	Medium/mode	Speech & text	Text	Text
	Scope	All	Some	All
	Delay tolerance of input information	None	None	None
Outcomes/produced output	**Explicit**	Yes	Yes	Yes
	Shared	Yes	Yes	Yes
	Novelty	To some	To all	To some
	Recorded	All types	Patient record Personal notes	Patient record
	Longevity	Short & long term	Long term	Long term
	Type of produced information	Constructive Cooperative Coordinating	Constructive	Cooperative Constructive
	Medium/mode	Speech & Text	Speech & Text	Text
	Scope	Patient care team members	Patient care team members	Patient care team members
	Delegation of responsibility	Predefined	On the spot	Predefined
	Delegation of tasks	Predefined	On the spot	Predefined
	Delay tolerance	Unknown	None	None
	Outcome type known in advance	Yes	No	Yes

characterising them. To identify system requirements by means of scenarios, it is necessary to perform thorough clustering analysis of the resulting characterisation of example scenarios. Various methods exist for this purpose. Contextual design is one example of an approach that adapts ethnographic methods of understanding human behaviour in context (for example, the workplace) and extends these methods to function within traditional software and usability engineering practices (Carroll, 1995).

In this study the manual analysis of applying the framework to a few scenarios indicates that a mobile EPR is beneficial in certain situations, for instance, when the documented decisions and plans are direct results of consulting formalised information from the EPR. Similarly the mobile EPR seems superfluous in other situations — for example, when a process outcome is short-term operational knowledge. Other findings suggest that even if the overall information needs and communication patterns in the different wards are similar, the use of the patient record varies greatly depending on the individual user, that is, how experienced the user is, how long he or she has been working in the particular ward, and how well-known the patients are. This confirmed our assumption that the mobile EPR has to be dynamic and adaptable to various situations and users.

When applying the framework to the example scenarios, we faced several challenges. Since a scenario is an abstraction of many underlying narratives, there is considerable variance from observation to observation, and it is therefore important to try to capture and describe this variance as part of a scenario narrative. Seemingly unfinished or inconclusive processes are common, as are deviations from plans or from normal scenarios. These aspects are important for the system design but difficult to capture in the proposed framework. Despite these challenges when modeling the framework, we believe that the final framework may serve as a constructive tool both before and during system design.

Creative System Development through Drama Improvisation

The following sections are based on three one-day drama workshops organised at NTNU (Svanæs & Seland, 2004). The main goal of the workshops was to develop a method that involves end-users actively in designing a mobile health information system through scenario building, drama improvisation, and low-fidelity prototyping. The method also enables system developers to gain a better understanding of the users' domain by observing how healthcare workers stage and act out current and future use scenarios.

Workshop Structure and Contents

The workshops were held in a full-sized model of a future hospital ward. The model contained several partly furnished patient rooms where most of the acting took place. Two groups of three healthcare workers (physicians and nurses) participated in each workshop. Besides the organisers and a few observers, two graduate students in

computer science taking roles as system developers also participated in the workshops. In addition a drama teacher was hired as a facilitator in the first workshop. The system developers were neither involved in the scenario selection nor allowed to suggest design solutions, but during the rehearsal of the scenarios they briefly discussed the scenarios and design solutions with the healthcare workers.

After a brief introduction of the participants, the organisers gave a general introduction to system development processes, to user-centred methods specifically, and the rationale behind using drama improvisation as a method. After the introduction the participants were introduced to simple warm-up exercises before they were split in two teams. Both teams performed a brainstorming session on communication- and information-rich situations from their hospital ward to identify scenarios to be dramatised later on. Example scenarios were written on Post-it notes and placed on a wall, clustering similar situations (Figure 4). After deciding which situation they would prefer to present, they decided upon details such as the exact number of participants and the time and location of the event.

The teams rehearsed their scenarios before presenting them to the other participants. Each scenario was presented twice, first as the team had rehearsed it and next with interruptions from the other team. An example of an interruption is that the physician's pager beeps, and he or she has to leave the room to check the message. The reason for introducing interruptions was to make the participants more used to improvising and changing their well-rehearsed scenario, in addition to obtaining realistic and more diverse situations.

After a short break the organisers presented a brief overview of various mobile technological solutions. The healthcare workers were handed low-fidelity prototypes (foam models) that could be used in the next variants of the scenarios. In the first workshop the participants discussed how they could incorporate this technology into their chosen situations, and they sketched "screen shots" on Post-it notes. In the second and third workshops the participants "developed" their systems as they acted. When seeing a need for some information, they stopped acting and sketched their solutions on Post-it notes attached to the prototypes. Again the teams acted out their scenarios in front of the other team but this time with "technology" incorporated as a part of the scenario. Figure 5 shows two nurses improvising new work practices using the low-fidelity prototypes. As in the former performances, the groups acted their scenarios both with and without interruptions. At this stage of the workshop, the interruptions were introduced to test the reliability of the suggested solutions.

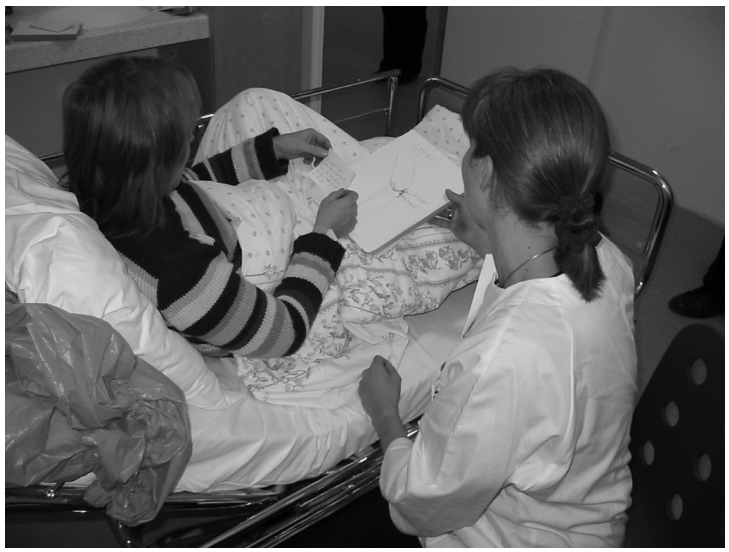
A plenary gathering where all participants discussed and summarised the workshop concluded the day. Topics that were discussed were the realism of the chosen scenarios, experiences from acting out the scenarios, and various considerations about the proposed technological solutions.

Findings: Drama Improvisation as Input into the RE Process

To evaluate the drama improvisation method, questionnaires were completed by the participants at the end of each workshop. These questionnaires were supplemented with

Figure 4. Nurses brainstorming work situations

Figure 5. Nurses acting out future scenario



interviews and discussions with the system developers and the healthcare personnel. In addition the system developers wrote preliminary reports from the workshops and subsequent requirements specifications.

The following sections discuss some important findings from the evaluation of the drama improvisation method.

System Developers' Understanding of the Domain and the Technological Needs of the Users

One of the most striking features of drama improvisation as a method is its ability to let system developers get a thorough insight into the domain without requiring their actual presence at the work site. The system developers in our workshops found it much easier to understand the domain through the health personnel's acting than by simply questioning health personnel or otherwise reading or listening to descriptions of work situations. *"Watching health personnel 'working together', even though fictitious, makes you think about things you previously haven't considered"* (interview with the system developers, 23 May, 2003). The workshops helped in detecting health personnel's information needs that the system developers were previously unaware of or thought were already being met. Likewise the opposite was also the case: in situations where the system developers predicted a need for formal and written information, the health personnel solved their information needs informally, asking each other.

Another issue considered important was the significance of health personnel talking together while acting out the scenario. Through their talking they explained and clarified for the system developers what was happening in the scenario.

The system developers were positive and quite impressed by the technological solutions suggested by the health personnel: *"I feel that they came up with some pretty clever solutions. And what's positive is that they came up with it themselves, and then it is more likely that they actually will use it"* (interview with the system developers, 23 May, 2003). The users' suggestions were perceived as a healthy corrective to the system developers' visions. System developers sometimes tend to design a more sophisticated and advanced system than users really require and want, thus neglecting the users' actual needs.

Communication between System Developers and Healthcare Workers

Good communication between system developers and future users is of great importance in user-centred design approaches. In our opinion, drama improvisation is a suitable method for facilitating communication and obtaining a common understanding of a system design project. It establishes a common ground, a third space, for both system developers and future users. Since the users are the domain experts and their knowledge and creativity are actively used in the design process, they may feel more conversant with the future system and therefore more willingly accept it.

When nurses and physicians work together with system developers, it is important to create a common language they all understand. "Telling by showing", as is the case when

work situations are dramatised, is a natural way to describe everyday work and is easy and intuitive to understand. Thus drama becomes a common language of the system developers and the healthcare personnel.

Another important point is that simply bringing system developers and future end users, in this case health personnel, together and providing them with time to talk and ask each other questions within an informal atmosphere proved helpful in the process of identifying requirements. Because the participants acted scenes out rather than merely analysing or describing them, a playful atmosphere was created. This resulted in discussions and a lot of interesting information being shared in the breaks between the formal schedules. As the acting sessions took place outside the hospital, the system developers were also able to "freeze" the situations and ask clarifying questions without fear of disturbing real patients.

Creating Requirements Specifications Based on the Workshops

Based on the last two workshops, two preliminary requirements specifications were created. These specifications demonstrate one of the main limitations of the method: Some functional requirements were described in detail, while others were missing due to the specific focus in the workshops. This implies that the method has to be supplemented by other RE methods to explore the remaining functional and non-functional requirements of the system.

Another important issue for the outcome of the workshop is the participants' personal opinions and technological skills. As some participants had strong opinions regarding solutions, they tried to take a leading position in defining the technological needs. The organisers therefore had to make sure that every participant's opinion was heard. Likewise the different participants did not always agree on what solution would be the best in their daily work. This led to healthy discussions about advantages and disadvantages of the different solutions, but it also complicated the resulting requirements specification, as the various solutions had to be considered.

Discussion

The techniques presented in this chapter are both based on human-centred system development, but they contribute in different phases of the human-centred system development cycle. One main difference is that the drama improvisation method is more interactive and the users are directly involved in specifying the requirements of the system, even if this is not explicitly stated. The framework approach, on the other hand, puts strong demands on researchers to "translate" observations into examples of representative scenarios, characterise them via the framework, and then deploy the results in the system design.

In a real hospital setting a wide range of real-life situations can be observed, in contrast to drama improvisation where a one-day workshop typically includes only two (fictional)

situations. Furthermore the outcome of the workshops depends very much on the individual participants. It is therefore crucial to try and find representative, "average" users. During observational studies all groups of employees can be watched in their daily work. This gives a more complete picture and a better understanding of the context of use. However, it is impossible to "freeze" situations when conducting field studies, and the observers might hold back questions in order to interrupt as little as possible in a busy environment. In the workshops freezing situations and asking questions were perceived as very useful by the system developers.

We believe that both methods presented in this chapter are promising and complementary contributions to requirements elicitation and analysis, not only for hospital information systems but also for a wide variety of complex, sociotechnical systems. Observational studies are particularly useful for gaining knowledge of the domain while drama workshops seem especially important in the introductory phase of a project, in order to create a common ground for the system developers and some of the end users of the system. The drama improvisation approach has also proven advantageous when system developers have little or no knowledge of the domain and when it is inconvenient to perform field studies; for instance, when a project involves a large group of system developers. When combining the methods, field studies can be used to identify situations of interest prior to the drama workshops and to validate situations that have been developed during the workshops, and as such they may reinforce each other's potential.

Both techniques presented in this chapter focus on user requirements elicitation and are not sufficient for producing complete requirements specifications. As previously discussed, the methods are particularly useful for gaining knowledge of the domain in the introductory phase of a system development project, but they must be supplemented by other, traditional, methods for requirements gathering and analysis (for example, questionnaires, surveys, interviews, analysis of existing documentation, prototyping, and so forth).

Acknowledgments

We would like to thank the staff at the University Hospital of Trondheim for their cooperation both during the observational studies and by participating in the workshops. Thanks also to Ann Rudinow Sætnan, Øystein Nytrø, and Dag Svanæs for valuable comments and contributions.

This research was financed by NTNU Innovation Fund for Business and Industry and Allforsk Research.

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Endnote

[1] The project includes members from Department of Computer and Information Science, Department of Sociology and Political Science, Department of Telecommunications, Department of Linguistics, and the Faculty of Medicine at NTNU. MOBEL was initiated in 1999 and since 2003 has been part of the Norwegian Centre for Electronic Patient Records (NSEP) in Trondheim.

Paper C

Context in care - Requirements for mobile context-aware patient charts

This paper appears in *Medinfo 2004 - Proceedings of the 11th World Congress On Medical Informatics*. Studies in Health Technology and Informatics, Vol. 107, pp. 597–601, IOS Press, 2004.

Context in Care – Requirements for Mobile Context-Aware Patient Charts

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Abstract

The hospital ward is a highly dynamic work environment, in which healthcare personnel rapidly switch from one task to another. The process is partly planned, and partly driven by events and interrupts.
A mobile electronic patient chart (MEPC) will be an important tool for supporting order entry and accessing, communicating, and recording clinical information. The users need to switch from one context to another with minimal delay and effort. Context-awareness, the ability to sense relevant situational information, can allow the user interface of the MEPC to adapt to various situations.

In this paper, we present a future scenario from the coronary care unit. This scenario is analyzed and discussed in order to develop requirements for design methods, context models, and system properties of the MEPC.

Keywords

Handheld computers; Point-of-care systems; Computerized Patient Records; Context-Awareness; User-computer interface.

Introduction

Emerging information technology is steadily making patient information more widely accessible to healthcare personnel through the migration of paper based records to computerized patient records (CPR). Due to advances in mobile technology, the CPR can now be accessed by healthcare personnel in a wide variety of situations through mobile terminals. The work activities in the wards can be described as a combination of formal procedures, informal practices, and mobility. Despite the number of clinical situations and tasks handheld computers can be used in, most mobile clinical information systems remain unaware of the situation of use, and do not adapt. Navigating such systems, seeking relevant information, can be a process involving multiple and complex steps.

One answer to these challenges suggests imbuing mobile patient chart systems with *context-awareness* – the ability to sense situational information relevant to the interaction between a user and an application [1]. Most research activity within context-aware computing has focused on sensing and making use of situational information such as *location*, *time*, *identity* and *action* for automating services. This paper argues that more abstract notions of context, e.g. task, roles, and plans, will have to be considered when designing mobile context-aware tools for healthcare personnel in clinical settings.

This paper explores some aspects of the rich "context space" of clinical ward activities, and gives an example of mobile clinical computing that is different from most other mobile application areas. Our contribution is a set of requirements for context models, design methods, and system properties.

To illustrate some of the situations where a future *context-aware* mobile electronic patient chart (MEPC) [2] could be useful, we first present a scenario from the Coronary Care Unit (CCU). After presenting the background and motivation of our work, we discuss some aspects of the health care domain and why designing mobile context-aware tools supporting ward activities is challenging. The example scenario is then decomposed and analyzed in terms of contextual triggers and context information. We discuss requirements for realizing the context-aware MEPC based on the decomposition and analysis of the example scenario.

Example: Coronary care scenario

It is in the afternoon. Dr. Davis is on call and has just arrived at the ward.

Almost immediately she is called upon by nurse Neil (using the MEPC) who asks about patient Palmer's medication – more specifically he asks about the patient's dose of Warfarin (an anticoagulant).

After checking the status of the patient, Dr. Davis is about to enter the medication dose, but then she is called to patient Adams who has had a ventricular tachycardia. She has to go there immediately, leaving the medication of patient Palmer unfinished.

As she is approaching patient Adams, vital information is read into Dr. Davis' earplug from the speech synthesis unit in the MEPC.

While Dr. Davis is working on patient Adams, the alarm goes as patient Taylor gets cardiac arrest. Since Dr. Davis is not available, Dr. Osborn from another ward gets a message on his MEPC. After Dr. Davis is finished treating patient Adams and has arrived in the office, the MEPC automatically displays the unfinished task of patient Palmer's medication.

Background and Motivation

The concept of context has been paid much attention to within research on human-computer interaction. Context information can be used to interpret explicit acts, making communication much more efficient [3]. With the introduction of Ubiquitous computing, the term "context-aware computing" has become a key issue in creating user friendly and efficient systems for computing devices of all sizes and for all purposes. The work of Dey, Abowd and Salber [1] represents in many ways the state-of-art within frameworks for context-aware application development. Additionally, several contributors have supplemented, or focused on aspects of context-awareness not covered in this framework.

Context has been considered as both a representational problem, and a problem concerning interaction [4]. These two separate perspectives on context draw on theories usually associated with positivism and phenomenology respectively. We want to point out that the presented requirements assume that these perspectives are different, and not mutually exclusive.

Recently, context-awareness has also been addressed within the field of health informatics. One example is the Clinical Application Suite (CAS), a multi-tasking software architecture that facilitates the development, deployment, and use of advanced clinical information management applications where the user's context is preserved [5, 6]. The CAS was a precursor for the Health Level Seven (HL7) Context Management Standard specified by the Clinical Context Object Workgroup (CCOW) [7]. The standard describes an architecture (Context Management Architecture – CMA) that serves as a basis for synchronizing and coordinating clinical applications so that they automatically follow the user's context [8]. The CCOW Technical Committee has developed and ratified several versions of the standard, each version adding new specifications. One important area under discussion for a future version of the standard is CCOW/CMA for handhelds, which introduces new and challenging issues.

The report "The Clinical Headings Version 3: Context and Clinical Records" produced by NHS Information Authority has proposed a set of terms to capture the context in which clinical terms are set [9]. These terms were known as the 'context of care' and consist of four groups of terms: Attribution terms, heading terms, status terms, and link terms. The report also describes a formal model of the context terms.

An example of a context-aware clinical system is a prototype of a medicine administration system that has been developed by Centre of Pervasive Computing in Denmark and tested at Aarhus County Hospital [10]. The system is able to register and react upon certain changes of context, such as the presence of a nurse holding a medicine tray for a patient.

The challenges related to design of context-aware tools are multi-faceted. Lack of suitable models and methods, technological issues related to building a context-aware infrastructure, and interaction issues [1] represent challenges which have to be met. Below, we present important issues directly related to design of context-aware tools for clinical settings. These issues have been a central motivation for this paper.

Health care is knowledge intensive: Health care is to a large extent knowledge-driven. Knowledge is seldom an explicit attribute such as location, time or identity. Tacit knowledge, for example, may be difficult to describe and utilize. Intuition is an example of implicit knowledge which plays an important role in healthcare personnel's decision making [11].

Context-aware applications generally make use of explicit and static information, where the detected context information triggers one specific service. These assumptions are not valid for applications supporting health care. It is easy to get context-information wrong, even when building sophisticated context-aware applications. This could have fatal consequences in clinical settings.

Ward activities are situation-driven: Ward activities are also driven by sudden and often unforeseen events, such as the incidents referred to in our example scenario. Determining in advance which services to trigger under which circumstances may prove difficult. Even discovering the right triggers for a specified event are sometimes a non-trivial matter.

Aspects of context in care

Dey, Salber and Abowd defines context as: "Any information that can be used to characterize the situation of an entity, where an entity is a person, place, or object that is considered relevant to the interaction between a user and an application, identity and state of people, groups and computational and physical objects" [1]. In our setting, the entity the chart user. The context also includes information about relevant record content, reminders, orders, or requests.

Formally, we can look at a context as a database of facts that hold in a certain situation. It is this database that a context-aware system will sense, and react on. The database can contain facts about the physical world, user actions, and other information. For any context, there exists a hierarchy of more general contexts, each with less (specific) information. Guha and McCarthy [12] have described various context models according to the lifting (generalization) rules that they employ. For now, we only need a basic understanding of more and less general contexts.

A context will obviously change as things happen in the information system and the real world. Such a proceeding of contexts will be called a context pathway. However, we also want the user to change the context explicitly, i.e. navigate by contexts. For example, the user should be able to:

- Change to a partly specified context that has occurred.
- Spool backwards through a pathway of contexts.
- Jump to any, partly specified, preprogrammed, or explicitly chosen context.

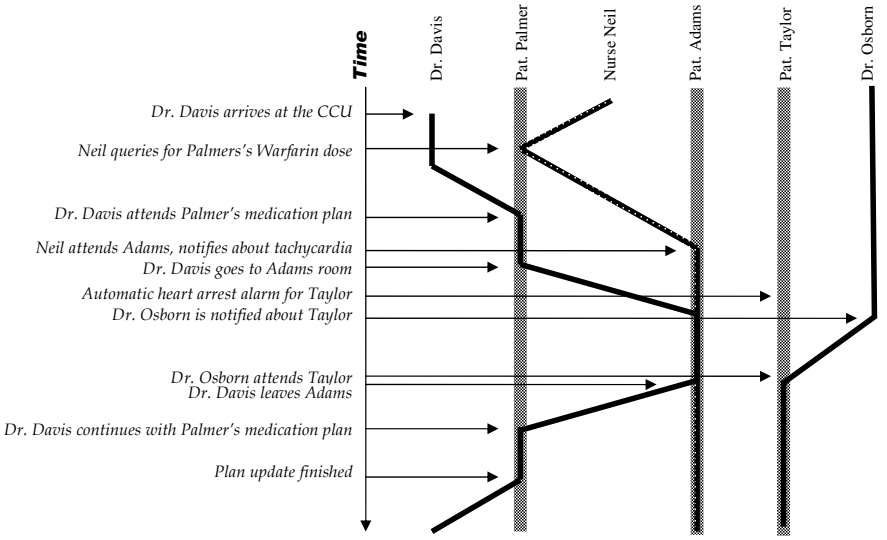

Figure 2 - Context pathways in ward example

- Send a reminder to someone with an attached context.
- Predetermined reminders can be regarded as part of the context.
- Regard choosing a patient in a menu as conceptually the same as walking close to the patient.
- Block certain (disturbing, irrelevant) context elements.
- Search for contexts.
- Switch to the context of another role at a specific point in time.
- Switch between contexts, stack them, and assign priority.

Explaining the example scenario

Returning to our ward example, figure 1 depicts the context pathways of different persons in the ward. We assume that all healthcare personnel have MEPCs connected to an advanced clinical information system with plans, reminders, and sufficiently rich record representation. The narrative underneath gives an outline of context changes, events, notifications, and the behavior of the user interface for Dr. Davis' MEPC.

1. Time, identification, location
It is in the afternoon. Dr. Davis is on call and has just arrived at the ward.
As she arrives at the ward, she logs onto the information system. Based on current time (start of the shift), her role and identity, and the location (CCU), the display of the MEPC shows a list of patients that are new to Dr. Davis, new test and examination results for already known patients, and other relevant information.

2. Notification, identification, context change
Almost immediately she is called upon by nurse Neil who asks about patient Palmer's medication – more specifically he asks about the patient's dose of Warfarine (an anticoagulant).
The query from the nurse is in form of a standard request for an assessment. The context of the assessment consists of an identification of patient Palmer, and the relevant part of his medication plan for Warfarine that nurse Neil was studying on the MEPC when sending the request. Dr. Davis is notified by the request (being part of her context). She accepts it, and immediately changes to the context that nurse Neil had when sending the request. Dr. Davis' former context is pushed, and can be resumed at a later stage. Her actual decision with regard to Warfarin depends on several factors, for instance, the diagnosis of the patient (e.g. atrial fibrillation or deep vein thrombosis), if the patient is set up for surgery, and new blood test results. All this information is automatically shown on her MEPC.

3. Notification, identification and context change
After checking the status of the patient, Dr. Davis is about to enter the medication dose, but then she is called to patient Adams who has had a ventricular tachycardia. She has to go there immediately, leaving the medication of patient Palmer unfinished.

Yet another predefined request is issued by monitoring equipment, or by nurse Neil. This time the request only refers to the context of the apparatus, i.e. physical location. The MEPC may find out who the patient is from background knowledge.

4. Task, identification
As she is approaching patient Adams, vital information is read into Dr. Davis' earplug from the speech synthesis unit in the MEPC.
Dr. Davis accepts the request and the MEPC switches context appropriately. If the patient is known, new or relevant information may be displayed or read through her earplug.
Along with the alarm, important patient information (e.g. name, location, date of birth) and the tachycardia procedure is shown.

5. Task – role filtering of request
While Dr. Davis is working on patient Adams, the alarm goes as patient Taylor gets cardiac arrest. Since Dr. Davis is not available, Dr. Osborn from another ward gets a message on his MEPC.
The system detects that Dr. Davis is busy helping patient Palmer. The request is routed to Dr. Osborn from another ward, who is the nearest available doctor on call.

6. History reminder, location
After Dr. Davis is finished treating patient Adams and has arrived in the office, the MEPC automatically displays the unfinished task of patient Palmer's medication.
Dr. Davis gets a reminder about the unfinished medication task.

Based on the decomposition of our scenario, the proposed underlying MEPC system seems to fit its purpose in terms of ward activity supportive context functions. Communication between healthcare personnel is supported (messaging), as well as coordination of activity (alarm routing, reminder function). In other words, from a system perspective the proposed MEPC system might seem to meet all the requirements we have discussed.

Requirements for context models

In addition to the basic features of a context model from the user's point of view, some global system requirements must be met in order to have a sound and safe system:

1. All important information must be visible in some context within reasonable time.
2. Reminders must be captured and handled within a reasonable time limit: The higher priority, the shorter delay.

Requirements for design

In order to discover which context information is essential for healthcare personnel, and in what way the specific context information is used, deep insight into daily ward activities is necessary. Design methods which are characterized by a high degree of user involvement, such as user-centered design is therefore appealing. Especially, iterative design where the users take part of all stages, like within the Scandinavian tradition, is a promising alternative within system design [13]. Techniques like role-playing can be used to explore important aspects of mobility and the role mobile electronic tools play when they are introduced in an activity. Such techniques may also prove valuable for designers of mobile context-aware tools in clinical settings, especially during the early phases of requirements gathering.

System properties

The following system functionalities represent the most important considerations to be taken into account when designing mobile context-aware tools for healthcare personnel.

1. Caution concerning automatic execution of services
Greenberg [14] suggests that context-aware systems generally should be "fairly conservative in the acts it takes". This principle certainly holds for context-aware tools supporting ward activities. In particular, services the system can perform which directly concern the treatment of the patient should always be confirmed by the authorized healthcare personnel before execution. As a result, the context-aware functions related to a MEPC should focus on supporting *presentation of information* and *attachment of context information for later retrieval* as described in the conceptual framework of Day, Abowd and Salber [1].

2. User control
User control does not simply imply that the user should be notified, or that he should have to confirm every action the system intends to take. Rather, for seamless integration with day-to-day ward activities only potentially "risky" actions should have to be explicitly confirmed by the user. An additional aspect of user control is giving healthcare personnel the option of configuring both the user interface and context-aware functions of the MEPC.

3. Coordination of perspectives
By giving healthcare personnel the option of configuring the user interface and context-aware functions, there is also potential danger which calls for special attention. Enabling the individual user to put his perspective on "the world", may result in that some context information filtered out by everyone at the same time. Consequently, information concerning a patient may be lost. If every member of a care team, for example, is able to disable all notification regarding a certain patient, the result could obviously be disastrous. An important system property is therefore to support coordination mechanisms guaranteeing that no information remains "unseen" by all healthcare personnel simultaneously.

4. Navigating in context
A MEPC that is aware of its own location, as well as surrounding healthcare personnel, patients, and medical devices allows location-based automatic or user-controlled navigation in the

patient chart. This may be supplemented by physical actions like scanning tags on a particular patient.

Tagging of information for later retrieval is a central function for many context-aware devices. Time-stamping information in itself, however, does not make the MEPC more user-friendly. The MEPC should provide means for navigating between different chart contents classified according to episodes of use, for example location, activity, roles, and other context attributes. Important parts of gathering requirements are to discover and classify relevant episodes of use. The MEPC could even allow for healthcare personnel to define their individual classification of episodes.

Conclusion

We have discussed various requirements for realizing a mobile electronic patient chart (MEPC) which can sense and utilize different sorts of context. In order to illustrate the rich "context space" of clinical settings, an example scenario from the Coronary Care Unit was explained and analyzed in terms of context changes, events, notifications, and the behaviour of the MEPC user interface. The analysis points out particular requirements on context models, design, and system properties for the context-aware MEPC. We have elaborated on these requirements to make them usable for designing mobile devices that support healthcare personnel in a user-friendly, efficient and safe way.

Acknowledgments

This work was supported by Telenor R&D and NTNU Innovation Fund for Business and Industry.

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Paper D

Does the EPR support the discharge process? A study on physicians' use of clinical information systems during discharge of patients with coronary heart disease

This paper appears in *Health Information Management Journal*, Vol. 34, no. 4, pp. 112–119, 2005.

Reviewed articles

Does the electronic patient record support the discharge process? A study on physicians' use of clinical information systems during discharge of patients with coronary heart disease

Inger Dybdahl Sørby and Øystein Nytrø

Abstract

This study has been performed in order to categorise and measure usage of different information sources and types in a well defined stage of clinical work. The underlying motivation is to improve computer-supported presentation and retrieval of relevant information and to be able to evaluate the functionality of a future improved interface to the electronic patient record (EPR). By observing 52 discharge processes and categorising information types and sources, we have observed that the paper chart is used as a primary source of information about recent events and procedures, while the EPR is mostly used for retrieving background information and verification. Direct communication with other clinicians and the patient is also important during the discharge process. Results from an additional survey show that the physicians report greater use of the EPR than the result from the observational study. The study clearly indicates that there is a large potential for improved EPR systems that support the physicians in their work regarding discharge of patients, especially in the future planning part of the discharge.

Keywords*: Computerised medical record systems; patient discharge; discharge planning; observation*

This paper describes a study that was conducted in order to investigate to what extent clinical information systems – in particular, the electronic patient record (EPR) system – support clinicians in critical and information intensive tasks such as patient discharge. The study was performed at a Norwegian university hospital in 2004. The underlying motivation behind the study was to improve computer-supported presentation and retrieval of relevant information and to be able to evaluate the functionality of a future improved interface to the EPR. By studying how and where relevant information is represented in current clinical information systems, and the cost of retrieving that information, an impression can be gained of how the EPR system supports – or does not support – the physicians in a specific situation. This study is a step towards a more complete survey of information usage in several clinical situations, which is necessary when developing future situation-aware and user-friendly interfaces to clinical information systems.

EPR systems and other electronic information systems are extensively used in Norwegian hospitals, although as yet only a few hospitals are 'paperless' and paper based information systems are essential in most patient-centred work (Lærum, Ellingsen & Faxvaag 2001). The most obvious reasons for the limited use of EPR systems are that today's systems do not support the healthcare workers' real needs because the systems are not always available, they are not integrated with other clinical systems, they do not support the clinical procedures performed by the different healthcare workers, and they are not context sensitive or adaptable to individual needs (Dahl, Sørby & Nytrø 2004; Sørby, Melby & Nytrø 2002).

In order to be able to develop better EPR interfaces that really support physicians in their patient-centred work, it is necessary to investigate how current information systems are used. This is complicated and time-consuming, as every physician has his or her own working style or pattern, and each patient has an individual investigation and treatment plan based on their condition, previous illnesses and other important factors. However, at least two stages of a hospital stay are to a certain degree well defined and predictable; hospital admission and discharge. In this study, we focused on the discharge of patients in one particular hospital ward. The discharge process includes preparations and writing a preliminary discharge summary, the physician then conducts a discharge conversation with the patient, and finally writes or dictates a concluding discharge summary. The discharge summary serves as a basis for further treatment and follow-up of the patient when transferred from hospital specialist to primary care. The quality and content of discharge summaries have been discussed in several studies (Archbold et al. 1998; Solomon, Maxwell & Hopkins 1995; van Walraven & Rokosh, 1999; Wilson et al. 2001). However, few systematic evaluations to investigate to what extent EPR systems and other clinical information systems are used in the discharge process have been performed.

The underlying research questions of the study were:

1. To what extent does the EPR system support the physicians in the discharge process?
2. Is the physicians' work, in relation to the discharge of patients, characterised by regularity?
3. What areas of the discharge process can be improved by appropriate computer support?

Our main hypothesis was that the EPR system does not satisfy the physicians' information needs during the discharge process, and thus is not preferable to other information sources. We also presumed that the discharge process to a certain extent is characterised

by regularity. Our third hypothesis was that certain areas of the discharge process can be improved by appropriate computer support.

Method

The study was carried out in the Department of Cardiology at a large Norwegian university hospital (922 beds) during the period March to September 2004. The first part was an observational study of physicians' work regarding discharge of patients, including preparations and writing a preliminary discharge summary, conducting discharge conversations with the patients, and dictating final discharge summaries. Every physician working in one particular ward (15 beds) during the study period participated in the observational study. This ward takes care of patients suffering from coronary heart disease. Most of them are undergoing extensive heart examinations such as percutaneous coronary intervention during their hospital stay. The patients who were followed in this study were mainly suffering from angina pectoris or heart failure, and the investigation of their heart disease typically led to hospital stays of three to five days.

Several information systems, both paper based and electronic, are used in this ward. The most important paper based systems are the patient chart and the patient record.

The *patient chart* is a binder that contains the most essential information regarding the current hospital stay of one or several patients in the ward, such as printouts of the most recent laboratory and test results, medication charts, and plans for further treatment (Ellingsen & Monteiro, 2003; Sørby, Melby & Nytrø 2002).

The patient record contains old information about previous hospital stays. Other paper based systems are reference books such as *Physician's Desk Reference* (PDR) and *ICD-10 codes overview*, *personal notes*, and *patient lists.* The main electronic information systems include the EPR system, the Patient Administrative System (PAS), an integrated interface to a Picture Archiving and Communications System (PACS), Laboratory Information Systems (LIS), and various specialist systems.

The observations were conducted by two medical students who performed non-participatory observations of physicians during the discharge process. The medical students were interested in medical informatics, but they had little or no prior research experience.

The observational study was followed up by a survey distributed to every physician at the Department of Cardiology, totalling 30-40 physicians. The survey was carried out in order to validate the results of the observational study. The survey is further explained below.

Observational study

The observational study (also described in Sørby et al. 2005) took place during the period of March to June 2004. The participants included two chief physicians with many years of experience in the ward, three medium experienced senior residents, three newly hired assistant residents, and one young house physician. Both male and female physicians were among the participants.

A total of 52 discharge processes were studied, and the observers spent 100 hours in total in the hospital ward. The medical students followed one physician at a time, observing the physician's work concerning the discharge of patients. During the first week of the study, the two medical students observed 10 discharge processes together in order to coordinate their observation notes and to agree on a standard for the remaining observations. The observers used a note-taking form partly based on a form described in a textbook on task analysis for interface design (Hackos & Redish 1998: pp. 270-271). The form was changed twice during the study, based on the students' experiences and feedback. The changes of the form only led to easier note-taking for the students, and had no effect on the content or the quality of the resulting observation forms.

The first main part of the form included nine columns; one for each known/expected information source. The sources were paper based and electronic patient records, the patient chart, ICD-10 code overview, X-ray reports or pictures (including other picture results such as CT and MR), PAS (not integrated with the EPR), PDR, colleagues, and patient. Personal notes were an important additional information source for some physicians. During the observations, the appropriate table cells were marked 'X' with an exception for the ICD-10 codes and the PDR which existed both on paper ('P') and electronically ('E'). In addition, the columns marked 'Supplementary information' could be used if several sources were used to find, control, verify, or check consistency of some information. In order to focus on patient-specific information, and eliminate regular use of static reference tools, we have omitted PDR and ICD-10 usage from the further analysis.

The second main part of the form was used to describe the information that was retrieved from the selected information source. The last main part included a field for the observers' personal comments or questions, as it is important to separate their own thoughts and interpretations from the 'objective' observations noted in the 'Information' column (Hackos & Redish 1998). The forms were filled in chronologically, from top to bottom. In addition to the notes taken by the observers, a few of the discharge processes were videotaped for further analysis.

The contents of the 52 observation forms were coded into matrices (one matrix per observation) containing information sources versus information categories. In order to ensure consistency, one of the students performed the coding of all the observation forms. The information categories were adapted from a discharge summary template suggested by the Nor-

1: Distribution of total number of information elements retrieved from human, paper based, and electronic information sources

	Information sources			
Information categories	**Human** (Doctors, nurses, patient)	**Paper based** (Record, chart, notes)	**Electronic** (EPR, X-ray, PAS)	**Sum**
Patient administrative information: biographical data, family/social history	34	72	15	121
Past clinical information: allergies, previous illnesses, reason for referral	18	55	23	96
Present clinical information: diagnosis and procedure, progress and treatment, findings and examination results	17	164	61	242
Future clinical information: assessment, follow-up, medications, info to next of kin, medical certificate	82	121	26	229
Other: unanswered tests, function level	2	1	0	3

wegian Centre for Informatics in Health and Social Care (Ree 2002). During analysis of the results, most of the information categories were divided into four disjunctive groups of different temporal significance:

- *Future clinical information*: Information that pertains to plans and future patient care. This group contains the categories Assessment, Follow-up, Medications, Info to next of kin, and Medical certificate.
- *Present clinical information*: Information about current state and hospital treatment. This group contains the categories Diagnosis and procedure, Progress and treatment, Findings and Examination results.
- *Past clinical information*: Historic/permanent patient information. This group contains the categories Allergies, Previous illnesses, and Reason for referral.
- *Patient administrative information*: Information not related to the patient's current hospital stay: biographical data and family/social history.

Survey

In order to validate the findings from the observational study and to gain insight into potential differences between perceived and actual use of different information sources during the discharge process, a survey was distributed among the physicians at the Department of Cardiology shortly after the observations were finished. The survey consisted of a few questions on one page and a form similar to the form used in the coding of the observations. The questions were:

1. Position (Head Physician, Resident or Other).
2. Working experience (Number of years/months at department of cardiology, Number of years/months at any hospital).
3. Did you participate in the observational study? (No, Yes, 1-3 times or Yes, more than 3 times).
4. Do you have any general comments regarding the EPR system or other clinical information systems that are used at your workplace?
5. Do you use a determined procedure or sequence in your work regarding discharge of patients, and do you experience that the available information systems are supporting these tasks?
6. What sources do you use when you gather various types of information in relation to discharge of patients (including preparations, discharge conversations, and discharge summaries)? (Values: 0 [never] 1 [sometimes], 2 [often]. The values were plotted into tables consisting of information types versus information sources).

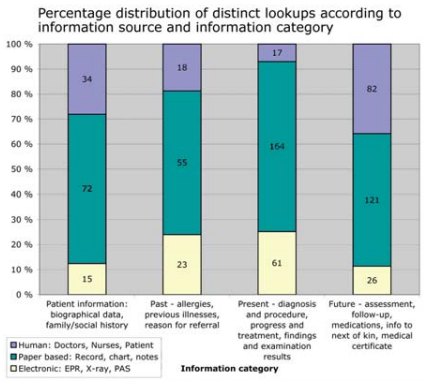
Appendix A shows an example of a survey response (translated from Norwegian).

The survey was distributed by email to every physician at the department. The physicians could fill in and deliver the survey electronically or on paper. The survey was also presented and distributed at a morning meeting where the chief physician urged the other physicians to respond to the survey. The time usage for filling in the survey was estimated to be approximately 10-15 minutes. After the first distribution of the survey, seven physicians responded. The survey was once again mentioned at the department's morning meeting and re-distributed by email in September, which led to another nine answers. In total, the survey was distributed to between 30 and 40 physicians (the exact number of recipients is not known due to the rotation scheme of the residents and the house physicians, and hence corresponding variations in the email lists at the time of the initial distribution and the re-distribution and reminders).

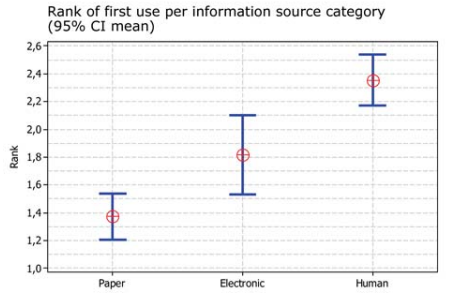
Results

The results from the observational study are presented below according to information categories and sources, followed by the survey results.

2: Percentage distribution of information elements retrieved from human, paper based and electronic information sources



3: Mean rank of first use per information source category



Observational study: information categories

During the 52 discharge processes, a total of 735 information elements were identified, 688 of these were patient specific and belonged to one of the four information categories mentioned in above. Appendix B shows the total numbers of information types versus information sources. Box 1 shows the distribution of the information elements categorised in the three groups of information systems: human, paper based, and electronic. Box 2 shows the relative distribution of the information elements retrieved from the different information sources.

Observational study: information sources

The EPR was used as an information source in 27 of the 52 observed discharge situations, while the patient chart was used in 51 of 52 situations. The number of sources used in the discharge processes varied from one to nine (average: 3.77 sources), while the number of information elements varied from only two to 25. By analysing the sequences of first time usage of each information source type (i.e., paper based, electronic or human) for every observation, we were able to calculate mean values for each of the information source types. The resulting numbers are shown in Box 3. The results of this analysis show that paper based information systems were most often used as primary sources (average rank: 1.37), while the electronic sources were often used as secondary sources (average rank: 1.82), for example, when the physicians could not find the expected information in the available papers. To what extent the electronic information sources were used varied a lot, depending on the individual physicians. The younger physicians showed a tendency to use the EPR as a primary information source more often than the more experienced and older physicians.

The human information sources were mainly used as third choice (average rank: 2.36), often in order to verify data collected from other information sources.

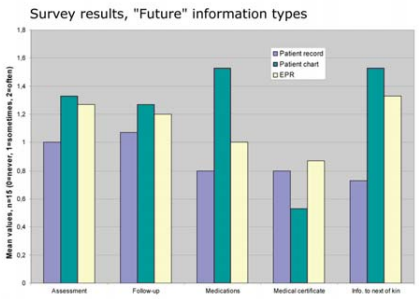
Survey results

A total of 16 physicians responded to the survey; among them where eight head physicians and eight residents. Seven head physicians and eight residents completed the survey. One additional head physician responded but reported that he had not been involved in the discharge of patients lately and hence did not complete the survey. Eleven of the respondents had not participated in the observational study, one head physician had been observed between one and three times, and three of the residents had been observed more than three times. The residents had been working in the department between three months and two years, while their clinical experience varied from one year to 10 years. The head physicians' experience in the specific department varied from five to 20 years.

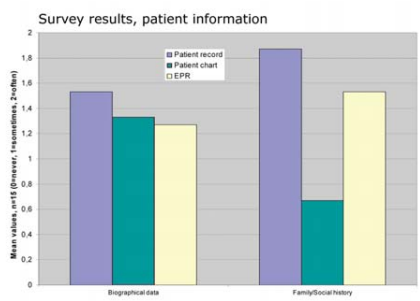
The answers to questions four and five of the survey varied to some extent. To summarise, the physicians were mainly satisfied with the EPR system when it works as intended. However, most of them found it cumbersome and time-consuming that different systems like PACS systems and the EPR are not integrated and hence they need to switch between several systems to get access to all relevant information about one patient. A few of the respondents reported that they did not use the system much because they already knew most of the important information and/or the nurses printed out the necessary information from the various information sources prior to the discharge process. Most of the physicians reported that to a certain degree they use a fixed procedure when discharging the patients, but only two of the respondents answered whether the available information systems support the discharge process. The answer to this question was respectively 'sometimes' and 'yes'.

The results of question six were summarised in one table. Some of the findings from this question are shown in Boxes 4 and 5. Box 4 shows the mean values of the physicians' responses regarding future clinical

4: Survey results: mean values of physicians' use of patient record, patient chart and EPR for retrieving future clinical information



5: Survey results: mean values of physicians' use of patient record, patient chart and EPR for retrieving patient administrative information



information types while Box 5 shows the corresponding patient administrative information types.

Many of the physicians completing the survey reported that they used the EPR system often (value 2) to find most of the relevant information types. Some also reported surprisingly little use of the patient chart.

Discussion

The study presented in this paper was performed in order to investigate how physicians, exemplified by cardiologists, use various information sources in the patient discharge process. All the patients in the study had been treated for similar heart diseases, such as angina pectoris or heart failure, but there were large variations in their previous medical histories and thus the volume of the patient records and, for instance, the extent of medication of each patient. Consequently, these factors had implications for the complexity of the physicians' work regarding the discharge process. This is clearly shown in the individual observational notes, as they vary from only two information elements to 25. The results of the observational study show that *Patient administrative information* is almost constant, and has surprisingly low reliance upon electronic sources (12%); the main sources for this information type are the paper record and chart. The high percentage of human sources can be interpreted as need for validation of information (and patient identity). Historic patient information (*Past clinical information*) is mainly taken from paper sources, which is costly and difficult to find in old, and often large, records. The paper chart is obviously the most convenient source of *Present clinical information*, in addition to actually remembering the patient and the course of actions. Human sources are surprisingly little used, even if they are easily available. There is considerable variation in work style; we have seen an effect of physicians writing personal notes, later used in addition to chart and other tools. Much of the *Future clinical information* is about plans regarding future treatment and medication (involving colleagues and the patient), and the necessary assessment and decisions are often made during the discharge process. We have also seen that development of medication plans and prescriptions involve searches in *many* separate sources that frequently are inconsistent and incomplete (Rognstad & Straand, 2004).

Due to the limited time during which the students performed the observations, not every observation included the entire discharge process. Most of the observations, however, included the physician's preparation for the discharge conversation, including writing a preliminary discharge summary. Most observations also included the discharge conversations, but due to time pressure of the physicians, the final discharge summaries were not always written immediately after the discharge conversations, and hence some observations do not include the writing and dictating of these summaries. However, this also means that some discharge summaries were written separately, some time after the patient left the hospital and possibly by a different physician from the one who performed the actual discharge of the patient. A few of these situations were also observed and are included in the analysis.

The nine physicians that participated in the study varied in age, gender and experience, both as clinicians and in the specific ward. Every physician had his or her own established working pattern, and this varied a lot from individual to individual. In similar studies, prospective participants have been excluded if they had less than, for instance, one month of experience in the ward being studied (Brown, Borowitz & Novicoff 2004). In our study, however, no such exclusion criteria were used, as we regard physicians with little experience of particular interest since they are even more dependent on appropriate information systems than the more experienced physicians. Even though the number of physicians participating in the study is limited, the sample is fairly representative as it included every physician working in the specific ward during the observational study period.

The quality of observational studies depends to a large extent on the observers; their knowledge of the

domain, and their ability to transform the observations into data and written information that can be analysed. The subjects being observed might also be affected by the presence of the observers. However, by using medical students as observers, the intention was to minimise this problem, as the physicians are used to being followed by students and house physicians. The note-taking form that was developed prior to and iterated during the study helped the students in structuring their observations, and at the same time it allowed for comments and questions that could be discussed later.

The physicians completing the survey reported that they used the EPR often to find most information types. Some also reported little use of the patient chart. This corresponds poorly with the more than 50 observed discharge processes where the patient chart is used in approximately 50 percent of the enquiries and the EPR in only about 10 percent. The main reasons for this discrepancy might be related to the design of the survey and the physicians' personal interpretations of the questions. This is also one of the reasons why using surveys as a means of evaluating the use of information systems is difficult. One example of this is when the value 2 ('often') is used for the information source EPR; does this mean that the physician often used the EPR system to find information, or that a nurse had done it and printed the information, or that the physician thought that he or she has used a lot of *time* to find information in the EPR system? Another aspect that needs to be taken into consideration when comparing the results of the survey and the observational study is that only four of the survey respondents had participated in the observational study, and so it is only possible to use the survey as an additional source of information regarding the physicians' use of the various clinical information systems.

Despite the weaknesses in the methods used in the study and the dissimilarities between the observational study and the survey mentioned above, the analysis of more than 50 different discharge processes gives a good impression of how the various information sources are used in the discharge process at the Department of Cardiology. Even though this is a very limited study performed in only one hospital ward, this department is one of the most complex departments in the hospital, characterised by high activity and large variations in the patients' illness patterns; it is thus expected to be fairly representative of Norwegian hospital departments. At the time of study, all main regional hospitals in Norway used the same EPR system product.

The analysis of the results has so far not been used for more qualitative descriptions of the discharge process. However, the analysis clearly shows that the EPR and other clinical information systems are not integrated into the clinical practice, as they are still not preferred to paper based systems even if they are available and contain the needed information. This means that there is an obvious need for improved user interfaces to these systems that would make it easier for the physicians to retrieve and produce relevant information when preparing and performing the discharge of patients.

Conclusion

Our research hypotheses were to a large extent confirmed. The analysis of the observations shows that today's EPR system is not preferable to paper based information systems, as the current EPR system was not designed to support the discharge process in particular. The analysis also shows that the discharge process is predictable to a certain degree, but with large individual variations due to different working patterns of the various physicians, and also due to large variations in the patients' illness histories. This was also confirmed by the survey results. We have seen examples of discharge processes where the physician has known the patient well and most information has been retrieved from the physician's memory, while other situations have required the physician to search for information in up to nine different information sources. A new and improved EPR system would be preferred by every physician in every discharge situation in order to provide the most recent and correct information; hence it has to be simple and easy to use but also flexible and adaptable in order to support the different working styles of individual users.

Acknowledgments

We would like to thank the staff at the Department of Cardiology at the University Hospital of Trondheim for their cooperation during the study. This research was financed by the strategic research area Medical Technology (<http://www.ntnu.no/medtek>) at NTNU and the NTNU Innovation Fund for Business and Industry (<http://www.ntnu.no/idefondet/>).

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Appendix A: Example of survey answer (translated from Norwegian)

Survey: Physicians' use of various information sources in discharge of patients

Completed surveys can be delivered to *<person>, <place>*

1. Position and ward:

Resident	X
Chief physician	
Other (please specify)	Changed department in May

2. Working experience:

Number of years/months at dept. of cardiology	8 months
Number of years/months at any hospital	2 ½ years

3. Did you participate in the observational study?

No	
Yes, 1-3 times	
Yes, more than 3 times	X

4. Do you have any general comments regarding the EPR system or other clinical information systems that are used at your workplace? (Keywores: Satisfied/not satisfied, reasons why the systems are much/little used etc.)

Electronic record is practical. But it is very bothersome that one has to log into four different programs to get information about one specific patient (The Laboratory answers program rarely function via DocuLive). Useful to have ICD-10 codes electronic.

5. Do you use a determined procedure or sequence in your work regarding discharge of patients, and do you experience that the available information systems are supporting these tasks?

Generally quite similar sequene. I use a lot of information that is available on paper at preparation for discharge (patient chart). Practical and good quality assurance to be able to get x-rays answers directly via the computer.

Please turn the page and fill in the table on the other side

6. What sources do you use when gathering various information types in relation to discharge of patients (preparations, conversation and discharge summaries)? Values: **0** (never), **1** (sometimes), **2** (often).

Information sources⇒ / **Information type ⇓**	Patient record (paper based)	EPR	Patient chart	ICD-10 codes (paper based)	ICD-10 codes (electronic)	ICD-10 codes (persoal list)	Wise-Web/ PACS	PAS (patient administrative system)	PDR (paper based)	PDR (electronic)	Collegues	Nurses	The patient	Personal notes
Biographical data	2	1	1										1	
Diagnosis and procedure	2	2	2		2	2	2				2	1		1
Allergies	2	1	2										2	
Previous illnesses	2	2	2										1	
Family/social history	2	2											1	
Reason for referral	2	2	2										2	
Progress and treatment	2	2	2								2	1	1	1
Unanswered tests (absent answers to relevant tests/examinations)							2				2			2
Functional level												2	2	
Findings and examination results	2	2	2				2				1			2
Assessment	1	2	2								2		2	
Plans for follow-up														
Medications		2	2										2	
Medical certificate													2	
Information to next of kin		1	1								1	1	2	
Comments: (The reason why some sources are used little, specific types of information that require searching many sources, other comments)	Expert knowledge, judgement, holistic evaluation, talks/discussions during rounds and at morning meetings/heart meetings/x-rays meetings are also important in the process.													

Thank you for finding time to complete the survey!

Reviewed articles

Appendix B: Total distribution of information types versus information sources

Information types	Information sources: Patient record	EPR	Patient chart	ICD-10 (p)	ICD-10 (e)	X-ray	PAS	PDR (p)	PDR (e)	Colleagues	Nurses	Patient	Notes	ICD-10 (personal list)	Sum	%
Biographical data	2	11	58	0	0	0	0	0	0	0	1	22	0	0	94	12.8
Diagnosis and procedure	3	8	12	15	6	0	0	1	0	2	0	0	1	6	54	7.3
Allergies	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0.1
Previous illnesses	14	15	18	0	0	0	0	0	0	0	0	14	0	0	61	8.3
Family/social history	3	4	9	0	0	0	0	0	0	0	0	11	0	0	27	3.7
Reason for referral	4	8	18	0	0	0	0	0	0	0	0	4	0	0	34	4.6
Progress and treatment	3	22	52	0	0	0	0	0	0	1	0	10	0	0	88	12.0
Unanswered tests	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0.1
Functional level	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0.3
Findings and ex. results	1	10	92	0	0	12	9	0	0	4	0	0	0	0	128	17.4
Assessment	0	7	15	0	0	7	0	0	0	7	0	1	0	0	37	5.0
Follow-up	0	5	8	0	0	0	1	0	0	5	0	23	0	0	42	5.7
Medications	7	6	88	0	0	0	0	16	0	8	0	34	0	0	159	21.6
Medical certificate	0	0	2	0	0	0	0	0	0	0	0	3	1	0	6	0.8
Info. to next of kin	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.1
Sum	37	96	374	15	6	19	10	17	0	27	1	125	2	6	735	99.8
%	5.0	13.1	50.9	2.0	0.8	2.6	1.4	2.3	0	3.7	0.1	17.0	0.3	0.8	100	

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Paper E

Empirical Grounding of Guideline Implementation in Cooperative Clinical Care Situations

This paper was presented at the workshop *AI Techniques in Healthcare: Evidence-based Guidelines and Protocols* held at ECAI 2006, Riva del Garda, Italy, 29th August, 2006.

Empirical Grounding of Guideline Implementation in Cooperative Clinical Care Situations

Inger Dybdahl Sørby and **Øystein Nytrø** and **Thomas Brox Røst**[1]

Abstract. Clinical practice guidelines and protocols are designed in order to fulfill the goals of EBM and to achieve best practice in care and treatment. These idealized decision process models present a highly abstract view of actual clinical practice. In this paper, we discuss how methodical observations of clinical care situations and trajectories of care activities can be used to study and improve guideline *implementation*, the process of transforming a guideline into a plan for clinical work. This is a step towards an ideal empirically grounded guideline lifecycle. We present a framework and concepts for representing observable attributes of situations, actors and action trajectories. The example data that are presented in the paper are taken from an observational study at a local hospital.

1 INTRODUCTION

Guidelines and protocols based on evidence based medicine (EBM) and other knowledge of best practice in care and treatment promise increased quality and efficiency of care. However, guidelines are idealized models of decision processes, based on a highly abstracted view of actual practice. In a real hospital ward, the decision processes involve different roles and persons, multiple information systems and sources, intertwined care activities and often complementary goals. Guidelines are only relevant if they can be enacted and transformed to reality. Vice versa, a guideline can only be validated if its intention, or meaning, can be expressed in terms of observable effects. We believe that decision support in ward situations is highly situation-dependent. In order to describe information needs and computer support, we have developed, used and validated various methods and frameworks for observing and characterizing care situations and trajectories of care actions. The overall goal of this paper is to enable empirical development and validation of guidelines. Towards this goal we have developed:

- Methods for observing complex care situations.
- Frameworks and concepts for representing observable attributes of situations, actors and action trajectories.

2 BACKGROUND

Clinical practice guidelines (CPGs) and protocols are usually based on EBM and 'gold standards', with the goal of indicating the decisions and tasks most appropriate for optimizing health outcomes and controlling costs[9]. However, recorded evidence is only one of many factors in the clinical decision making process. The nature of clinical decision-making has changed from being an individual activity to a task shared by several (human and other) agents who are able to communicate with each other[5, 2].

A. ten Teije et al. [18] describes a challenge for future relevance of guideline supported work:

> Enhancing the adherence to guidelines by supporting them with computerised tools aiming at integrating the guidelines more in the daily workprocesses of practitioners.

One response to this challenge is to try to understand the process from the practitioners point of view. The practitioner is able to distinguish between aspects of clinical care on different levels:

Intentional aspects, which includes clinical, medical, patient and organizational objectives, as well as abstract notions of effects, goals, indicators [13].

Behavioural aspects, which embodies practical, clinical work performed alone or in a team, related to a specific patient and with local adaptation and resource bounds [12].

Social and organizational aspects, which encompasses knowledge about individuals, processes and organizational cooperation [3].

Clinical practice in a hospital ward is a far cry from the verifiable and formalized rigor of a clinical guideline. For the purpose of this paper, we introduce the *plan* as the *implementation*, or instantiation, of one or more guidelines that is relevant for a patient, and which eventually is acted out, or realized, by real people on real patients. A guideline, however executable, does only exist in a book, a computer or peoples heads.

We are interested in the mapping between a guideline and a plan, and the most fruitful path of attack is to observe the activities of clinical work that may be attributed to a plan, and correspondingly, to a guideline.

Figure 1 depicts how clinical reality realizes a plan, and how the plan is an implementation of a guideline, which in turn achieves a set of objectives. Concepts defining the different levels of abstraction are listed underneath, and the three transformations between the levels are described by corresponding verbs.

3 METHODS: OBSERVING CLINICAL SITUATIONS

To be able to characterize cooperative situations in a repeatable and efficient way, we have developed a series of frameworks for structured observation and documentation of properties of situations, actors, interactions and processes (see [14, 15]). The objectives in developing these frameworks have been to concentrate on observable

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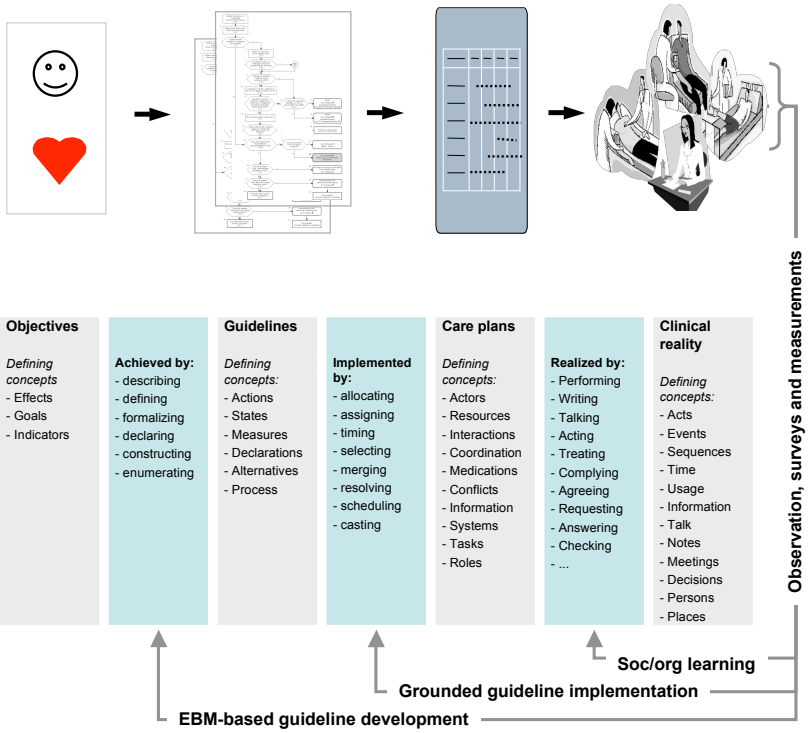

Figure 1. Clinical reality realizes a care plan, which implements a guideline, that achieves a set of objectives

characteristics of clinical situations, instead of implicit characteristics and concerns like efficiency, failures, success and goals.

A *clinical care situation* can be defined as a time-limited process or sequence of actions/tasks (for an individual patient) in which the cast (actors filling roles) does not change, and which has identifiable start, preconditions, end, and result. Classification of situations, i.e. their similarity, is determined by the values of the attributes of the situations we observe. A situation is for example medication, in which an actor performs specific tasks (administering drugs to patients). The actions or tasks may or may not be observed. An *actor* is either a system or a person that fills a role in a situation. A *role* is a set of abilities associated with an actor (in a situation).

To characterize the sequence of actions of a situation, we use the concept *trajectory*. A trajectory is the course of any experienced phenomenon as it evolves over time and the actions and interactions contributing to this evolution[6].

Table 1 shows the current framework of context attributes used to characterize the clinical situations and some of the corresponding values found in an observational study. The study was conducted at a large Norwegian university hospital (922 beds) during a two months period in 2005. One experienced medical student performed non-participatory observations of physicians' clinical work (e.g. prerounds meetings and ward rounds). The observational study is also briefly described in [8]. Physicians from two different hospital wards participated in the study. The participants included both chief physicians and residents. The example data presented in this paper was collected at Department of Cardiology. The ward takes care of patients suffering from coronary heart diseases. Most of them are undergoing extensive heart examinations during their hospital stay. Fig. 2 shows a tentative guideline for the diagnosis of heart failure, based on [7] and [17].

The patients who were followed in this study were mainly suffering from angina pectoris or heart failure. During the observational study, the medical student spent 20 days in the hospital wards. The student followed one physician at a time, recording information about various clinical situations by the means of an observational note taking form. The student recorded information about sequences of events in each situation. The recorded information consisted of sequences of acts with associated activities/triggers, rules, locations, main actors, roles, co-actors with associated roles, patient ids, illness histories, reasons for admission, situation start and end time, information sources, information types, purposes, results, and advance knowledge.

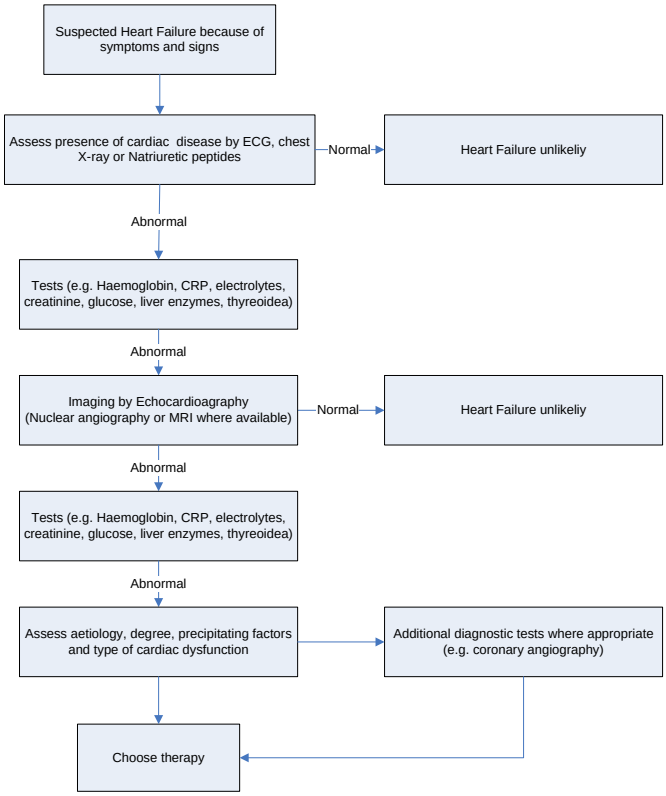

Figure 2. Guideline for the diagnosis of heart failure

3.1 Events and communicative acts

The *Events* attribute of the observational data can be classified in several categories as shown in Fig. 3, where the main part of the leaf nodes consist of *communicative acts*. The communicative acts can be characterized as either assertive, commissive, directive, expressive, or declarative, as described in [12].

3.2 Trajectory of acts example

Figure 4 shows an example of a trajectory of acts obtained from the observational data. The example is taken from a pre-rounds situation. The primary actor (trajectory perspective holder) of the situation is a senior resident (in this example 'Senior Resident 7'), and the coactors are a nurse ('Nurse 8'), and several information systems/sources (i.e. 'EHR' (the Electronic Health Record system), 'PAS' (the Patient Administrative System), 'Patlist' which is a list of the patients in the ward, and 'Patient chart' which is a binder that contains the most essential information regarding the current hospital stay of one or several patients in the ward, such as print-outs of the most recent laboratory and test results, medication charts, and plans for further treatment. The *Information type* values in this example are 'Name' (patient name), 'New' (changes since last pre-rounds situation), 'All' (patient overview), 'Med' (information related to the patient's medications), 'Findex' (findings and examination results), 'Blood' (blood test requests and answers', 'Explan' (planned treatment/examinations/tests), and 'Medplan' (medication plan). The arrow style indicates whether the communicative act is asynchronous (stippled arrow) or synchronous.

4 DISCUSSION

Structured observation of clinical behaviour can be used for various purposes. Our main objective has been to explore the correspondence between the intentional model represented by the guideline and the behaviour of clinicians and systems in reality. In order to bridge the gap, we have postulated an explict or implicit *plan* that implements one or more guidelines. So far, the emphasis of the community has been on guideline formalization in order to make guidelines executable in the context of a computer system. However, clinical practice is not enacted within computer systems, but by real clinicians.

Table 1. Framework for categorizing clinical situations

Attribute group	Attribute	Example values
Situation	Type	Pre-rounds, Ward rounds, Discharge conversation
	Planned	Yes, No
	Location	Office *n*, Patient room *n*, Hallway, Meeting room
	Trigger	After pre-rounds, Ad-hoc
Patient information	History	Diabetes, hypertension, cerebral infarction
	Reason for admission	Confusion, chest pains, dyspnea
	Category	New patient, Well-known patient, Ready for discharge
Actors	Roles	Head physician, resident, nurse
	Abilities	Interventions, delegation, decisions, medication
	Systems	EHR, Patient Administrative System (PAS), PACS, LIS
	Medium	Electronic, paper-based
Environment	Events	*See Fig. 3*
	Information source	Patient list, Preliminary discharge report, Prescription
	Misc.	Start time, end time

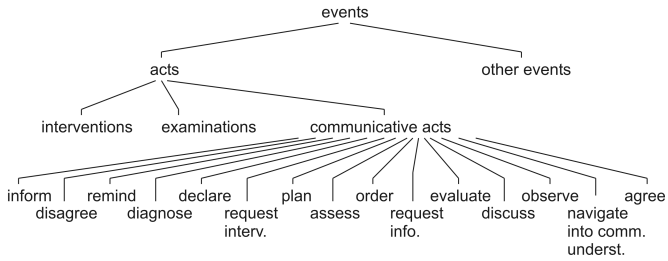

Figure 3. Classification of observed events

This chapter discusses the potential impact of structured observations on guideline compliance, implementation, validation and design.

4.1 Guideline compliance

Compliance to a guideline may be on different levels of abstraction. Referring to figure 1, we can find compliance with:

Guideline intent The indicators and outcome is achieved by the performance of the involved persons. Advani et al. [1] have developed a scoring scheme for evaluating adherence to guideline intentions that requires retrospective evaluation and survey. Most likely, this sort of compliance can not be found trough observations, but only by querying the involved persons.

Guideline model Compliance with the actual guideline representation can only be achieved when there is a close correspondence between actions and guideline, for example in the case of an executable guideline integrated with the record system. Quaglini et al. [11] have described this in an analysis of non-compliance and elaborate on the notable gap between the goals of the practitioner, the limitations of reality and the abstract level of the guideline.

Guideline implementation Compliance with guideline implementation in this context means compliance with detailed plans, including allocation of roles, use of resources, responsibilities and use and production of information. This type of compliance can be analysed by combining patient record content [16], behaviour [4] and surveys.

Since explicit care plans are almost non-existent, we regard compliance analysis by means of structured observation as speculative.

4.2 Guideline grounding and implementation

Grounding refers to the mapping of guideline concepts to real-world activity and behaviour. Our notion of implementation consists of a set of mappings, or interpretations, from guideline concepts to a locally executable plan:

Actions in the guideline must be mapped onto actors and interactions in the plan.

States in the guideline must be mapped onto declarable or observable situation features.

Measures in the guideline must be mapped onto examinations or devices.

Declarations in the guideline must be mapped onto acts of diagnosing, stating, agreement etc.

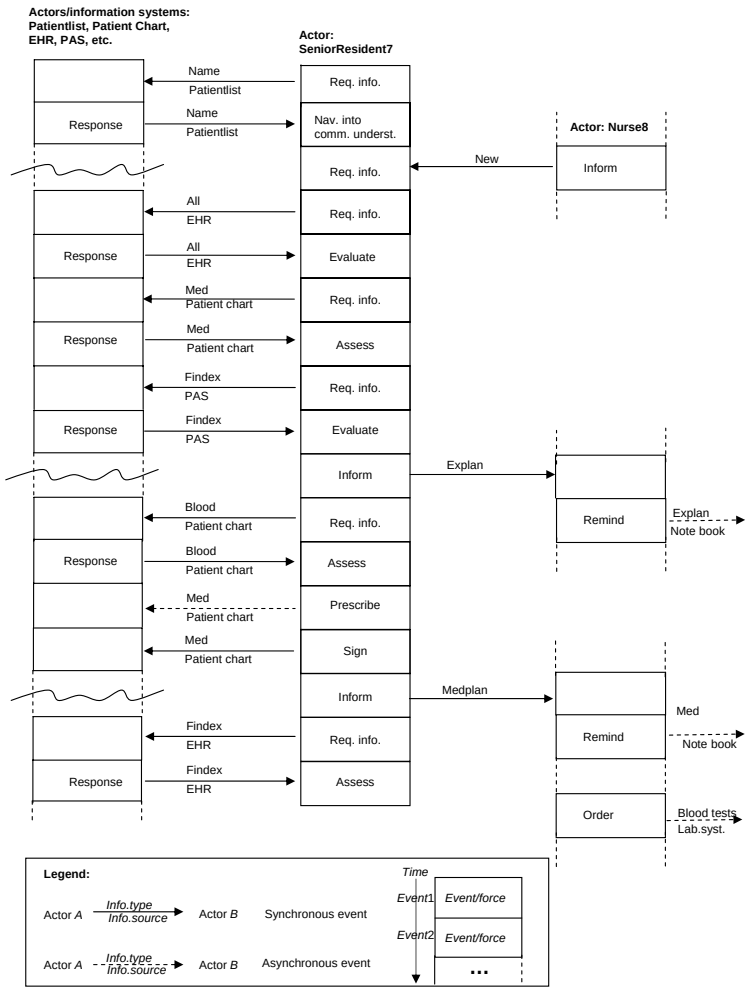

Figure 4. Trajectory of acts, primary actor SeniorResident7

Alternatives in the guideline must be resolved or mapped onto choices and tests in the plan.

Processes in the guideline must med mapped onto tasks, roles and well-defined care situations.

This mapping process is non-trivial, and is usually a major activity of cooperative clinical work. Presenting, agreeing, discussing and reaching common understanding are labor intensive and critical in order to avoid errors and inefficiency.

By repeated observation of clinical practice that implements and realizes a guideline, we expect that we will be able to induce mapping patterns and corresponding plan templates.

4.3 Guideline validation

Unless specific observable activities are intended by the guideline, as for example the case with guidelines governing cooperation and patient interaction, guidelines cannot be validated solely by observing clinician behaviour. However, failure to find mapping patterns and plan templates, signifies that the guideline is not implementable. The clinicians may be compliant to the guideline intention, but by means not prescribed by the guideline. Non-implementable guidelines prob-

ably also imply guideline invalidity.

4.4 Guideline design

An interesting application of manual or automated observation of (communicative) behaviour is empirically founded development and induction of new plans, and indirectly, new guidelines.

5 CONCLUSION AND FUTURE WORK

We have presented a framework for performing structured observation and characterizing care situations and trajectories of acts. We believe that this framework can be used as a complement to other formal methods for implementing clinical guidelines and protocols, as not every dimension of the clinical care situations is observable (e.g. goals/intentions, decision models and so on).

The next step in our research is to perform more observations using the proposed framework for structured observations, with a special emphasis of analyzing the communicative act trajectories identified in the care situations. We also aim to perform a mapping between our observable situation attributes and various dimensions of existing guideline models, based on the eight dimensions for comparison of guideline-modeling methodologies described by Mor Peleg et al.[10].

ACKNOWLEDGEMENTS

We would like to thank the staff at the University Hospital of Trondheim for their cooperation during the observational studies and medical student Siri Haug Strømmen for collecting the data. We would also like to thank the referees for their comments which helped improve this paper. This research was partly financed by the strategic research area Medical Technology (`http://www.ntnu.no/medtek`) at NTNU and the NTNU Innovation Fund for Business and Industry (`http://www.ntnu.no/idefondet/`).

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Paper F

A Study of Clinicians' Information Systems Usage in Patient-Centered Situations - Preliminary Results

This paper was accepted for and presented as a poster at the 12th World Congress on Health (Medical) Informatics (Medinfo 2007), Brisbane, Australia, 20-24 August, 2007.

A Study of Clinicians' Information Systems Usage in Patient-Centered Situations – Preliminary Results

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Abstract

This paper presents preliminary results from an observational study performed at a Norwegian university hospital. The purpose of the study was mainly to validate a method for performing structured observation of clinicians' patient-centered work. One fifth-year medical student spent 20 days in two different hospital wards, following 7 physicians from one to seven days each. The observer recorded data from several ward situations such as pre-rounds meetings, ward rounds, and discharge situations. The data was recorded by means of an observation form consisting of a mixture of codes and free-text fields. The initial analysis of the data confirms that the method is an efficient and useful means for studying clinicians' information and communication patterns in hospital wards. In the paper we also briefly discuss some of the strengths and weaknesses of the method, and at the end some comments regarding future work are given.

Keywords:

Observational study, Structured observations, Mobile health information systems, Requirements engineering

Introduction

This paper presents an extensive observational study performed during a two-month period in two hospital wards. The data was collected through non-participative observation of physicians.

The purpose of the study was to record information about physicians' information source usage in their daily ward activities. The method is based on a framework for performing structured observations, developed iteratively and used in several previous observational studies [1]. The framework has been used as a tool for studying and capturing information and communication patterns among healthcare workers in hospital wards, in order to be able to elicit and produce comprehensive requirements for the user interface of mobile clinical information systems.

Structured observation is a technique derived from the ethnographic technique participant observation, a technique used for elicitation of knowledge about situations, actors, interactions, and communicative patterns. Structured observation is the planned watching and recording of behaviour and/or events as they occur within a well-known/predefined environment.

Several other papers discuss how observational studies can be used as a supplement to other methods in the design of health information systems [2], [3], [4], [5].

Methods

The study (also briefly described in [6] and [1]) was carried out at a large Norwegian university hospital during the period July – September 2005. The observations were conducted by one fifth-year medical student. The student performed non-participatory observations of physicians in two hospital wards (Division of Gastroenterology and Department of Cardiology). The medical student were interested in medical informatics, but had no prior research experience.

The aim of the study was partly to validate a previously developed method for performing structured observation (see [1]).

During the study, the medical student spent a total of 20 days in the two hospital wards. She followed one physician at a time, observing the physicians' daily patient-centered work. The participants included one chief physician with many years of experience in the ward, medium experienced senior residents, assistant residents, and one young intern. Both male and female physicians were among the participants.

The data was collected by means of an observation form based on and further developed from previous, similar studies (see [1, 5, 7-9]). The observer recorded data regarding the physicians' use of various information sources for retrieving and storing patient-related information in several common ward situations (e.g. pre-rounds meetings, ward rounds, and discharge). One *situation* is here defined as a time-limited process or sequence of actions/tasks (for an individual patient) in which the cast (actors filling roles) does not change, and which has an identifiable start, preconditions, end, and result. The recorded information consisted of sequences of acts with associated activity, rule, location, main actor and role, co-

Activity	Rule/trigger	Place	Main actor	Role	Co-actors	Role(s)	Patient-ID	Reason for admission (R/A)	Time	Information Source	Direction I/O	Information	Purpose	Patient category
Pre-rounds	Continue after interruption	OFF4	R9	PR	Nur9	GR	P57	Admitted due to unstable angina. Must be carefully watched when considering further treatment.	10:50	PATLIST	I	NAME	Name of the patient	New patient for the pysician. Under investigation
										NUR	I	NEW	Changes since admission	
										EPR	I	ALL	Overview of patient	
										NUR	O	FINDEX	Info. about examination	
										PC	I	MED	Review med.	
									11:05	PC	O	MED	Sign	
Examin.	The physician is under specialization and is obliged to perform a certain number of US examinations. Will receive a pager call if such an examin. is to be performed	OFF4	R9	PR	CP13 on phone (Nur9GR)	Ex	P67		11:10				The physician is paged from the ultrasound lab. Both the patient and the ultrasound machine are ready	
		LAB2	R9	PR	HP13	Ex	P67		11:45				Perform US examination	
Suppl. work	Quest. arose after pre-rounds. Asks before patient rounds in order to be able to give the answer to the patient during rounds	LAB3	R9	PR	CP12	Ex	P55	As previously described	11:50				Discuss with colleague if the patient can delay aniography until tomorrow or if the pat. should start on K-vit. and wait for INR level to decrease until tomorrow.	New patient for the pysician. Particular examination
Rounds	After pre-rounds	PR10	R9	PR	Nur9	GR	P41	Like Day 12	12:02	PATLIST	I	NAMEROOM	Overview of name of patient and where patient is placed	Under investigation
										PAT	O	MED	Inform about cease of med	
										PAT	O	FINDEX	Info about result of examination	
									12:08	PAT	I	NEW	Changes since yesterday	

Figure 1 – Excerpt from observational data (Dept. of Cardiology).

actors, patient ID, illness history, reason for admission, situation start and end time, information sources, information types, purpose, results, and advance knowledge. No sensitive or personal identifying data was recorded. Most of the recorded information was coded on-site by means of predefined values, while for instance 'Purpose' and 'Result' consisted of short free-text notes.

After four days of observation at Division of Gastroenterology, the collected data was evaluated. This resulted in an expansion of the observation form of four new free-text columns; 'Illness history', 'Reason for admission', 'Advance knowledge', and 'Patient category'. The purpose of the extension was the wish to perform more qualitative analysis of the data.

An example extract of the observation form with observational data recorded in Department of Cardiology is shown in Figure 1. The example shows data from one pre-rounds situation, one examination, one supplementary work situation, and one ward rounds situation. The main actor in all the situations is resident 'R9', and co-actors are one nurse (Nur9) and two chief physicians (CP12 and CP13). The roles of the main actors are all 'patient responsible' (PR), and the co-actors are one nurse ('Nur9'), who is the team leader ('GR'), and two different chief physicians ('CP12' and 'CP13'). Patients 'P41', 'P55', 'P57', and 'P67' are in focus and the locations vary from Office 4 via Lab2 and Lab3 to Patient room 10. The pre-rounds situation consists of six information/communication related acts. The resident uses four different information sources/systems; the patient list (for retrieval of the name of the patient), the nurse (NUR) for retrieving changes since patient admission (information code 'NEW'), the electronic patient record (EPR) for getting an overview of the patient (information code 'ALL'), and the patient chart (PC) for information about the patient's medications. Information output (direction 'O') is given to the nurse (about examination), and the medication form in the patient chart is signed. The ward round situation is a communication mainly informing the patient (PAT) about ceasing a drug and the result of an examination, and the patient informs the physician about any changes since the day before.

Results

During the study, 20 days of observation were performed (11 days at Division of Gastroenterology and 9 days at Department of Cardiology). A total of 7 physicians were followed; among them 1 chief physician, 5 residents, and 1 intern. The co-actors of the situations consisted of other physicians, nurses, patients, and relatives. Approximately 70 patients were involved in the study.

The clinical work situations in the two different wards are to a large extent similar. The numbers of the observed situation types from the two wards are summarized in Tables 1 (Dept. of Cardiology) and Table 2 (Div. of Gastroenterology).

135 situations consisting of a total of 525 acts were recorded from Div. of Gastroenterology, while 190 situations/1032 acts were recorded at Dept. of Cardiology.

Analysis

The observational data have so far been mainly processed in Microsoft Excel and manually inspected and analyzed.

Since the observation form was changed during the observations at Div. of Gastroenterology, these data are not complete. Thus, the initial analysis presented in this paper has concentrated on the Cardiology observations.

Table 1 – Summary of observations from Dept. of Cardiology. The first part gives the number of observed situations per main actor (residents"R7", "R9", and "R14", and chief physician "CP9"). The next column shows the number of situations related to drugs (prescription, administering or assessment) and the associated information sources used for gathering or recording drug information. The two last columns denote minimum and maximum number of events or communicative acts in the various situation types.

Situation type	***Main actor***				**Sum**	***# drug rel. situations***	***Sources for drug information***	#events per situation	
	R7	***R9***	***R14***	***CP9***				*Min.*	*Max.*
Pre-pre-ward-rounds	5	-	-	-	5	1	COL, NOTE	2	2
Pre-ward-rounds	7	22	11	24	64	62	PC, NUR, PDR, EPR	1	16
Ward-rounds	7	21	11	24	63	23	PAT, PC, NUR	2	11
Examinations	-	8	2	6	16	-	-	-	-
Office work	-	8	9	13	30	4	PC, NUR, PDR	1	9
Discharge prep.	-	-	2	4	6	6	PC, PATINFO	8	15
Discharge meeting	-	-	-	4	4	3	PATINFO, RES, PAT	2	10
Heart meeting	-	1	-	1	2	-	-	-	-
Total	19	60	35	76	190	99	-	-	-

Due to various reasons, situations related to drugs have been particularly in focus. Table 1 shows the numbers of drug related situations with respect to the various situation types and the information sources associated with the various situations. The only information sources used in the pre-pre-ward-rounds situation are the colleague (COL) and a personal note. 62 of 64 pre-rounds situations included medication information, basically retrieved from and noted in the patient chart (PC), with additional information found in the EPR and the PDR (physicians' desk report). The output information (about new or changed medicines) is written in the PC and/or given orally to the nurse who enters the information in the nurse information system. During ward rounds, the patients provide feedback regarding the effects of the medicines, and based on the information, the physician might change the medicines on the patient chart and the information is also given to the nurse who participates in the situation. During office work, the patient chart is still the main source of medication information, in addition to the nurse and the PDR. When preparing the discharge summary, the physician summarizes the medications in the patient info. form, and during the discharge meeting this form is given to the patient and some more information is given orally to the patient from the physician.

The table also shows minimum and maximum of events per situation in order to illustrate the variations.

172 of 525 (33%) acts were related to drugs at Div. of Gastro., while the corresponding numbers are 244 of 1032 (24%) for Dept. of Cardiology.

Discussion

The collected data are based on the observations and subjective interpretation by one medical student. In this initial analysis, the quality of the data seems good, but there are certain aspects that should have been discovered and discussed during the observations in order to make the subsequent data even more accurate (e.g. noting several patients in the same spreadsheet row or missing patient IDs).

As mentioned in the previous section, the data from the Division of Gastroenterology was not complete and hence the data has not been analyzed. However, the missing fields are mostly useful for qualitative analysis, and hence the data can be used in strictly quantitative analysis.

The study was mainly performed during summer time, and thus the ward staff was reduced and the remaining physicians had more responsibilities than they normally do (e.g. chief physicians performing ward rounds). However, this does not make the collected data less valuable, as it is important to capture variations. We find it particularly interesting to follow interns or newly hired physicians who are not as experienced as e.g. chief physicians, and thus they are even more dependent on the quality and usability of the available information systems.

The physicians in the hospital wards work on a rotation scheme, and the observer followed various physicians on call. The number of days observing one physician ranged from one to seven, but we do not consider this a problem as we did not analyze the data with respect to the individual physicians.

Detailed analysis of observed situations involving the patient chart with a particular focus on medication situations can serve as an important tool for requirements elicitation and specification when designing new information systems as a replacement for the paper-based patient chart.

Conclusions and Future Work

The observational study presented in this paper was partly performed in order to validate and improve a method for conducting structured observation of clinicians. The results of this study confirm our previous findings:

- Structured observation by means of pre-planned forms is suitable for gathering information regarding information and communication practice in hospital wards
- Using apprentices (medical students) as observers is beneficial as they know the domain and they are seen as non-intrusive in the hospital wards
- The data recorded via structured observation differs from e.g. survey data, and the detailed contextual information of the various situations is valuable when eliciting and specifying requirements for new mobile clinical information systems

Future work

The analysis of the data collected in the observational study is only initial and has been mainly qualitative and manually performed. There is a large potential for more quantitative analysis of this or similarly collected data. Based on the main coded columns (information source, direction, and information type), various analysis with respect to clinicians' information and communication patterns can be performed.

One most interesting prospective is to associate each event of the observed situations with communicative acts (e.g. inform, declare, request information etc.). This can be used to create communicative act profiles (see e.g. [10]) of the situations in order to find similarities and perhaps identify common missing information situations and other information that can provide useful input to the design of new mobile, clinical information systems.

Another potential aspect of the methods used in this study is to follow patients from admission to discharge and analyze the patient trajectories. The result of this analysis can subsequently serve as a basis for producing new or improved clinical guidelines and treatment protocols [11].

In order to validate the method described in this paper, our next step is to ask two or more observers to record data from the same situations, but without comparing notes or discussing during the observations. When evaluating the recorded data, it is possible to measure the accuracy of each observer. As a result, the observation form and/or the pre-defined codes may be altered in order to increase the quality of the observational data.

Acknowledgments

We would like to thank the staff at Division of Gastroenterology and Department of Cardiology at the University Hospital of Trondheim for their cooperation during the observational studies and medical student Siri Haug Strømmen for collecting the data.

This research was partly financed by the NTNU Strategic Research Area Medical Technology and the NTNU Innovation Fund for Business and Industry.

Table 2 – Summary of observational data from Division of Gastroenterology. Main actors are residents "R1" and "R2" and intern "I1". 135 situations are observed.

Situation type	***Main actor***			**Sum**
	R1	***R2***	***I1***	
Pre-ward-rounds	37	6	20	63
Ward-rounds	15	7	-	22
Other meetings	5	1	5	11
Office work	16	7	-	23
Discharge prep.	1	4	-	5
Discharge meeting	-	-	-	
Morning meeting	5	-	6	11
Total	79	25	31	135

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Paper G

Towards a Tomographic Framework for Structured Observation of Communicative Behaviour in Hospital Wards

This paper appears in *REFSQ 2007 - Proceedings of the international working conference on Requirements Engineering: Foundations for Software Quality* (edited by P. Sawyer, B. Paech, and P. Heymans), LNCS 4542, pp. 262–276, 2007.

Towards a Tomographic Framework for Structured Observation of Communicative Behaviour in Hospital Wards

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Abstract. The research presented in this paper investigates how observation of information- and communication-intensive work in hospital wards can be used to produce requirements for mobile clinical information systems. Over a number of years, we have explored how important properties of clinical situations can be captured through structured observations of actors, processes, and systems. In the paper, we present experience from four observational studies of a total of more than 400 hours in hospital wards. Based on the observational studies, we propose a framework for structured, tomographic, observation of clinical work practice. We also briefly discuss and illustrate how the field data can be analyzed and used as input to the requirements engineering process.

1 Introduction

Traditional software engineering is challenged by the complexity and information intensity of healthcare. Even at the smallest hospital, an individual clinician takes concurrently part in many care processes, in different stages, with different partners, often having different roles, using many means of communication, and a variety of existing paper- and computer-based information systems. It is not uncommon in larger Norwegian hospitals to have hundreds of separate information systems in clinical use. An objective of hospital IT-policy is to integrate or replace the functionality of all the specialist systems in one suitable architecture, with portal-based interfaces, and thereby improve information quality, ease of access and information flow. However, it is a huge challenge to integrate both information and functionality from diverse components and sources into comprehensible user interfaces.

One of the aims in our research on context-aware mobile patient record systems has been to develop techniques for characterizing situations, procedures, roles, actors, and problems that can be aided by the introduction of such systems. Criteria that identify where such systems will *disrupt* good practice are

also important to establish [1]. This research on groundwork and context naturally supplement various user centered requirements elicitation techniques and methods [2–4].

Collecting and mapping knowledge about the information environment, the context, for the future software system is explorative, difficult to focus and potentially costly. The validity may also be problematic.

In order to improve the collection of context knowledge, we propose a *framework* that establishes different dimensions of observations, a process for focusing and refinement of observation protocols, and finally iterative exploration of the collected contextual knowledge. The framework enables a tomographic, slice-wise, view of reality by structured observation and documentation of situations, actors, interactions, and processes. Our objectives in developing the framework have been:

- To be able to characterize cooperative situations in a repeatable and efficient way
- To concentrate on observable characteristics of situations, instead of implicit characteristics and concerns like efficiency, failures, success and goals
- To be able to change perspective, level of detail, and observation technique according to focus of interest
- To be explicit about what characteristics remain constant, and thus not interesting, during iterated observation of other, varying characteristics.

While the framework is meant to be used in the initial stages of the requirements engineering (RE) process, we believe that it can be useful for making scenarios and use-cases directly based on empirical knowledge, and thereby make them more valid, and more adaptable to changes in reality.

The paper is organized as follows: Section 2 presents the problem domain of healthcare information systems and briefly discusses related RE issues. Section 3 reviews four succeeding observational studies with varying problem foci:

1. high-level characteristics of varying information-intensive, complex, cooperative care situations in the ward with many human actors and few computer systems
2. information use in sequences of situations related to one specific task (patient discharge) with multiple system actors (many different information systems and a few human actor roles, but many distinct persons in that role)
3. information use in similar situations, but with one task (medication) and many actors
4. elicitation of situational properties from the perspective of one actor role (a physician) over longer periods of time

In Sect. 4 various aspects of the observational studies and the framework are explained. Section 5 provides a discussion of the approach, and finally, Sect. 6 concludes the paper and gives some paths for further improvement and validation of our approach.

2 Background and Related Work

The healthcare domain is characterized by a high intensity of information, knowledge, and communication. Healthcare workers are to a great extent mobile while performing patient-centered work, and they also often have to handle interruptions and unexpected situations and events. The information systems used in this domain are steeped in challenges of sociotechnical nature [5], and hence traditional requirements elicitation and analysis techniques are not appropriate when designing new systems.

For many years, ethnography has been recognized as an important complement to existing human centered methods by both the requirements engineering and the HCI research communities [6], and several papers report on various approaches to incorporating ethnography in the RE process (e.g. [7–11]). Still, the practical impact of this approach has been minimal [6]. One important reason for this is that ethnographic studies are normally very time consuming and the unstructured, detailed field notes of the ethnographers are often difficult to transform into formal requirements. We propose an approach to overcome some of these difficulties by performing focused, structured observation of communicative behaviour in hospital wards.

Our approach enables

- efficient and easy recording of field data as interpretation is done immediately during observation. This is in contrast to e.g. video recordings and unstructured field notes.
- field data that give a reasonably 'objective' map of reality and that are appropriate for further quantitative and qualitative analysis
- performance in several system development stages (i.e. the approach can be used both before and after the introduction of new information systems)

3 Observational Studies in Hospital Wards

The following sections briefly describe four observational studies performed at a local University Hospital during the period 2002-2005. The research was performed as part of the MOBEL (MOBile ELectronic patient record) project at NTNU [1], and the main objectives have been to study and capture information and communication patterns among healthcare workers in hospital wards, in order to be able to elicit and produce comprehensive requirements for the user interface of mobile clinical information systems.

3.1 Study 1: Characterizing complex cooperative situations

The first observational study was performed in spring 2002 by two PhD students (with background from sociology and computer science). The main purpose of the study was to identify and characterize situations that would change, improve, or even become superfluous by introducing a mobile, electronic patient chart in

the hospital ward. Likewise was identifying situations that would *not* benefit from such an information system important. Five days of non-participatory observations in two hospital wards were supplemented with informal interviews with the health personnel, and also with experiences from a more extensive observational study performed by the sociologist in a third ward. During the study, the observers followed physicians and nurses in their daily patient-centered work, taking free-text notes. Based on the notes and supplementary information, 11 example scenarios were extracted. The scenarios included meetings, ward rounds, medication administering and other important ward situations. Subsequently, the scenarios were characterized by means of a previously developed form, consisting of attributes with corresponding predefined values. The attributes were grouped in three main sections: *process attributes*, *input attributes*, and *outcomes* (see [1] and [12] for details). The main attributes were related to the produced or exchanged information; i.e. type, amount, medium/modality, information/knowledge flow, and time perspective/validity. Other important attributes concerned contextual information such as participants/actors and planning, delegation, and decision-making issues.

Table 1 shows an example scenario abstracted from the observations with corresponding characterization.

3.2 Study 2: The Patient Discharge Process

The second observational study took place during spring 2004. The purpose of the study was to investigate to what extent clinical information systems - in particular the electronic patient record (EPR) system - support clinicians in critical and information intensive tasks such as the discharge process. Prior to the study, the initial observational framework was adjusted to fit the study perspective: One (well-defined) sequence of situations related to the discharge of patients in one hospital ward (i.e. preparations and writing preliminary discharge report, discharge conversation with patient, and dictating final discharge report). The observations were performed by two apprentices (medical students) with little or no experience from the hospital ward. The medical students followed one physician at a time, observing the physician's work concerning the discharge of patients. A total of 52 discharge processes were studied, and the observers spent 100 hours in total in the hospital ward. During the observations, the students used a note-taking form with pre-defined information sources (e.g. Electronic Patient Record, Patient Chart, Nurses), sequentially noting what information that was gathered from the various sources. Later, one of the medical students transcribed the notes to spreadsheet matrixes consisting of information types versus information sources. The data collected from the 52 discharge processes were summarized in one matrix and analyzed. During the analysis, the initial 14 information sources were grouped into three categories: Paper-based, electronic, and human. The observational study and the results are described in further detail in [13] and [14].

Table 1. Example scenario and characterization

Example scenario: Medication per patient

One of the nurses in the patient care team uses information from the patient chart to put today's medications for the ward patients onto a medicine tray. Later, the nurse in charge inspects the medicine tray to ensure that the medicines correspond to what is recorded in the patient chart.

Facet	Attribute	Values of example scenario
Process	Number of participants	2-4
	Number of roles	Two
	Number of role levels	Two
	Composition	Predetermined
	Decomposition	Yes
	Scenario nature	Formal
	Regularity	Daily
	Scheduling	On the spot
	Variance of required info.	Somewhat
	Location(s)	Predetermined, fixed
	Spatiality	One place
	Temporality	Asynchronous
	Information exchange	One-to-many
	Initiation	On demand/Precondition
	Delay tolerance of scenario start	None
Information input	Novelty	To some
	Recorded	Patient chart
	Longevity	Short term
	Medium/mode	Text
	Scope	All
	Delay tolerance of input. info	None
Outcomes/ produced output	Explicit	Yes
	Shared	Yes
	Novelty	To some
	Recorded	Patient chart
	Longevity	Long term
	Type of produced information	Cooperative, constructive
	Medium/mode	Text
	Scope	Patient care team members
	Delegation of responsibility	Predefined
	Delegation of tasks	Predefined
	Delay tolerance	None
	Outcome type known in advance	Yes

3.3 Study 3: Drug Prescription and Administration Situations

As part of their Master's thesis work ([15]), two Computer Science students developed the observational framework further in order to be able to produce requirements for a context-aware interface for drug prescription and administration (i.e. getting, picking, controlling and delivering the prescribed medicines to the patients, and documenting this process). Their first version was an extension of the characterization form presented in Sect. 3.1. The students collected data by means of non-participant observation, interviews, and video recording, focusing on situations related to drug prescription and administration. However, when analyzing the data, the students found that the observed situations were disconnected and the collected data were insufficient in order to capture contextual attributes beyond traditional aspects such as time, place, task, and actors. They therefore decided to focus on the patient process as sequences of related situations in order to be able to capture contextual attributes that were important for the outcome or the decisions made in the different situations. The resulting analysis form with an extract of the example observational data of one patient process is shown in Fig. 1. The example data is taken from one drug administra-

Situation no.	ID	Information source	Information	Direction	Purpose	Result	Type	Trigger	Location	Participants	Physical	Result of	Leading to
8.1	Nur.	Patient chart (F1a)	Regular med.	I/O	Look up medications and dosage	Sign.	Drug admin.	Regular	Pat. room, hallw.	Nurse	Trolley: hallway. 2 beds, 2 pat.		
8.2	Nur.	Marevan form	INR	I/O	Determine dosage	Sign.							
8.3	Nur.	Patient	Drug	O	Administer drug	Received							
9.1	Res.	Patient list		I	Overview		Pre-rounds	Regular	Group room	Resident, nurse			
9.2	Res.	Patient chart (F1a)	Regular med.	O	Sign.	Sign.							
9.3	Res.	Patient record	Record note	I	Understand the intention behind the note	Nothing new??							
9.4	Res.	Test result	Blood	I	Overview								
9.5	Res.	Nurse	Intestinal function	I									S9.6
9.6	Res.	Check list	Intestinal function	O								S9.5	
9.7	Res.	Test result	Urine	O	Sign.	Sign.							
9.8	Res.	Test result	Blood	I	Check								
9.9	Res.	Patient chart (F1b)	Fluid (in)	I	Control fluid balance	Not dehydrated							
9.10	Res.	Nurse	Drug effect	I	Control drug effect	Seems less Stiff							S9.11 S9.12
9.11	Res.	Patient list	Drug effect	O	Reminder							S9.10	
9.12	Res.	Supervision	Neurological	I	Check	Old: Start paroxan						S9.10	
9.13	Res.	Nurse	Network meeting	I								S7.2	

Fig. 1. Analysis form with example data from observation of drug administering and pre-rounds situation, Department of Geriatrics (translated from Norwegian)

tion morning round and one pre-round situation. The column 'ID' identifies the main actor of the event, in this case the nurse and the resident physician. The remaining columns contain the information source, the information type, information flow direction (in/out), the purpose and result of the event, and some general values valid for all the events of the situation. The two last columns refer to the relationship between various elements of the sequence.

3.4 Study 4: Following Physicians

A fourth instance of the observational framework was developed and used during a two-months period of extensive observation in two different hospital wards in 2005 [16, 17]. One fifth year medical student performed non-participatory observations of physicians' clinical work (e.g. pre-rounds meetings and ward rounds). The participants included both chief physicians, residents, and interns. The example data presented in this paper was collected at the Department of Cardiology. During the observational study, the medical student spent 20 days in the hospital wards. The student followed one physician at a time, recording information about various clinical situations by the means of an observational note taking form based on and adapted from the form described in Sect. 3.3. The student recorded information about sequences of events in each situation. The recorded information contained situation activity with associated trigger/rule, location, main actor and role, co-actors, patient ID, illness history, reason for

Activity/ Trigger	Rule	Place	Main actor	Role	Co-actors	Role(s)	Patient-ID	Reason for admission (RFA)	Time	Information Source	Direction I/O	Information	Purpose	Patient category
Pre-rounds	Continue after interruption	OFF4	Res9	PR	Nur9	GR	P57	Admitted due to unstable angina. Must be carefully watched when considering further treatment.	10:50	PATLIST	I	NAME	Name of the patient	New patient for the pysician, Under investigation
										NUR	I	NEW	Changes since admission	
										EPR	I	ALL	Overview of patient	
										NUR	O	FINDEX	Info. about examination	
										PC	I	MED	Review med.	
									11:05	PC	O	MED	Sign	
Examin.	The physician is under specialization and is obliged to perform a certain number of US examinations. Will receive a pager call if such an examin. is to be performed	OFF4	Res9	PR	HP13 on phone (Nur9GR)	Ex			11:10				The physician is paged from the ultrasound lab. Both the patient and the ultrasound machine are ready	
		LAB2	Res9	PR	HP13	Ex			11:45				Perform US examination	
Suppl. work	Quest. arose after pre-rounds. Asks before patient rounds in order to be able to give the answer to the patient during rounds	LAB3	Res9	PR	HP12	Ex	P55	As previously described	11:50				Discuss with colleague if the patient can delay aniography until tomorrow or if the pat. should start on K-vit. and wait for INR level to decrease until tomorrow.	New patient for the pysician, Particular examination
Rounds	After pre-rounds	PR10	Res9	PR	Nur9	GR	P41	Like Day 12	12:02	PATLIST	I	NAMEROOM	Overview of name of patient and where patient is placed	Under investigation
										PAT	O	MED	Inform about cease of med	
										PAT	O	FINDEX	Info about result of examination	
									12:08	PAT	I	NEW	Changes since yesterday	

Fig. 2. Extract of observational data collected at Department of Cardiology (translated from Norwegian). The perspective is one resident physician ("Res9") in several situations (pre-rounds, examination, supplementary work, and rounds) with different patients ("P57", "P55" and "P41"), various information sources (Patient list, nurse, electronic patient record (EPR), Patient chart (PC), and Patient), and co-actors (one nurse ("Nur9") and two head physicians ("HP12" and "HP13")

admission, situation start and end time, information sources, information types, purpose, results, and advance knowledge. Most of the recorded information was coded on-site by means of pre-defined values, while for instance 'illness history', 'advance knowledge', and 'purpose' consisted of short free-text notes. An extract of the recorded data is shown in Fig. 2. In the example figure, the free-text columns 'Illness history', 'Result', and 'Advance knowledge' have been removed in order to make the figure more readable.

3.5 Lessons Learned

The first observational study described in Sect. 3.1 lead to a number of representative ward scenarios. The scenarios provided useful insight into the daily patient-centered work of clinicians. However, the situations were detached and further analysis would require more detailed information about the various situations. When preparing the second observational study, the focus was therefore narrowed into one specific procedure: the patient discharge. The first study was performed by observers with little domain knowledge. For the second study, two medical students were hired. Knowing the terminology and understanding the vocabulary of the clinicians, the students were able to grasp much more of what they observed than the first observers. The students had little or no experience from the hospital ward, and hence they were open minded and they also found the observational study interesting as their own domain knowledge was increased. In order to make the observations efficient, an observation form was

developed prior to the data collection, consisting of several pre-defined information sources and several other fields for free-text notes. The evaluation of the second observational study led to the conclusion that using medical students (apprentices) for data collection was very beneficial. This became evident in the third observational study, which was performed by two computer science master's students. Without prior domain knowledge, the students initially had to spend several days in the hospital ward in order to be able to understand what was going on before they could start developing the observation form and concentrate on their main task. Based on the observation form from Study 2, the students developed several iterations (stage 1 and 2 of Fig. 3) and tested them in the ward. They also used the resulting data to improve some prototypes of a user interface for a medicine adminstration module. The fourth observational study was based on the experiences from the previous studies. A medical student was hired to perform the data collection, and the observation form was adapted in order to comprise more information regarding the patient illness histories and the physicians' background knowledge. This lead to a form consisting mostly of coded information but also some free-text columns.

Table 2 summarizes the different examples presented in Sect. 3 with respect to different features of the observations.

Table 2. Summary of observational studies

	Study 1 Overview	*Study 2 Discharge*	*Study 3 Medication*	*Study 4 Physician*
Type of observational method/ observer	Non-participatory observation by observer with some domain knowledge	Non-participatory observation, and talk-aloud by somewhat experienced clinician observer	Non-participatory observation, possibly with interface logging/ recording, by observer with knowledge of information representation and systems	Non-participatory, talk-aloud observation by somewhat experienced observer in apprentice role
Perspective	An omniscient observer	All actors (physician, information systems)	The medication plan/ system	The physician
Level of detail	Wide, non-focused, high-level, with minimal domain	Fixing situation, process and actor attributes. Repeat over situation.	Fixing actors (system and user)	Fixing role. Repeat over role
Sequential span	Repeated over many situations	Repeated with roles, actors, task and situations constant. Changing individuals (patients and physicians)	Repeated with roles, information systems and situations constant. Changing context or location of the situation. Changing patients.	Repeated with role constant
Sit. attributes /recorded info.	Process, actors, no information characterization and no task sequences	(1) + information source and sink, information type, named roles, communicative acts, action sequences	(2) + context of situation	(3) + background information

4 A Framework for Structured Observation

The following sections introduces some definitions and goes on to explain the proposed observational framework.

4.1 Definitions

In order to simplify the further discussion, the following informal definitions are used:

- A *situation* is a time-limited sequence of actions/tasks for an individual patient in which the cast (actors filling roles) does not change, and which has an identifiable start, preconditions, end, and result. Classification of situations is determined by which attributes of the situations we observe. A situation is for example medication, in which an actor performs specific tasks (administering drugs to patients). The actions or tasks may or may not be observed.
- An *actor* is either a system or a person that fills a role in a situation.
- A *role* is a set of abilities associated with an actor (in a situation).
- *Situation attributes* can be used to define or characterize observed situations by a range of predefined values. The attributes can be grouped into several facets of the situations (e.g. process related attributes and information related attributes), and they may be *implicit*, as common knowledge among the participants, or *explicit*, and can be observed by a (trained) observer. Examples of explicit situation attributes are number of participants, type and source of an information element, location, and possibly dependent situations (for a specific perspective). Implicit attributes may be preconditions for the situation, whether the situation was planned or unplanned, and degree of programming (i.e. according to a standard procedure).

4.2 Framework Application

The proposed observational framework is, as the term implies, something that has to be adjusted and adapted to a specific use. The framework consists of four separate stages as illustrated in Fig. 3. The stages are described in the following sections:

Stage one: Focusing and developing observation forms The first stage of the observational framework is to identify the specific focus of the observation, engaging one or more observers, and deciding on observation and data collection techniques (i.e. developing observational forms, deciding which attributes to include in the form, and identifying the range of the attribute values).

Stage two: Data collection and transcription Based on the techniques and perspectives chosen in stage one, the observational studies are performed and the data is recorded and transcribed. The output of this stage are the actual transcribed observations.

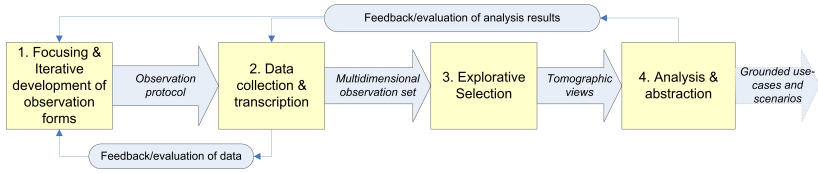

Fig. 3. Framework application process

Stage three: Explorative selection Stage three of the framework concerns the process of transforming the field data into data that can be analyzed and processed. This includes selecting 'tomographic segments' of the total span of observational data.

Stage four: Analysis and abstraction Stage four involves analysis and abstraction of the data. Appropriate analysis tools and methods must be carefully selected, depending on the outcome of the former stages of the framework process, the nature of the recorded data, and the amount of data (i.e. qualitative vs. quantitative analysis).

4.3 Focusing and Iterative Development of Observation Forms

Our observational framework identifies several dimensions of observation that have to be considered when planning the observational study:

I. Perspective of observation Which is the situation as confined to the perspective from a specific actor, individual, role, system, or artifact. For example, we can observe the hospital as viewed from a specific patient, from the nurse team leader (instantiated by several persons) or from a specific system (e.g. the patient chart). Figures 4 and 5 illustrate how the observational span is changed according to various perspectives. Observe that this use of 'perspective' is not a synonym for 'viewpoint' as used by the RE community to denote stakeholder's requirements from a stakeholder's perspective.

II. Level of detail in observation Which is simply a ranking of either the attribute domain (number of different distinguishable values for each attribute, or the number of attributes/decomposition of attributes) or the span of situations captured by continuous observation. E.g. an observation that *Actor A* interacts with *Actor B* is high level, but the observation that *Actor A* asks *Actor B* (about *Patient P*) is lower level.

III. Sequential span This is the span in which we keep some aspects constant and other aspect are allowed to vary. There are two alternatives:

- a natural succession of different situations in which one artifact or actor is observed or maintaining the perspective. This is illustrated in Fig. 5b and c. For example, observations from the perspective of one physician using one (or more) information systems for a prolonged period of time

– a succession of different roles or contexts enacting through a situation or a process (e.g. discharging patients), as illustrated in Fig. 5a.

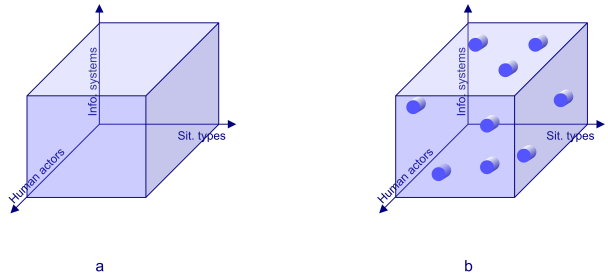

Fig. 4. a: Span of observation perspectives, b: Observations of detached situations

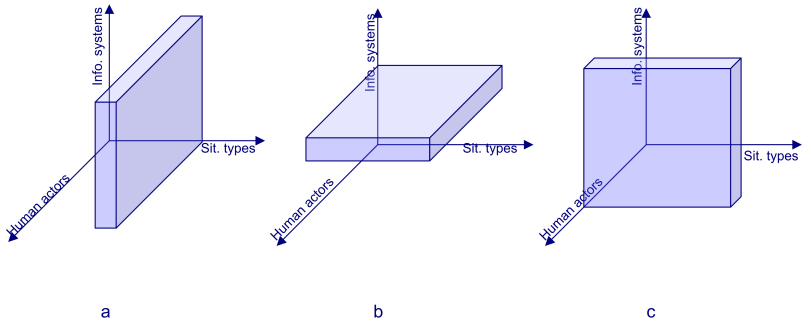

Fig. 5. a: Focus on one (or closely related) situation type(s) (e.g. the pre-rounds meeting), b: Focus on one information system (e.g. the electronic patient record), c: Focus on one actor (e.g. the physician)

4.4 Example Analysis

Examples of produced output of stage one are observation forms used in Study 2-4 (see Sect. 3). As a supplement to other RE methods, the outcome of the data analysis and abstraction (e.g. scenarios, use cases, and information flow sequence diagrams (see e.g. [17]) may be used in the requirements specifications

process. One interesting approach to field data analysis is to create *communicative acts profiles* of various observed actors/situations [18]. Each event of the observed situations is associated with one pre-defined *communicative acts* code, and the results can be visualized through e.g. radar plots. This technique can for instance be used to illustrate similarities, differences and variations in working style and information source usage between individual healthcare workers, roles, and hospital wards. It is also possible to create profiles of specific activities (e.g. drug related events), in order to be able to elicit requirements for an information system supporting this particular activity.

Figure 6 shows an example of a communicative acts profile for *ChiefPhysician9* at Dept. of Cardiology during 24 pre rounds situations. The angular axes of the plot show the 12 communicative acts that have been identified in the observational data, and the radial axes indicate the number of each act found in the selected observational data set. The communicative act 'Navigate into common understanding' is abbreviated 'NCU'. The graph shows how paper-based (the patient chart, patient record, patient list, Physician's Desk Report), electronic (Electronic Patient Record, Patient Administrative System, WiseWeb (a web-based user interface for X-rays pictures and radiology reports)), and human information sources are used in 220 communicative acts during the 24 pre-rounds situations.

5 Discussion

The basic idea with our approach is to be able to:

- keep some aspects constant
- constrain variation

along one or more of the dimensions described in Sect. 4.3, thus allowing more detail or variation of observation along other dimensions, and more goal-directed observation. The data collected from these studies can be seen as a 'map of clinical reality' with varying zooming options. The data from Study 2 and Study 4 are quite detailed, and provide valuable information about the actual information and communication practice of several clinicians. This is in contrast to other workflow/process models that are often created as a means to analyze and improve current work practice in connection with the development of new clinical information systems.

While Holzblatt [19] argue for the validity of 'consolidating' multiple observations into general truths about users and situations, we do not have enough experience to claim that a similar approach is valid for our observations. The accumulation of repeated observations is not intended to give greater confidence in the results, even if that would be possible given enough time and observers. It seems obvious that some of the methods of epidemiology could be used for analysis. We have also tried to use various clustering and process mining tools to try to give more insight into the observations, but with little success so far.

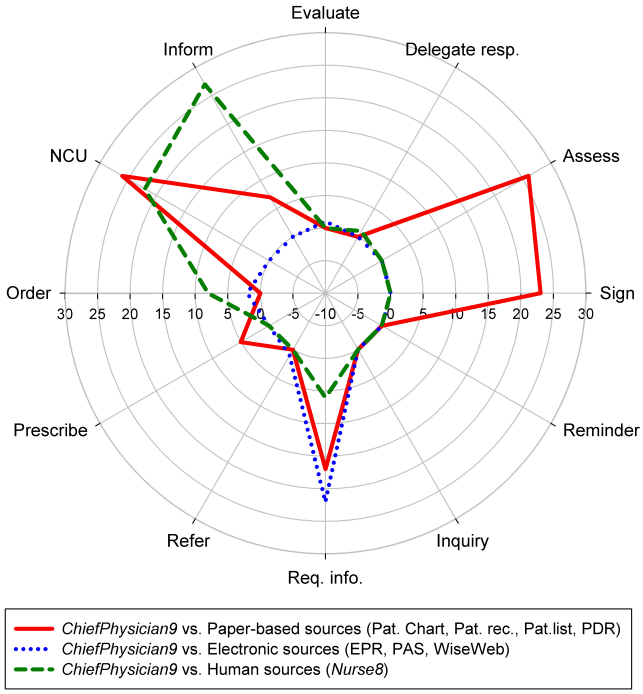

Fig. 6. Communicative Acts Profile for *ChiefPhysician9* (Pre Rounds situations, Dept. of Cardiology). Number of Comm. Acts: 220 (24 Pre Rounds situations)

The quality of the recorded data depends to a great extent on the individual observer(s) and the transcription/interpretation of the data. Less free-text entries and more pre-defined codes makes the recording faster and possibly more accurate, but there is also a risk of entering wrong codes and losing important contextual information.

By various analysis of data gathered from observations it is possible to investigate the effect of for instance introducing new information systems. Simulation, based on real data from observations [2] may be a very powerful tool.

6 Conclusions and Future work

We have used our observations both for making requirements and prototypes, and as a basis for qualitative and quantitative descriptions of work practice,

information use and communicative practice. Presenting and analyzing the resulting requirements, and corresponding prototypes, is beyond the scope of this paper, but is the subject of further work. However, we have found that:

- observational frameworks must be adjusted to the domain and situation iteratively.
- observations, after calibration, are repeatable among trained observers
- parallel surveys, with the same actors, give results that are 'idealized' and deviates considerably from what we observed [14]
- the ability to control and focus the observations makes the method agile and efficient
- clinicians are used to being observed and followed by medical students, hence hiring apprentices for observational studies is very convenient, non-disruptive and efficient in our domain

We have gathered requirements for the mobile patient chart interface both from existing commercial prototypes, by traditional use-case modeling, trough participatory design and not least from ongoing design processes in hospitals. The requirements developed are surprisingly different, and complementary. We believe that structured observation as described here is an important supplement when planning and designing user interfaces to computer systems in healthcare.

Acknowledgements

We would like to thank the staff at the University Hospital of Trondheim for their cooperation during the observational studies. Thanks to Thomas Brox Røst and the referees for their comments which helped improve this paper.

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Paper H

Analysis of Communicative Behaviour: Profiling Roles and Activities

This paper appears in the *Proceedings of the 3rd International Conference on Information Technology in Health Care: Socio-technical Approaches* (edited by J.I. Westbrook, E. Coiera, J.L. Callen and J. Aarts). Studies in Health Technology and Informatics Vol. 130, pp. 111–120, IOS Press, 2007.

Paper H is not included due to copyright.

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