This dissertation is about support systems in use for coordination of advanced on-the-ground work activities. Focus is given to work in domains of health care and manufacturing. Both computer and paper-based information and communication technologies (ICT) are found to play an important role for coordination of nurses’ and machinists’ every-day actions. Within the vast field of Computer Science (CS), design and development of computer systems for support of coordination is an important undertaking. The research and development communities of Human Computer Interaction (HCI) provide practical and conceptual tools of interest for this study. In the research projects of which I am a participant and in the research community of Computer Supported Cooperative Work (CSCW), use of ICT in a work context is a central concern.

My interest is then oriented towards coordination, not in ordinary office environments, but in health care and manufacturing where the core accomplishment is realised in treatment or transformation of a material work object. This means a focus on documents as an expression of coordination and as integrated in a flow of work. My studies over a period of eight years, with nurses and partly with CNC machinists, have resulted in collection of a rich empirical material. Ethnographic studies, CS and the conceptual framework of Cultural-Historical Activity Theory (CHAT) provide data, the theoretical ground and methodological guidelines in this thesis work. From the outset, the design of computer-based prototypes for nurses’ documentation tasks are designed and tested. Further, the thesis highlight studies of employed and integrated technologies in the workplace, and wrap up with contributions to the design of computer support systems.

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Support Systems in Use - for Coordination of Advanced On-The-Ground Work Activities

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Abstract

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For a long time I have had the privilege to be part of a number of research and development groups. Those have been stimulating for my thoughts and interactions with other people. To finally make my time-consuming daily work to result in this doctoral thesis my teachers and closest collaborators are of greatest importance.

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I would also like to emphasise the importance of Yrjö Engeström's theoretical work as most influential on my making meaning of research and the world of peoples' work activities. Further, I have had the privilege to be acquainted with the Center for Activity Theory and Developmental Work Research, University of Helsinki (Recently reorganised and given the new name: the Center for Research on Activity, Development and Learning – CRADLE) and the Computer Science Department, University of Aarhus. Connected to those places and in international research environments, Yrjö Engeström and Susanne Bødker I would like to mention among all those who have inspired and been influential on my study.

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My co-authors Hannes Persson, Berthel Sutter, Paul Davidsson, Johan Holmgren, Dawit Mengistu, and Marie Persson have also contributed to the included papers and had a significant influence on my thesis work.
As the very prerequisite for this study are the workplaces at Ronneby Municipality Elder Care, and the manufacturing company Kockums Maskin AB, Kallinge. In the elder care I have “shadowed” and studied nurses, assistant nurses and other personnel. At the manufacturing company I have also shadowed CNC machinists and their co-workers and managers. Although without mention anyone with name, my sincere gratitude is with all the individuals who have allowed me to come close into their every-day actions and who have had a lot of patient with my field research work and me.

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Finally, I want to dedicate this study to my close relatives and especially to my children Måns, Anton and Ellen.
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1. Introduction

This study is about support systems for coordination of advanced on-the-ground work activities. On coordination of work, I use two perspectives, of which one is from a computer science position and the other is related to work science. Since work in some areas of society is increasingly influenced by computing technologies, advanced on-the-ground work activities is a particular interesting field for deeper studies. In such, as this thesis is an instance of, a tempting question is how computing fit to the workers demand of support in their activities, and further how such technologies can be better designed. Empirical findings from this research put forward the complexity of work in which human interactions are realised. Further, the findings reveal artefacts of various kind as indispensable components in the activities of which computers and computing are integrated and given meaning - to a great extent by the workers themselves. Consequently, the findings carries a message of design considerations for computing at work.

The expression “on-the-ground work” is perhaps felt as an awkward phrase but the dictionary explanation of a “place where real, practical work is done” seems appropriate to capture the particular interest in this thesis. Alternative expressions might be to use “shop floor work” or “front line work”, and even “non-office work”, in trying to pinpoint what is and what is not the field that is explored. In this thesis, the place of the research interest is alternatively denoted with help of the above expressions. Nurses and CNC machinists belong to very different realities although complex dependencies of other people and technologies is characteristic of both domains. Further, they also have in common that work tasks are advanced which means they must make accurate observations, measurements and alignment of their own operations with those of others. In contrast to the paradigmatic role of workers at the assembly line, they are mobile workers on the shop floor work! (the term mobile worker is adopted from Sellen and Harper, 2002). So, with my explicit interest of contemporary on-the-ground work, I aim at actions on and with the material world that are crucial for realising welfare.

During most of the time for my research I have approached humans at work and their interactions through computers with ideas and concepts of Cultural-Historical Activity Theory (Commonly abbreviated: CHAT. Sometimes the shorter ‘activity theory’, abbreviated: AT, is used, which I will do in the following of this introductory paper). From that, in this thesis, I get into dialogue with concepts of computing which attempt to deal with the same problems. The concepts of workflow, and connected notions of coordination, are not seldom used elsewhere in attempts to create machine constructs of essentially human capacities. One branch of the latter, of which I have been partly involved, is the development of multiagent sys-
tems which may effectively improve other technical infrastructures, but which in some cases is also considered as making the human out of a machine.

**Approach**

In my approach, I set out to explore the landscapes of work that is realised by practitioners in health and medical care and by machinists in metal manufacturing industry. Throughout all the studied cases of this thesis, the AT framework have been a reminder and a support in studies of activities in the field. Two questions have followed my observations of computing: how support systems for coordination are part of advanced on-the-ground work, and what it does mean for design of computing in such work. So, this thesis is conducted in line with what Kuutti (1996) suggests: activity theory as an alternative framework for Human Computer Interaction (HCI) research and design.

**Coordination and work flows**

Coordination is a key concept for a focus on what is going on at work and for understanding design of information support systems for it. Numerous examples point at a great potential with better interaction between people, computers and work. Concerns are raised about work that doesn't match expectations of doing the right thing at the right place while power interests are manifested in changes imposed by technology deployment. My understanding is that any individual, as for example a patient at the hospital or the worker on any workplace, is affected by actions made by other people and by phenomenons as technology might suppress or enhance. Regardless the intricacy of human power relations, evidently the work place realities are changing which in turn demand changed technologies in our lives. A great potential for improved better technologies is suggested, and often asked for, from highly complex work places such as those found in health care. Hendrich, Chow and Goshert, (2009) provide an example:

> Nevertheless, studies of medical-surgical units suggest that nurses spend only 31% to 44% of their time in direct patient care activities. Changes to the nurse work environment could increase the amount of time nurses have available for direct patient care by removing obstacles to the efficient performance of routine nursing tasks.

> The resulting Proclamation for Change, now endorsed by multiple health systems and professional and consumer organizations, cites patient-centered design, systemwide integrated technology, seamless workplace environments, and vendor partnerships as the cornerstones of transformational change.

The sought after change will depend partly on the technologies to be used. But what interest will be served, who will benefit and where to will a change lead? Those questions I argue is also a concern of the designers of
the same technologies. The complexity of work and the role a computing system might play, is a dynamic whole which demands a developed understanding of both the proposed system and real existing relationships of people and supporting artefacts in their on-the-ground work.

Consequently my choice of field is directed by a strong interest in cases of advanced accomplishment of treatment or transformation of a core work object. Prominently in the actual studies, such objects are in the first place a person’s illness and troubles originating in a skin ulcer or a wound that is hard to heal, and secondly it is cast metal to be precision machined. Even if those work objects are very different, they have in common a long history of development of pertaining materials and work methods. To meet current standards of such work, it takes advanced work performance, which connects and integrates actions carried out by several related workers over a considerable period of time. Coordination is required and is to a great deal taken care of by the workers themselves. Their practice is then characterised not only by actions of direct treatment or transformation of the work object, but also of talk and artefact mediated coordination that is needed for several peoples successful contribution to work.

The computing interest in this thesis recognises that coordination in the work place is realised through talk, but to a great deal also in writing and reading documents. Following is that the intriguing quest of improved support systems for further developed work, directs the attention to documents that are long-lived and concrete parts of a realised support system.

**Support systems**

What support systems might amount to, and how to design in order to achieve coordination, are then concerns addressed by this thesis. Since the approach is to a great deal to study actual systems in use from the perspective of the practice itself, I hope to be able investigate real world problems and suggest a direction for solutions of such. Questions about how workers’ individual contributions are performed and put together, and what role various artefacts play in their work activities, effectively instructs my choice of method and means of data collection, that is carried out mainly from within the workers’ everyday environment and circumstances.

To be very clear about why and how I try to grasp the reality of work and computers, I would say that my approach is to study people with ethnographic means in order to understand their way of doing and making purposeful achievements. From the beginning and throughout the thesis' studies, this has with a few exceptions been the fundamental way of performing my research. In that I follow practitioners closely at their work places, I am able to observe, and sometimes throw in questions, while data records are produced in close connection to the work actions carried out.
A challenge in trying to grasp such realities is that they often require a rich setting in terms of peoples’ interactions, their artefacts involved, and the dynamics of change and development of the practice itself. The world might seem to "be messy sometimes" but the ethnography reveals much of systematic dependencies, constraints and possibilities in peoples working life. The individual workers of today need to perform within complexities that connect, and coordinate to others’ work. A picture of systematic relations and patterns is then there to be studied. To make my approach even more clear, I can try to make a contrast and figure an alternative computer science perspective that takes a start from and within a technical, or to say a computational system. It would be feasible to collect research data as generated from, for example script functions that produce logs of peoples’ dealing with computers in the work place. To "reach out" from such a standpoint from within the technology and to see peoples’ interaction would for sure be delimited by the connected sensors’ capabilities. With no doubt, such produced data should contribute to work place studies. But to be effective and to keep up with a not too narrow view, I believe my ethnography inspired approach serves well.

From hand written notes, still photos, audio and video recordings, the studied work practices are found to be very organised with systematic relations that are possible to discern. The ethnography is then my way to approach people at work in order to collect data for this research. Further, based on my selected focus and the data, activity systems as understood by activity theoretical concepts, do emerge in my orientation that set out to capture the work practice details and their relation to a context on the shop floor.

As this thesis will prove, the approach is also a way to "reach in" and investigate computers and computation in the studied real world cases. The approach explained here is then fundamental in most of the included papers, as well as in the methodological section and other parts of the introductory paper. Nevertheless, I myself, and the co-authors of included papers, strive to use words and a language to not be concealed within a particular research community. My hope is that a combined computer and work oriented vocabulary, will be readable, although the next paragraph take up a wide world view.

In many parts of today's working life, division of labour has become ever more sophisticated. With the development of new technologies, an individual worker is able to perform tasks with higher precision and that is why even more accurate performance is expected than before. The output from each individual worker makes a very specific contribution to a whole process of realising a product or a service. To align those discrete contributions and to put them in a proper order in right time, coordination work seems as an increasingly demanding and crucial aspect of work. On a global level, a recurrent observation is that humans of all nations are deeply
connected and dependent of each other. On a local level, those dependencies are also there to see, performance of single individuals need to be coordinated and hooked into others’ doings and makings.

Ever since the rise of the industrial revolution new technologies have strongly influenced society. For many people their life is turned into hard labour in serving and attending to the machines. Although a new work order is proclaimed for capitalist production, there is still many places where repetitive and low skilled labour is the reality. Obeying orders and running the machinery is the legacy from mass production, in which central management and workers are related in line with the old work organisation model, see figure 1. As a case in point, immigrant workers at a California electronic board production company had to attend, on paid work time, a study program for thinking new and taking responsibility of change. So, even if the products in a sense were “high tech”, the continued organisation didn't differ in a significant way compared to the old way of management (Gee, Hull, and Lankshear, 1996). In such work it is still functional with a clear separation between those who plan and give orders, and those who perform and execute work. However, behind declarations of change, isn't it likely that some work is organised differently? The new discourse stresses the importance of empowerment. Gee, Hull, and Lankshear (1996) give an interpretation of the concept:

The new capitalism stresses fully informed workers who actively participate in the quality culture of the organization and have (and take) full responsibility for all the organizational ramifications of the jobs they do. This is what is meant by 'empowerment.'” (p. xv)

Consequently, the notion of workers participation and a changed view of production, might be taken as an ideal but not an accurate account of most of contemporary work. However, in other parts of production, the thing to make and the equipment it takes, do require a practice that is more complicated and not managed in the old way?

Figure 1 depict the straight forward way to organise work typical for the high time of mass production. Within parenthesis is added a reminder of
health care work as it was organised a hundred years ago. To great deal it was seen as a charity undertaking in provision for the poor sick. Since then it has developed much and today (at least in Nordic countries) are nurses', assistant nurses', physicians', and other health care staffs' work highly organised. In terms of technology use and complexity of work performance, this mostly publicly provided activities can be considered as roughly equal in scale and required competencies compared to manufacturing and other industrial domains.

Even if it would be valid with a study covering the whole range of places where work is carried out in practice, time and other constraints direct my attention to advanced on-the-ground work. There I find skilled nurses and machinists who perform actions that are different and often beyond the capabilities of other people at work. Information and communication technologies (ICT), and in specific computing, are taken as potentially important features of their practice. In following the more advanced workers and with an interest in technologies, the scope of this thesis is delimited and the attention is directed towards the practitioners' use of various kinds of documents at work.

State of the art

With the above presented approach, the findings of this thesis are discussed in relation to the above old model (see figure 1) and a revealed state of contemporary work organisation where support systems are in use. Documents are taken as very much an equivalent to a general notion of ICT that include electronic as well as other used materials and formats employed for reading and writing purposes.

The question if its is feasible to exchange paper with electronic documents are not dealt with in particular, but the role documents play in advanced work is a central theme in this thesis. Properties and affordances of paper and electronic documents in office work, are studied and compared in Sellen and Harper (2002). They conclude that the office is not paperless and they recommend development in which the different formats are better combined. Building on Sellen and Harpers' findings, Dahl, Svanaes, and Nytro (2006) report about field studies and laboratory testing of paper and computer documents in a hospital. They find significant differences between paper and electronic documents and suggest strategies for further development of pervasive computing in health care.

In a software development company Andersdotter (1999) study the role of paper and computing documents with similar method and focus as in this thesis. She finds that the cultural established notions of 'page' and 'row' on standard sized papers sheets (the "A4" size) is a practical measure in dialogues about a shared software design. She also observe the abundant occurrence of paper documents brought into design meetings and close to the computer when the individual write software code.
Karlsson (2006, 2009) recognises in studies of ordinary occupational work the prevalence of various literacy practices. Carpenters, truck drivers, assistant nurses, construction workers, pre-school teachers, and salespeople do write and read daily in a variety of modes. Findings from those above mentioned studies are to a great deal in line with this thesis, although here is provided an additional finding and recognition of workers as also designers of some document features.

Olsson (2004) has a focus on design of systems and interfaces for use by “skilled users” that have “major responsibilities, and perform work that demands efficiency and expert knowledge.” (ibid, p. 38) Her study has in some aspects a similar approach as this, and she is “interested in the actual work people are doing.” (ibid, p. 10) In domains of dentistry and driver environments in trains (p.11), Olsson has made ethnography inspired field work. Results are gained in an action research approach aimed at creating novel solutions, much in line with a Participatory Design (PD) tradition. The usability aspects of new computing design is emphasised and Olsson conclude: “that user involvement in systems design is imperative for increasing the usability of computer systems.” (ibid, p. 62)

In health care and peoples' home environment, Tap (2004) explores interactional features of technology in use. He has made ethnographic studies in which he “relied both on field notes and video recordings.” (p. 27) With an ethnomethodological understanding he has a focus on artefacts, not in isolation but as collections in mundane every-day use. It is about “how the user, using the technology, becomes accountable” and he states “Different interactional features give different accounts that make the work more or less visible for others to see.” (p. 41). So, an important finding is that people create much of their understanding and their relations in practice when actions are realised. Thus, his study has a similar approach and reach results that are related to this thesis.

My interest and focus is on human work and in particular the role and effect technologies actually do have on-the-ground work. Computers and software are today technologies that permeate much of work, in some cases with little but in others with significant computational powers. Peter J. Denning, a most distinguished representative of the ACM (Association for Computing Machinery), together with Craig Martel, articulates computing as a science in which nature itself teach us to make better computer technologies. The examples they draw on as arguments for what is called Great Principles of Computing (GPC), are found in biology, physics and

1 On a dedicated web site for GPC, the great principles are presented on an overview page: “Peter J. Denning and Craig Martell 6/18/07.

/.../ we concluded that computing principles can be grouped into seven categories: Computation (meaning and limits of computation); Communication (reliable data transmission); Coordination (cooperation among networked entities); Recollection (storage and retrieval of information); Automation (meaning and limits of automation); Evaluation (performance prediction and capacity planning); Design (building reliable software systems).”
astronomy. Reflecting upon those principles, I argue for also another source of inspiration to further studies of what computers can, or in a future, may be able to do.

In human culture, written signs preserved in some stone, paper or in other material, is the technology that has followed all known human history and will most likely continue to be an important precondition for further development. Written numbers and words are entities that permeate work and to a great extent other aspects of human life. Those material forms with signs inscribed into it, we often denote as documents that are various forms of artefacts that afford us to write, store, later read, and in many cases also to add more and further change its content. With a start in the 1940's and throughout the history of computing, numbers and words are the human readable representations that computer machines are able to interpret, do process, store and make accessible in another time and place.

Dealing with words and numbers is to great extent what ICT is about: to take advantage of a culture- historical developed artefact, crystallised as a little set of characters made integral to most parts of society and mediating much of our lives. The document and character combination is a technology that materialise the most foundational building blocks for the design and use of various information systems. Some types of documents may contain images, pictures and other graphics that is not written language characters. In later computer history, ICT is able to deal with also such forms of documents and in many ways expand and affect our use of both written text and graphics. However, in the actual performance of most tasks, the human mind is not primarily concerned to make a distinction between paper and computer based information. The content is significant while the form is secondary or simply irrelevant. As a researcher, I am able to have another angel in observing such practices. With interest in the relation between content and form of documents, I can gather data related to humans' interactions with each others but also study those technologies in use that make it happen – or cause certain limitations on what is currently possibly to do.

The thesis contribution

A summary of the thesis contribution is here structured in two parts: (A) the overarching contribution and (B) the more specific thesis contribution related to the third sub research question (q3). So, the overarching research question: How are support systems for coordination part of advanced on-the-ground work and what does it mean for design of computing in such work? - is supported by three sub research questions. Those are addressed below, and dealt with in a more elaborate way in the Results chapter. Within that the three tables 2, 3 and 4 summarise answers to the

three sub questions: (q1) What discernible practical uses of documents are of most importance for coordinating advanced on-the-ground work?; (q2) What document features are the most significant to coordinating advanced on-the-ground work?; (q3) How can this study contribute to the design of coordinating support systems? The third question, and related contribution, give emphasise to the thesis computing interest and adds more detail to the overarching question and contribution.

(A) Three main findings form the overarching contribution. Firstly in that, it is shown that the practitioners work to great deal rely on a coordinating framework (this is visualised in figure 6). Secondly, the thesis recognition of power relations within and between design communities do emphasise that practitioners, that is nurses and machinists in this study, not only use but on their own initiative take part in design of the support systems as they integrate in their work practice. Thirdly, in the practitioners'/workers' use of coordinating support systems they attend to double horizons of their activity system. It means they are, not only motivated by the actual transformation of the work object, but intermittently they realise a longer time perspective that includes the future of the same object.

(B) The second contribution part explains the coordination framework, which consists of a number of combined documents. Regardless if the document format is paper-based or digital, the following three features are of most importance: (I) To be sustained and integrated the document system must be re-designable to match changes in the work activity; (II) A new document component must be re-designable, that is compatible with the already integrated components in its appearance and ability to be combined; (III) A computing ICT support system will better serve coordination if on-the-ground workers are able to co-configure the system together with specialist designers.

Reader's guide
To get a quick grasp of the thesis the included 6 figures and 6 tables can be useful. Those are made to visualise core elements of this introductory paper consisting of 10 chapters. They are an integrated and condensed expression of the more extensive text, which in turn points to even more detailed accounts in the included seven papers.

Figure 1 (Chapter 1. Introduction) depicts the old view of organising work, typical of the age of mass production. It is a necessary background for understanding change of the mode of production and change of work. In the chapter my approach and the importance of support systems for coordination of advanced on-the-ground work is presented. The state of related research is outlined and the contribution of this thesis is briefly summarised.

The figure 1 relates to the history of ideas that still prevails. In figure 2 (Chapter 2, Two perspectives on coordination) the coordination loop visual-
ise a management perspective in accordance with the old organisation model (figure 1) while it is also an established computing understanding of work. Both the mentioned computing, and an activity theory perspective, is used in the thesis. This combination is presented in chapter 2, and so far the studies motivation and approach is explained. In chapter 3 (The empirical studies) is outlined the foundational interest and the empirical ground of the thesis that set out to capture actualities of every-day work in the fields of health care and manufacturing.

In chapter 4 (The problem of design for other use) I make “a gybe” in the journey of this writing, and turn in direction of the core theme of the research as this thesis builds on. Design of support systems for actual use is presented in which I find support in Engeström’s (e.g. 1987 and 2008) and an activity theory understanding of the key problem of design for work activities. The combination of figures 3 and 4 highlight a contradiction between systems for design and systems for use of the same design. Figure 5 also shows an alternative way to design.

Table 1 in chapter 5 (Research questions) list the included 7 papers and indicate their importance relative the thesis research questions. Next chapter 6 (Methodological approach) gives an extensive account of my methodological approach. It includes a chronological summary of performed empirical work. Among other things, it also presents an activity theory notion of the unit of analysis for research.

Figure 6 depicts the coordination framework, which is dealt with in chapter 7. The figure 6 is a very abstract expression of the thesis core finding and relates back to and offers an alternative view to the old model of work organisation (figure 1). It builds on the empirical work, the used two perspectives on coordination and the theme of design of ICT support systems.

In chapter 7 (Results) the thesis results are given a comprehensive presentation. Tables 2, 3 and 4 summaries answers to the three sub research questions while at the same time, the chapter address the overall research question. In addition, the thesis results and contributions are briefly sketched in this chapter 1, and more detailed accounts are also given in the included 7 papers.

Chapter 8 (Discussion of the empirical results) is a discussion of the empirical results, while it ascertain the change of work organisation and the workers roles. Concepts of workflow and possible advantages of new ICT technologies are dealt with in further reflections. Table 5 and 6 highlight my continued discussion about spatial and temporal aspects of coordination and support systems.

Chapter 9 (Overall discussion) brings this thesis in an updated relation to the concerned research communities and suggest a renewed stance for a Nordic approach to design.
Chapter 10 (Summary) provides a brief summary and wrap up the thesis.

Outline in three sentences: Figures 1 – 3 is the background and context to the thesis, figures 3 – 5 visualise the design theme, and figure 6 is the main finding which is also an alternative to the old organisation model depicted in figure 1. Tables 1 – 4 provide a condensed account of the empirical work and analysis as given by the included papers 1 – 7. Tables 5 and 6 visualise my discussion of physical distance and temporal aspects of support systems for coordination (see also the list of figures and tables in the beginning of the thesis).

2. Two perspectives on coordination

How coordination of work was conceived during the industrial era in 19th and 20th centuries, I take as similar to what figure 1 may suggest. Although it is a rough and average view, management in large organisations for mass production did have control of what, when, how and by whom work should be done. The owners, or their representative leaders, issued work orders, workers executed, and in some way the outcome was accounted for. That is the old way of straightforward coordination of work, although it is still a reality in many places. But, in ongoing and historical change of work, the roles and relations between management and workers are changing. Therefore, at some places of on-the-ground activities, new forms of organising and employment of new technologies, imply the rise of advanced work as realised by skilled workers. It can be assumed there are mainly two different perspectives on coordination which is indicated above in the introduction. In this thesis, what I for short denote as Denning’s, is the same as detailed in the GPC, to be considered as an authoritative computer science understanding. Another work oriented perspective I find in activity theory. In this thesis, neither of the perspectives provide a complete guidance, but the assumption is that the combination will serve to make more clear what is going on in contemporary work. In the following I outline coordination as understood in attending to the both perspectives.

A common explanation of "coordination" is to enable people and things to work better together. Research in different fields highlights coordination as means to explain a studied phenomenon or complex of reality, but due to the different character of research, different meaning is assigned to concepts that have the same name. Below in this section is on the one hand coordination as presented by Peter J. Denning, a representative and spokesman of ACM, and on the other hand an activity theory understanding. The two perspectives are explained through examples of which the last one is from the research I am involved in. To juxtapose the two perspectives in a context of advanced on-the-ground work activities I believe is
beneficial for both in creating a better informed knowledge. The perspectives will meet at some point, but to bring those different understandings of coordination into a boundary object (Star, S.L. & Griesemer, J.R., 1989) and make it work for both positions is a challenge. I believe it is possible but require analysis of observations from real existing work put together with possibilities inherent in computing as such. This attempt is truly in line with a fundamental tenet of this thesis, that is to follow and be inspired by a cross disciplinary approach to better understand human computer interaction. The thesis will present results but future will judge how fertile it is to merge perspectives on coordination.

Denning advocates in a number of publications (and in particular a given speech available on Youtube.com\(^2\)) that coordination is one of seven categories that clarify Great Principles of Computation, see e.g.: Denning and Martell (2007); Denning and Medina-Mora (1995). According to this ACM perspective, coordination does ”concern how autonomous entities work together toward a common result.” (Denning and Martell, 2007). The aforementioned entities are further explained as interacting agents that can be humans or computational processes. A graphical depicted ”action loop” has a requester and a performer identified in a relationship closed by ”four time segments culminating in request, promise, delivery, and acceptance.”

This model with a circular relation through four culmination nodes is taken as the foundational element of all coordination protocols that abstract the pattern of interaction among the entities, see figure 2. One such loop can be linked to other action loops which will result in a network

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called an action process or workflow. Denning and Martell claim that "Most individual human interactions are modelled by an action loop in which a performer delivers a condition satisfying a customer" (ibid, p. 2). Thus, the action loop is charged with a connotation of straight economical transactions taking place on an archetypal market place for exchange of commodities\(^3\). To make the model effective in work analysis, several such loops will be identified and connected on an action process or workflow map. In such mapping of work, speech acts are the crucial things to be attentive to:

> Constructing a map of the work flows as they are actually performed is a process of listening for the speech acts that trigger state-changes in the process (ibid, p. 49).

In given examples by Dennig and Martell, the processes of work cover an entire organisation or business with hundreds of people involved during a period of weeks or months. The created map is found as useful for management to measure production and spent time. Breakdowns or bad performance can be identified and a re-engineering of work might result in a significant change of sources of information as input to the process or in a reduction of not necessary action loop elements in the workflow. Denning in the youtube speech, and Denning and Medina-Mora (1995) emphasise as a key concern that work tasks shall be completed: "The common workplace expression 'closing the loop' signifies completion of a work flow." (ibid, p. 45) This concern for delivery is supposed to be shared among the workers as commitments in chains of requester performer relations. Explicit statements are the signs of commitments that are thought of as the driving force that make an organisation tick:

> This network represents a new conception of work as the fulfilment of commitments to some one's satisfaction. It displays how a small set of verbal statements (speech acts) drive the information and material processes of an organization (ibid, p. 55 Conclusions).

Apparently, such a computing perspective emphasises human's verbal statements as signifiers of commitments to work. But isn't it a management perspective with interest in a large enterprise? In the high-time of mass production, a centre of command for planning and control of hundreds, or even thousands, of peoples' work was perceived as feasible. The paradigmatic example of the Ford industries (see e.g. Womack, Jones and Roos, 1991) during the first decades of the 20th century is essentially

\(^3\) In Denning and Medina-Mora (1995) the same action loop is presented as a relation between a 'customer' and a 'performer': "The basic work-flow loop connects a customer (a person making a request or accepting an offer) and a performer (a person making a promise) in a four-phase cycle. The loop moves toward completion as participants make key declarations: (1) the customer says, "I request"; (2) the performer says, "I promise"; (3) the performer says, "I am done"; and (4) the customer says, "I am satisfied."
about a centre of command that managed to know enough and effectively control standardised work of highly standardised products typical for the technology advancements of that time. The individual worker's work was reduced and strictly confined into a few tasks. Those in turn were closely connected to an innovative combination of man and machines which effectively assembled many contributions into the final product. At the shop floor of such industries, orders given to a single worker followed a prescribed set of specific tasks to the particular machine and its required operation. Orders of what to do and accounts of work completion were at the time very much in the hands of management.

Advanced work of today can't be planned in detail and that is why decisions to some extent are up to the workers own local control. To coordinate several individual's work is actually one of the workers' ordinary work task among all the others. Activity theory offers a perspective on human work but doesn't promise a predictive view of what is going on. Instead, observations of a work context and its historical development provide a ground for analysis of driving forces and inherent contradictions that might be used for a deliberate change of the studied workplace. This also provide this thesis an object-oriented perspective on local circumstances which I find promising for an understanding of individual's coordinated work.

With use of a longitudinal study in the multi-organizational field of children's medical care in the Helsinki area of Finland, Engeström (2000) discusses activity theory as a framework for analysing and redesigning work. A physician's reading of lab results on a computer display is the starting point of an example of work.

As the observation is extended, the physician, assisted by a nurse, goes to an examination room to see the patient. The patient, a 1-year-old boy born prematurely and now with a chronic lung condition, has acute breathing difficulties. The physician's attention is now focused on the patient, and on the patient's father.

The physician makes a phone call and invites a lung specialist into the examination room. As she arrives, the physician lets her take the lead in the decision-making actions concerning the next steps of the patient's care. Within some 10 minutes a string of four rather distinctive actions was observed (Engeström, 2000).

So, the approach builds on detailed observations in the local circumstances of peoples' work. To make sense of the actions and analyse the potential for work development, they are taken as strings of “actions as successive, momentary instantiations of a wider and more stable system of collective activity.” For that, Engeström uses the model of the human activity system (Engeström, 1987, p. 78), see figure 3. In my discussion here, I use the above example to make the point that: how and in what order the actions
unfold, in what way people come together and interact, that is not possible to model and map to a computing system whatever the reason might be for such a digital execution. Many work practices as we find in health care, and elsewhere, can not be supervised from a remote position. Adherence to a map of requester-performance relations will not suffice because this kind of work is not motivated by a plan made elsewhere. The physician, nurse, specialist and the parent follow what sense they make in being oriented towards the child and its health condition. The activity system consisting of the child and father, the practitioners, and all the complexities of instruments, tools, methods, and developed social relations, are together what generate commitment to do the job. In the example, the child and its breathing problem is the object of work that motivate the individual's to realise the “four rather distinctive actions” that is “(1) reading medical records and test results, (2) examining and diagnosing a patient, (3) making a phone call to invite a specialist into the scene, and (4) deliberating and making a decision concerning the next steps of care to the patient” (Engeström, 2000, p. 961). An analysis of the observations makes it possible to unfold structures in the activity system, and possibly identify tensions as signs of inherent contradictions causing problems to desired functioning and outcome of work. No management or computational system can pre-determine the performance of actions in advanced work, of which the child hospital case is one example. But how about manufacturing work?

In paper 6 is given an example in which a machinist and an apprentice shall make a set-up for a new work batch in the CNC machine (CNC = computer numerical control). According to our observation, it is a work lasting about 2 hours, including actions of (1) collecting tools, material and documents, (2) lifting and alignment of a fixation device, (3) measuring, (4) loading material, (5) running a test cycle, (6) unloading machined pieces and grinding edges, (7) make a more precise measurement, (8) calculate further adjustments, and (9) changing the CNC software program. Indeed, in the set-up is used a folder document that list the procedure's ordinary production work on half a paper sheet page. In addition the list refers to other documents of other procedures, an engineering drawing, tools to be used and the Quality Control department as an involved resource.

For the machinist it is a demanding work in the centre of what is expected from him as a trained and experienced worker. It is reported that the set-up work is very seldom done in a way that result in a faulty outcome. Consequently, the machinist was fully alert and focused on the meticulous tasks of which most took place at the machine front, by the control panel, and at a table close to the machine. Repeatedly he moved back and forth between places for hands-on making and to a position where he was able to make an overview assessment of work in progress. The apprentice intervened at some particular moments when her reading of documents made it possible for interaction with the machinists. Actually she contributed in co-
ordinating the strings of actions that eventually completed the set-up work. A little talking interleaved their interaction but also other significant things were part of realising work. The tasks at hand to deal with were perceived by the workers through instructions and instruments mediating the actual status of work.

Measurements of the actual position of the fixation device in the machine front, sounds and a display of machine status during the testing cycle, the most sensitive instrument measurement of the machined cast pieces were only some of the actualities the workers included in their advancements towards completion of the set-up. So, as a very abstracted account, the combination of the metal material to be transformed, the fixation device and the CNC machine was: the work object the workers attended to; and the tools, instruments, and documents integrated in actions required to complete the work.

In activity theory terms, the actual status of the work object where mediated through tools, instruments and documented signifiers. On ground of that, the workers made their decisions and acted on the object in which wrenches, hex key tools, machine controls and more other artefacts mediated the actions in which the cast metal pieces were transformed. The documents integrated in the work functioned as footholds coordinating on the one hand the individuals own actions and on the other hand a coordination of the both workers contributions. Further, after the set-up, the actual document folder, now brought back to a more office like place at the shop floor, is a support for an account entered into a distributed computational system. Thus, knowledge about performed work might be used for coordination in the overall management system.

To wrap up the two perspectives, I find the Denning/ACM perspective concerned with overall management, to capture an entire business in order to reengineer its effective organisation. The activity theory with its foundational idea of mediating artefacts develops its perspective in the local circumstances in which peoples' doing and making are motivated by the work object. Support for coordination of such work is about the individuals idiosyncratic actions, and the more standardised actions to be coordinated with others. The individual coordinates actions for her or himself, such as the machinist in the above example, who interprets the alignment of the machine device, reads an instruction document, or either makes a more precise measurement or physically changes the position of the device. To continue the example: in another instance of work, the two machinists coordinate a proper preparation of the machined metal to be precision measured by other workers at the supporting Quality Department.

My conclusion of the two coordination understandings is that the Denning/ACM is focused on the construction of and commitment to follow a plan, while activity theory is attentive to analysis of actual work as it is mediated by artefacts in actions oriented towards the activity system's ob-
ject. The activity theory analysis might result in revealed disturbances as signs of contradictions affecting the activity, and also as ground for deliberate changes and development of work. Both perspectives can be used for understanding work, but the outcomes will most likely differ. Of special interest for both perspectives is when documents and computing systems are present at work. Coordination and drivers of actions are of mutual interest, although suggestions of design and further development of support systems is likely to differ.

3. The empirical studies

The thesis include papers from mainly two work domains, elder care and metal manufacturing. The practitioners are not stationary servants but moving workers with a presence in places distant and close to distinct work objects. Computer and paper-based documents play significant roles in both the studied domains. Since work of this kind will remain as central to society, it is somehow embarrassing that relatively few research studies are conducted with a focus on the actualities of everyday work in such activities. This thesis intend to contribute to a counterbalance and put the light on mundane but necessary and valuable work.

Throughout the thesis studies, document related actions are found to connect people with their own ongoing tasks and with other peoples activities in other place and time. The document actions actually do occur on-the-ground work and even so in very close presence to the work objects. A recognition that conditions and restrictions for performing such document actions are different, would for sure be interesting for aspirations of software-computing deployment. It is not the same to read and write in a physical environment very different from a regular office furnished place. Perhaps that fact is also an explanation of why rather few studies are conducted in such proximity to non-office objects. When considering the type and place of work, Swenson (2008) discusses what is reasonable to automate and what is not with an information system:

For example, driving a forklift to load goods from a truck into a place in a warehouse. Or to perform maintenance on a piece of equipment. It might be possible in the far future to automate these tasks with robots, but there are significant barriers to automation due to the physicality of the task (italicizing: HK). For the time being, we must treat these as human work.

With the examples given in the quote, articulation of the physical aspects of some work help to distinguish those work domains I regard has given too little attention from research. In advanced work at the shop floor the manufacturing workers do drive and operate some fork lifts while other lifting and transportation tasks actually are automated with robots. The physical aspects do matter in a fundamental way and will do so as long as people are workers. Advanced on-the-ground work such as nurses' and ma-
chinists' will most likely remain as long as patients and precision made metal components need some hands-on work. Inevitably, the physicality of such work will also remain but what role might documents and information systems have in the future? That question and the presence of people and the physicality of places where advanced on-the-ground work activities are realised, are the phenomenon that give this thesis its character.

In the following of this section I refer to research positions that are of importance as a background to the thesis. First I briefly explain the take off in research and development projects I have been involved in and then relate to the broader research communities. With reference to research with similar interest and approaches I argue for a better recognition of studies in actual circumstances of practice for the sake of better computing systems as support for peoples work.

From the outset, this studies build on research & development projects that had a design outcome that resulted in the Hedwig and Helar prototypes (see paper 1, 2 and 3). In those, key concepts for the software-computing work were built on data obtained from nurses acting as informants about their practice and as the subjects in ethnographic studies of their field of work. The main approach in later projects have had a clear ethnographic orientation in a number of case studies at nurses’ and machinists’ work environments respectively. The researcher has then entered into the field with a driving force to explore peoples’ interaction when and where they get their things done. Of interest has not only been what is going on in the computer interface, but also the rich flow of events - into which people integrate the use of various technologies.

The interest in people at the workplace require an attention to both human-human interaction and their interaction through and with artefacts such as computing systems. While technology advancements make new solutions attractive to work, the question is if the problem is understood and the intended solution is a good match. With increased complexity of work practices, the deployment of an ICT system becomes a considerable undertaking. It is a risk to impose a bad fit, or if understood and designed accordingly to the problem a new system might be beneficial for work. In a study using participant observation, interviews, and document analysis on the deployment of an Electronic Patient Record (EPR) system, Berg (1999) gives a detailed account. The advantageous of the EPR he explains with use of actor network theory concepts. As an intriguing example of the coalesced technology, he denotes order forms and other parts of the system as reading and writing artefacts that accumulate inscriptions and coordinate activities in the work practice. Regarded as a whole, the practice and the EPR is analysed with a computational fluid balance of a patient as a case in point. Berg summarises the potential with new technology:

In these terms, the coordinating and accumulating activity of information technologies can be characterized as affording an increase in complexity of the work.
practice without a simultaneous increase in complexity in individual interactions. Through the coordinating and accumulating activities of information technologies, the reach and/or intricacy of a practice's worktasks can increase. Through mediating and stipulating inscriptions and activities, doctor-nurse cooperation remains doable, and a continuously up-to-date fluid balance becomes possible (Berg, 1999, p. 391).

With ever more specialised knowledge and technical solutions, in the hospital and in other workplaces, work practices will benefit from enabling technologies such as the above mentioned. To achieve that, an alien position for design and construction of computation is not likely to be successful, not a least for the projected users – at the workplace. Design, inspired or more strictly directed by computer science, will intervene into peoples life if employed in their every day activities. This is a consequence more influential in a context of established social relations, and more prominent the more complex those relations amount to. Any designer might then account for his or her decisions. They will eventually make a difference, especially in purposeful human work, if their products are employed. This responsibility calls for an understanding, not only of the technology per se, but also for the intended practitioners task of taking care of the novel design. A computing designer is, like an building architect, inevitably also an interventionist in the society. This is a reminder to be aware of, and not settle for a reductionist stance in all aspects of development of computing systems. Nardi and O’Day (1999), who consider themselves as critical friends of technology, urge people to get involved in technology change:

> We believe that the lack of broad participation in conversations about technology seriously impoverishes the ways technologies are brought into our lives. Our aim is to show how more people can be more fully engaged in important discussions and decisions about technology.

The above message I take as also valid for those in a special position to shape new computing systems projected to be part of other peoples lives. To use the words of Nardi and O’Day, the spotlight should not always be on the technology “but on human activities that are served by technology.” Further, Nardi and O’Day define what they call information ecologies as “a system of people, practices, values, and technologies in a particular local environment.” (1999. p. 49). For me, investigations in local circumstances is a path for specialist designers to understand better the power relations that are at stake and what fruitful technology development that is possible to achieve. However, an ideal of harmonious and “seamless” integration of technology I find as a futile aim. Change at the workplace is ongoing and there will always be gaps, conflicts and inherent contradictions to argue about and try to reach negotiated solutions for.
4. The problem of design for others use

In this chapter we leave the background and turn towards design and its inherent problem. In the tradition of CS, much of creation and design of computing systems is taken as the sole concern of educated and trained specialists. In many cases that is truly a reality since decisions about others use is actually taken by specialists in their own specialist activity systems. Thus, the context of decisions are often alien to the context in which for example a health care support system is intended to be used. Since computing involves complex and intricate technical solutions, this problem will more or less always remain. But how to tackle it and find advantages ways to deal with design? This question has followed throughout my research and in this chapter I take Engeström’s (e.g. 1987, 2008) understanding of the design problem and use his triangular model of an activity system to support a theoretical outline of the central theme of this thesis.

For exploration of advanced work, that is not office work, this thesis has a point of departure in cases focused on front-line workers in their everyday activities. For analysis of how people and their artefacts are related and part of a context, activity theory has provided guidance. A few key concepts are the components in a frame work that is widely used, especially in detailed studies of the local reality in the field of peoples activities. Work of our time is to a great extent specialised and that is truly a fact in all the cases of this thesis. To get to grips with what other people do and are able to, the researcher most often try to look into a reality as an outsider in order to understand something he or she is unfamiliar with. In activity theory, human abilities are understood as the result of the historical development of artefacts of which some are made integral and important in a particular activity.

According to the theory, the notion of mediating artefacts are fundamental and useful for understanding human perception and doing and
making in the world (Vygotsky, 1986). To be emphasised is that all man
made things: language, symbols, physical tools etc, do have a mediating
function that is foundational for the culture we live in. But, with division
of labour and specialisation of work roles, people develop skills and their
familiarity with artefacts in different directions. Especially in more stable
and sustaining communities engaged with transformation of a work object,
a particular set of skills, tools, instruments and systems is developed. Con-
sequently, most individuals are to be considered as “outsiders” to most ex-
isting activities, of which each is strongly related to a particular com-
munity of people that are the “insiders”. The few concepts of activity theory
I find useful in attempts as a researcher to look into and make meaning of
a studied reality.

As visualisation of the central few concepts of activity theory, the well
known and much used triangular model helps to depict a perspective on a
studied case of work, see figure 3 (Engeström, 1987, p. 78). It is created by
Engeström and is built on the notion of human activity, which in turn is
Leontiev's extension of Vygotsky's ideas about perception and social devel-
opment in artefact mediated cultures. In analysis of an activity, the idea is
that the six nodes of the triangle do have real counterparts and that thor-
ough observations provide data that are analysed according to the model.
However, a triangle is only a snapshot of reality in which the analyst take
the perspective of the chosen subject that is a single person or a group out
of the community of the activity.

A series of triangle models will provide more to an understanding in
which for example the object component of the activity will be the common
denominator. Such a series of triangles can then reveal important changes
in the object and the subjects contributions to transformation and produ-
cing an outcome of the system. Further, the idea of using the model is to
identify contradictions, inherent in the activity and in relation to other
activity systems. It is depicted with an arrow headed lightning symbol
when a contradiction is found to be aggravated and affecting the studied
system. The identification can then be used just as an analysis result stat-
ing that the particular contradiction is of importance, but it can also be
more deliberately used for finding potential development outcomes in
change of the activity. That is the method of Developmental Work Re-
search (DWR) in which the analysis is continued in creation of potential
solutions to problems caused by the contradiction. Those are preferable
created in a collaboration with the activity community, which also in fur-
ther steps develops a design for change to be implemented in their live sys-
tem.
In the studied cases, the practices are much influenced by the existence of world wide markets for computers and software. In ever more accentuated specialisation, computing tools are made elsewhere, but deployed in the nurses' and manufacturing workers' practices. That is also here a fact, but one important exception in the manufacturing company is presented in following result section and in particular in paper 7. However, the market influence accentuate the problem of how advanced computing technologies are created, introduced and made part of ongoing advanced activities. Actually, this is the associated theme of our studies in the field. Contradictions are always inherent in one activity system but also in relations between two or more systems. In the production of complex computing systems, it is likely that the contradiction with a “consumer” activity is sharpened and the consumer part will experience severe problems in trying to integrate the new in their context.

In activity theory terms, it is recognized as a contradiction between the first activity of which the computing product is their object of work, and the receiving activity of which it is a tool to be integrated. In several studies this contradiction is found as causing severe problems (e.g. Hasu & Engeström, 2000; Engeström and Escalante, 1996) that for short can be described as two different activities developed too much in isolation from each other and that can not easily be brought together. Figure 4 illustrate the problem in which the lightning-shaped arrow indicates the contradic-

Figure 4: The contradiction between a delivery and a receiver activity system.
tion. In the figure I use as an example, a health care activity system as a recipient of a new computing system. The health care staff will regard it as one new tool among the other artefacts in use in their activity. The left triangle depict the activity system of the producer of the computing system, to be delivered to a very different activity (to the right).

With a historical time perspective, we witness an increased division of labour and consequently ever more technical specialisation. To make computers and software not only for its use value, but also for its exchange value as a commodity on the market, do have consequences. There is an interest to design a commodity, not for a particular use context, but as a mass market “shrink-wrapped” product. Delivery and attempts to deploy complex new computing systems are likely to cause problems with “gaps” and necessary adjustments, configurations, and learning activities to take care of by those who are the customers and receivers. In some cases, if the relationship is distanced with little connection in-between, or plagued by differing interest, the contradiction might result in a final rejection.

Engeström and Escalante (1996) give an example of rejection and provide an activity theory analysis that explains an important reason why a design and delivery of a postal service kiosk failed. A company set out to develop kiosks with an embedded, and networked computer system: “The Postal Buddy was a free-standing electronic kiosk that was supposed to enable immediate, online change of address as well as easy purchase of customized business cards, address labels, and stamps.” (ibid.) In a few years a couple of hundred kiosks were produced and installed in post offices in Washington D.C. and San Diego. With a contract aiming at deploying kiosks throughout the whole US the company formed a coalition with a design company. In interviews the producers explained that the Postal Buddy was meant to attract users in a human-like way, invoking affection. But the users at the local post offices had troubles to operate the machine. Left with frustration they didn’t experience feelings of affection for the kiosk. So, part of the explanation of the failure was that the love idea caused severe problems. In the end of 1993, the whole project was cancelled. Based on their analysis of the Postal Buddy case, Engeström and Escalante declare that: “What is meant to function as a tool is easily turned into an object; an instrument becomes an end in itself. Complex material and symbolic technologies demonstrate this tendency of displacement particularly strong.” Consequently, it can be stated that the contradiction between a producer and a receiver activity system might cause severe problems. The Postal Buddy case is an example of when the contradiction between the activity systems is ignored:

Although Postal Buddy Corporation and EDS [HK comment: Electronic Data Systems, an affiliated company that helped with government relations and financing] made some 350 modifications in the machine, they seem to have had little, if any, interest in reformulating and renegotiating the relationship between
the Postal Buddy kiosk and the rest of the local post office activity. The local post office remained a blank space, a missing link in the Postal Buddy network. The Postal Buddy kiosk was to be self-sufficient and independent of whatever else was going on in a post office (ibid, pp. 368, 369).

The same contradiction is prevalent in producerreceiver relations and typically it is more accentuated, and potentially troublesome, in the development of specialised and complex technologies such as computing systems. The figure illustrates the relation where health care staff are the intended users. In this thesis, empirical work provides several examples of tool - object displacement although they are not pointed out in the papers 1, 2, 3.

In Hasu and Engeström (2000) a controversy between a computing specialist and health care staff, illuminates when the contradiction between a producer and a user activity systems is aggravated in the sensitive phase of transfer of new technology into a hospital setting. On a planned test and service visit, but not announced for the users, the specialist is focused on the neuromagnetical measuring system (MEG) as the object in centre of his attention. At the same time the hospital staff is struggling with making sense of extensive gadgets and troublesome readings in a measurement procedure that is experienced as uncomfortable for the patient.

In a moment when the staff and the specialist meet, they get into interaction with statements about the MEG which not really reached an understanding but demonstrated a clash of, at that moment, different interests and angles on the new thing. However, the clash was not blamed for any personal bad feelings, instead it was taken as an indication of systemic relations inherent in the constellation of the both activities as the individuals belong to. Hasu and Engeström emphasise that tension and conflicts may be caused by historically formed contradictions:

Tensions and conflicts, more or less visible in a setting, are historically formed. The tensions and conflicts inherent in the setting may be seen as manifestations of systemic contradictions within and between activity systems that partake in the innovation process. Activity theory regards contradictions as moving forces of change and development in the innovation process (Hasu and Engeström, 2000).

Clearly it is very difficult to imagine and foresee all the things involved in future use of the artefact to be designed. In a similar way it is also very difficult for the practitioners to have a thorough understanding of the specialists' complex tasks in the technical domain. In the first three papers included in this thesis are reported computing as prototype production for potential further development and use by nurses in municipal elder care. A distinct clash between computing developers and health care staff is not reported, but the prevailing contradiction between specialists tool producing activities and the receiving use activities are evident. Nurses' work as characterised by attention to people and their health problems have its own pace and modes of interaction that is different to the realities of soft-
ware and computer design in environments that is more like ordinary office work (see an account of software developers work in Andersdotter, 1999). Default size and organisation of the computer display is due to desktop office work while it is not compatible with the nurses' developed practice.

Several ways to alleviate the typical design contradiction is tested and struggled with since the early years of computing. However, the problems still remains and I argue that the users', or preferably the practitioners' way of working and their demand of better tool support could be much better coordinated with the activities of specialists. Questions about Why, How and What new tool to be introduced in, for example, a health care activity might be better made as a concern for the practitioners and possibly also for their decision. Even if specialist work is a considerable undertaking, the intended recipients interest and involvement in the design should be possible to coordinate with decisions about and production of the technology.

When specialist competence is closely related with the design recipient activities, and construction and change of the technology is an ongoing effort, then the design contradiction can be handled in another way. As an instance of what Engeström call knotworking (2008), the studied MPS-system at Kockums Maskin AB (paper 7, see also about "Material Produktion och Styrnings"-system in Olhager and Rapp, 1985) reveal another pattern of relation between different activity systems, see figure 5. In that case, software-computing specialist are employees at the same company as the machinists who are among all the other staff that are the users of the computing system. There is no production for a market but it is an in-house development for the company's own benefit. At recurrent occasions at the company, the computing activity system is combined with the workers which in transient moments of time switch into a tool producing activity

Figure 5: Activity systems in knotworking.
with much of rules, tools, people as the same as in their ordinary work
activity. This is possible since division of labour is not rigidly constrained.

What it takes is a lot of coordination, in the actual case, partly made
possible with short physical distance between the specialist and the practi-
tioners. But, according to the analysis, the historical background date back
to the 1960s of the company, which has maintained computing tradition as
an in-house competence. It is found as most important to successful com-
puting where the users, with their specialists' support, design for their
own use.

Dependent on how design activities are organised in regard to people's
relations, the technology as such will be affected. In the manufacturing
MPS case, the on-going design where both workers and specialists meet,
the actual formation of computing concepts and constructs such as soft-
ware objects, networking, data base structures and users interface design
seems to reflect the social character of production of the computing system.

5. Research questions

The study's focus, research questions and contributions

My tighter focus on support systems for coordination directs me to be at-
tentive to "document at work" that on one hand is to study computers, soft-
ware, and other ICT artefacts; but also, to follow human actions and opera-
tions. As an expression of my focus, the overarching research question
for the thesis is the following:

- How are support systems for coordination part of advanced on-the-ground
work and what does it mean for design of computing in such work?

Related to the above question, the thesis intend to also answer the more
specific sub questions (where "documents" are understood as ICT regard-
less of paper, computer or other format holding a content):

(q1) What discernible practical uses of documents are of most importance
for coordinating advanced on-the-ground work?

(q2) What document features are the most significant to coordinating ad-
vanced on-the-ground work?

(q3) How can this study contribute to the design of coordinating support
systems?

The included papers provide reports of the empirical ground of the thesis
but also findings relevant to the various communities and publications in
which they have appeared. In this introductory paper the papers are used
as references to further analysis and answers to the above questions. For a
coarse-grained overview and the papers importance relative the research sub questions, see table 1.

Table 1: The included papers and related research sub questions.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Title of included paper in the thesis</th>
<th>q1</th>
<th>q2</th>
<th>q3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wound Care Documentation at Municipal Elder Care.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>What does it take to replace an old functioning information system with a new one? A case study.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Who is involved in HCI design? An activity theoretical perspective.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Applications of Agent Based Simulation.</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The Role of Paper and Digital Documents in Bedside Nursing Activities</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>6</td>
<td>Office Work in Shop Floor Work. A Case of Cast Metal Machining</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>7</td>
<td>Co-configuration of Computing Towards New Forms of Manufacturing Work</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

Findings of discernible practical uses of documents are based on materials collected from the chosen fields. In my analysis, it appears that nurses' and CNC machinists' use of documents is related to front-line work, i.e. work with the direct care of individuals or machining of metals. This use of the document is in turn linked to the design of these documents. Such design is partly the product of others' professional work, but not infrequently and to some extent also by those who will use them, such as the studied nurses and CNC machinists.

This thesis contribution is an attempt to answer the above questions. Briefly summarised the answers can, on the one hand provide insights into coordination of on-the-ground work, and on the other hand clarify boundaries of computer technologies and identifying the most promising development areas for future applications in such work.

6. Methodological approach

This study is carried out within computer science while it has a particular emphasise on computers and software as part of people's work practice. The title of the dissertation points to a focus on the coordination of activities "on-the-ground work", i.e. where work is oriented towards complex tasks that are not like ordinary office work. Through a compilation of seven articles that report from a time period of eight years, the empirical
work and reached analysis is here presented. In this introductory paper I have explained the thesis overall approach, research questions, its methodology, and the main discussions and conclusions to be drawn based on the empirical part, but I also try to put this thesis in alignment and discussion with related research areas.

This section "Methodological approach" intends to explain some methodological considerations about the chosen method and related techniques for data gathering.

**The study's main task and the ethnographic approach**

The study's main task is to examine coordination in on-the-ground work in contemporary practices, but the study also set out to identify development opportunities for improvements in the fields of computers and work. In order to successfully achieve coordination, it is assumed from the start of the study that documents of various kinds (predominantly on paper- or computer-based), do play a substantial role in the studied work places. Some documentation system is presumably established in practice ready to be examined in aspects of both content and form, regardless if the storage medium are computerised or paper based. Documents exists and permeates activities in the traditional office, but are also observed to be utilised in different kind of other workplaces. Thus, documents are taken as vehicles on a journey into coordination of on-the-ground work at the shop floor.

In this research I have an ethnographic approach in which I use myself as the data collector and record keeper of observations in the field. The captured data is thus connected to events on a full range as they take place in the actual work practice. Since the practitioners are very much "on the move and on the go" when they perform work "at the front of a machine or at the bed-side of an elderly", the researcher must also move around and follow closely. In such circumstances I have made records when acting like "a shadow" (Sachs, 1993) to a nurse or machinist. To follow with the practitioner in the field like that has had the advantage of an authenticated and approved presence in the studied work context. However, my ability to write field notes and make audio or video recordings are challenged by the material environment factors and sometimes by the practitioners' "hands-on" actions with effects up-on people or machines. Another difficulty is not to interfere unethically into individuals' life which sometimes and promptly restrict the researchers record keeping. Sometimes it is only possible to look and listen, but as soon as possible in a different place, recall and write the notes. On the other hand on other occasions, I have been able to directly make records of work practice carried out on the shop floor. In each such observation, it is the actual circumstance as it unfolds in the present situation, that determines to what extent and with what means the researcher can produce the field data documents.
Computer prototypes as products in joint development projects

In the first years of this study, I was responsible and partly initiator of two computing development projects. In autumn 2001 within the frame of a regular "project course", undergraduate students developed a computer prototype named Hedwig. It was intended for integration of digital photos with notes on performed care measures. Nurses in municipal elder care expressed a need for a more unified and better support of their regular treatment of wounds that are hard to get healed. Written notes in combination of digital photos were thought to better support nurses memory and their assessment of the healing development. Since it is a very problematic but a potential successful treatment, proper actions and a long time perspective are decisive for the actual outcome. Questions about "what is going on?" and "where-to is the healing process developing?", those were thought to be better answered with help of a series of photos on the wound put in combination with the nurses written statements.

The same ideas that triggered the first was also maintained in the second larger project during spring 2003. Students belonging to the study programmes "software engineering" and "people, computers and work" made another computer prototype named Helar. In this project more resources where allocated and two students made initially ethnographic field studies which are part of the empirical material for this thesis study. Most work in the project was carried out as a regular software engineering undertaking but the requirements for the product was very much determined by on the one hand nurses' needs as captured in filed studies and in a series of three participatory design (PD) sessions, while on the other hand a computing inspired idea of a peer-to-peer architecture for the prototype was also implemented. A methodological reflection asserts a very promising approach in which the nurses in the project designed most of the data content and the outline of the computer interface.

Since the project realised what the imagined photos and notes integrated could mean to the wound care, some valuable insights were gained from an effort of introducing a new technology in an established every-day practice (see in particular paper no. 1, 2, 3). Another lesson learned from the attempt to introduce a peer-to-peer networked prototype, is the overwhelming complexity to make it as an adaptable component in an already established computer infrastructure (see paper no. 1 and 2). It can be judged today as a fairly naive, but not the less a well-meant, initiative to hook a slightly different piece of software into an established computer operative environment with a rather alien culture of computing support. Not at least, the experience is a reminder of the delicate and complex quest it is to strive for interoperability within the Swedish health care system. Perhaps findings from another work context can be a productive source of change. In the metal manufacturing settings, a long and matured tradition
of maintaining a software-computing development capacity within the organisation, is perhaps a positive lesson (see further paper 7)?

Problems between Computer Science and working life

In academic disciplines of Computer Science (CS), design and development of computers and software is often perceived as something that professionals exclusively do. They are considered to make a relatively finished and complete product to be delivered and put into operation in other peoples work places. In such a producer-receiver relationship, those who receive are supposed as "non-specialists" in respect of computing. Also in this study, such taken for granted relationship is maintained in the relatively small development projects carried out in collaboration between students, researchers, and practitioners primarily within municipal elderly care (see paper 1, 2, and 3).

With a flavour of participatory design methodology (see for example: Kensing, Simonsen, and Bødker, 1998), the above mentioned Hedwig and Helar development projects have included different types of practitioners' influence on product development, but nonetheless, to a great deal they can be characterised by the predominant model of how to produce computer applications today. However, throughout this thesis study, the method of computing as exclusively a matter for only specialist developers, is questioned because of two reasons. First, recurrent efforts and struggle to adopt a computing product made by alien people at unfamiliar other work places, is a haunting problem that not least in the health care sector is reported to cause frustration and unpredictable difficulties. Second, in the empirical studies (in particular, see paper 7), the paradigm model is questioned by the practice itself since it is found that contemporary but not very much recognised computing does exist without clear demarcations or deep trenches separating people of different competencies.

Models for design and development of an inevitable contradiction

Computer science includes a variety of methods for design and development, ranging from the famous "waterfall model" as the extreme idea of strict separation, over various forms of iterative and incremental development, and, as an assumed other extreme, a model that emphasise "participatory design" which invites the non-specialist in moments of design and development. In efforts within the framework of activity theory, and in particular the Finnish experiences of Developmental Work Research, there is a theoretical approach to explain the intractable problem of delivery and adoption of instruments, systems, or tools developed and manufactured by another activity system. With use of the well-known triangular model of activity systems, the coordination between a tool-producing and a receiving activity system is illustrated as a contradictory relationship, see figure 4.
To me the contradiction is a promising source for focused studies in all kinds of producing and receiving relationships that is outlined above, and it is also a recurrent theme of this thesis.

The focus on advanced on-the-ground work

Academy's relationship to the surrounding society's working life is in many ways problematic and, as I believe, it has a great potential for improvement. A similar producer-receiver relationship as outlined above, is also commonplace with a contradiction between specialists who construct ICT-artefacts, and other generally considered non-specialists that are intended to take care of what is delivered by the former. It is to me an attractive challenge to further explore the contradiction between a research world and the surrounding society which encourage and fund the research in question, and which hopefully will be able to take advantage of it. Who receives and what are the implications of those external influences of research and development? Such questions leads me to the areas where an ICT-artefact is not the core thing to produce, but instead may be an integral and supportive component of everyday work.

The encounter between an ICT-artefact and an everyday activity of a non-office like character is a demanding but probably also a rewarding choice of study. When development of new technologies face the resistance of ordinary human activities that are central to survival of the society, it becomes harder for the researcher to get close, but on the other hand, findings will rest on a solid ground common to many people. In this study, the nurses and their colleagues who work in municipal elder care, as well as CNC machinists in manufacturing work, are cases of work on the shop floor. The expression front-line work mean to me, that it is there at the front, the workers performance realise the crucial transformations and changes needed to achieve desired values, and valuables, in our society. For the foreseeable future, the studied fields will continue to be central societal functions, while for sure they can benefit more from better ICT-artefact support.

Unit of analysis

For a computing system to be integrated successfully it takes coordination that has both a “technical and a social” character. Such adoption often requires significant change and deliberate actions to bring about improvements in the work place. But integration and alignment of everyday tasks is also and always a current and integral part of the actual execution of work. Therefore the object of analysis for this thesis must be restricted to be manageable while it also need to cover both technical and social aspects of the areas studied. My perspective is influenced by cultural historical activity theory which provides me with a few strongly related concepts.
Those are in a dynamic and dialectic relationship the building blocks in any activity system that functioning as a comprehensive unit of analysis, and as such it is also used in this thesis. According to activity theory, human activity is motivated by an object that is to be transformed. Further and still in line with the theory, since all purposeful activities do have a core object, it is fundamental to find a unit for analysis that capture it but is also meaningful for understanding the dynamics that change and transform the object. The least meaningful unit for analysis is thus taken as a guide in finding the material, tools, and systemic relations in which a group of people form one system, assumed to be motivated by one core object.

An activity develops its own history of which (according to Engeström, e.g. 1987) can be discerned six systematically related components: the object of the activity; a community of people who are motivated by the same object to perform actions and operations in order to transform it; a division of labour with roles distributed among the people in the community; a subject, or group of subjects that are members of the community, selected for a particular analytical consideration of the system; the artefacts that can be all kinds of instruments, symbols, concepts and support systems which mediate the subjects’ interaction upon as well as the response from the object; and a set of formal and informal rules established to keep the activity system maintained and operational (see also figure 3). Thus, an activity system has an object oriented character that develops historically. In this thesis, purposeful human work in elder care and manufacturing are studied, and in each case one or several activity systems do have its own object, such as the ailment of an elderly person to be treated or a cast metal to be machined. In this introductory paper I frequently denote such an object as "the work object", or "the object of work" in line with the studies focus on coordination of advanced on-the-ground activities.

An activity system can thus be studied through this object oriented perspective, but also indirectly through the kind of and configuration of integrated artefacts, but also with attention to every other related component. In this study the work objects are constituents of work for fulfilment of needs dependent on primarily substantial material conditions in the real world. According to the theory, the driving forces within and between the activity systems are understood as contradictions which are more or less influential and determining the possible direction of an ongoing development, or degradation and eventually a major break-down of the system. With an activity theory inspired analysis, the activity system is taken as the prime unit in order to find the dominant contradictions, and based on that, avenues of development and change might be revealed. Such a fully fledged analysis requires a broad and deep investigation of the historical and present circumstances. All results and the following conclusions are dependent on the quality and completeness of its empirical ground, which
in activity theory studies are data mainly collected with a take-off in people’s everyday practices.

The unit of analysis in a computer science work might be limited to the boundaries of only a technical system, but in this study, which dwells in the territories of both people and technology, I have taken the idea of activity system as a theoretically challenging and practically manageable unit of analysis. Even for the more technical and design-oriented section of the study, I find it to be a concept that fairly well mediates the chosen real-existing context.

**Chronology and extent of the empirical part of the two studies**

This thesis work has been going on since 2001 in a series of field studies together with two distinct design and development projects named Hedwig and Helar during autumn 2001 and spring 2003. In particular at Ronneby municipal elder care and later at the manufacturing company Kockums Maskin AB Kallinge, I have been part of and often the main responsible for ethnographic studies of core practices. The ethnographic studies provide the major part of empirical data captured in numerous pages of field notes, and in audio and video recordings. For a more detailed account of the empirical data, see list below:

2001 (autumn), Elder care: a six month R & D project produced Hedwig, a computer prototype that integrate digital images with wound care notes.

2002, Elder care: five visits, observations and interviews with health care practitioners, 31 photos, field notes, 60 + 40 minutes audio recording of which 10 + 5 minutes transcribed.

2003 (spring), Elder care: a six month R & D project produced Helar, a distributed computer prototype that integrate digital images with wound care notes, six participatory design sessions with 82 photos, 60 + 75 minutes audio recording of which 60 + 60 minutes transcribed.

2003, Elder care: five visits and observations, 53 photos, field notes, 62 minutes audio recording.

2004, Elder care: five visits and workshop with practical evaluation and interviews, 98 photos, field notes, 40 + 60 minutes audio recording.

2005, Elder care: four visits and observations, 50 photos and field notes.

2006, Elder care: four visits and observations, two "stimulated recall" sessions, 235 photos, field notes, 25 + 30 + 22 minutes audio recording of which 25 + 30 + 22 minutes are transcribed.
2007; Manufacturing work: seven visits with observations and interviews, 49 photos, field notes, 35 + 50 + 30 + 60 minutes video recordings of which 50 + 30 + 60 minutes are transcribed.

2008; Manufacturing work: two visits with observations and interviews, 18 photos, field notes, 82 + 6 minutes video recordings.

Specific methodological techniques used and developed

In the field close to the front at "the point of care", "at the bedside" or in the immediacy of on-going machine operations, it is assumed that document related actions the practitioners do, provide a feasible way to observe and gain insights into relatively stable traces of what is happening. An observed movement and triggered event can be connected to inscribed records stored in a document. If the researcher can obtain the document in question, further connections to other circumstances can be made in analysis work. In some ethnographic field works, the advantage of video recordings is favoured because of a full range of events can be captured in addition to spoken utterances by the subjects. In a way such recordings are nearly ideal with its full range of very rich data stored in a standard format.

At the shop floor I initially rejected the video cameras of earlier technology generations because of their size and clumsiness in movements. Large cameras seemed as not a good fit, especially not in the care recipients’ home like contexts. Instead the smaller digital still camera offered an alternative. Provided the camera was set not to trigger a light flash or a clicking sound, it proved to be sufficient in several intimate and sensitive settings. With a trained and steady hand, a lot of photos can be taken of which a great deal is good enough for making meaning out of time stamped snap-shots of reality. From a position close to the studied subject, this technique might preserve details of for example text inscribed in various documents. In later years, the new, small and very convenient video cameras can be used in nearly the same way, but from experiences of these studies, there is a gap to the high resolution images of still cameras.

Another advantage of a produced series of time stamped photos is the manageable, structured and easy accessible data set, which I have found effective in the analysis part of research. In particular document actions visible on paper and computer screens have proven to be captured good enough with a digital still camera. Next generation small video cameras are for sure likely to produced just as good image resolution and storage format. In the manufacturing studies, we found hand-held and moving small video cameras as convenient and useful but sometimes the environment put the device performance on the edge of what is "good enough" records. In particular spoken communication cannot be captured in all mo-
ments while a recording can be richer with individual and body mounted microphones connected to the video cam.

As it turned out, the field use of digital image techniques truly supported our focus on "documents at work". Since documents are in much use in contexts of the studied on-the-ground work, the approach can also be labelled as an instance of Institutional Ethnography (see e.g. Smith, 2005) although our studied settings has a shop floor instead of a regular office character.

7. Results

In this section I put together results based on the conducted research presented above in chapter 6: Methodology approach. To answer my research questions revolving around coordination and consequences for design of computational systems I take off from a visualisation of the main finding expressed as the coordinating framework, see figure 6. A more detailed investigation of the components of the framework is guided by my three sub research questions to which answers are given as summaries in table 2, 3 and 4. Those will be further explained below. Change of work and the mode of production is actually recognised in the figure 6 and becomes more poignant if taken as an alternative to the old model of work organisation visualised in figure 1. In many CS studies the complex world in between the centre of planning and the actual execution of work tasks is abstracted away. Here the empirical data and analysis reveals on-the-ground work activities and the shop floor office work including ICT support systems in use.

Figure 6: The coordination framework.

In my previous thesis (licentiate) my main concern was about a possible advantage to combine a computer science and an activity theory understanding of objects in the world and in future computational solutions for health care. The theme about objects is continued in this thesis while it is not emphasised in the same way. Work objects with an activity theoretical understanding are a sustained component in analysis made in my research
until now. The core objects that are dealt with are mainly of two kinds. Identified and diagnosed ailment of an elderly to be treated and changed into a more healthy state has been one recurrent work object during most of the time for this research. Cast metal to be precision machined for the automotive industry is the second most outstanding object.

In the following, results from field studies at Ronneby municipal elder care and Kockums Maskin AB are brought together since similarities can be assumed and, as the findings will show, a great deal is in common however tasks and expected outcomes from those practices are very different. In both domains we are in acquaintance with managers, special technicians, production leaders and other people in more or less specialised work roles.

In the centre of observations in this research are municipal nurses who work as generalists dealing with many diverse health care tasks of which one is wound care put forward in this research. In the manufacturing domain are CNC machinists, or more briefly ”machinists” the skilled occupational workers who we have followed in studies at the shop floor.

**Main findings from this research**

In a compressed format figure 6 visualises one of the three main findings of this thesis. It is then also an answer to the overarching research question: How are support systems for coordination part of advanced on-the-ground work and what does it mean for design of computing in such work? It is found a coordinating framework bound to the physical place of the work object, furnished and made working thanks to firstly the occurrence of designable (even so: re-designable, see further below and table 4) components and secondly the deployment and on-going integration of the framework that to a great extent is made by the practitioners themselves. Thus, the meaning for design of computing is to build on components that are re-designable by those practitioners that are in need of a computer support system.

The second main finding address power relations in design of support systems for ones own or others’ use. The third main finding is the workers’ attention to the double horizons supported by documents.

**Findings explained**

In more detail, the tables 2 – 5 provide the ground for the reduced picture visualised in figure 6. Especially table 2 that summaries “use of documents of importance for coordination”, is through codes “a” and “b” (right-most column) connected to figure 6. The “First coordination shop floor office” is in the figure distinguished with “(a)” and the “Intermediary shop floor office” with “(b)”. Those offices indicate a distance in the work environment where (a) is most and (b) is least distant to the work object. Actually, in both the studied environments, the occurrences of Intermediary
shop floor offices are not one but two or three “office places” oriented in successively decreased distance to the core activity object. In the analysis this distance appears as an essential feature of the environment in which the practitioners are moving.

The tables 2 – 4 are made as a condensed summary of findings, presented in the included papers. They are the actual ground for answers to the above stated three sub-questions of this research. In the following my writing is based on those tables of which each one row contain one “item” that is a distinct finding. To be noted is that all findings of the research is not accounted for, but is a selection of those most important for answering the sub-questions. For example, since the empirical material is rich, this thesis could have had another character, and then the selection would have been different. Thus, the tables have a “bullet point” character in order to present the result of analysis work related to my stated questions. Consequently, the tables are not an account of strictly obtained raw data, but instead to be considered as summaries from several sources of ethnographic observations in the work place. Analysis work has been conducted in conjunction with writing of the included papers. So, the tables which reflects that, do not intend to compare data from the separate domains of nurses' and machinists' work, but to present important findings pertaining to advanced on-the-ground work activities. In the following of this section I refer to some but not all specific items in the three tables. While I want to account for the relevant findings as a whole in the tables, it is not necessary to directly comment on each one to make my points. The reader, I believe, will see my view and at the same time get a feeling for the rich material provided by those studied work activities.

Since the nurses are on to move and on the go (see paper 2), they themselves develop and utilize a coherent document system that is functioning for support of individual as well as co-workers course of action, both in their physical work environment but also in connection with other places. The CNC machinists are also mobile workers in movements between machines, and like the nurses, they also develop a document system with similar characteristics. As this research shows, those practitioners not only perform core tasks in their occupation, they also do a considerable part of detail planning, negotiations and decisions about the work that must be coordinated with others contributions. That is why the practitioners develop a document system, partly and ongoing, as support system for coordination of advanced on-the-ground work.

In the following sections, with support in figure 6, I will further explore detail findings of document usage (table 2), significant documents features for coordination (table 3), and this study's contribution to design of on-the-ground computing systems (table 4).
Findings related to research sub question (q1).
Legend: Place for document use is indicated with 'a' = First shop floor office, and 'b' = Intermediary shop floor offices. See also matching 'a' and 'b' in figure 6, the coordination framework.

<table>
<thead>
<tr>
<th></th>
<th>Use of documents of importance for coordination.</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Master Plan / Day Calendar as shared planning resource and guiding framework throughout the work shift.</td>
</tr>
<tr>
<td>2</td>
<td>Binders and documents, a unique combination of those for each work shift.</td>
</tr>
<tr>
<td>3</td>
<td>Textual notes, brief notes from upcoming events, typically in movements, and close to work object.</td>
</tr>
<tr>
<td>4</td>
<td>Textual notes, from periodically performed actions. E.g. taken measures in wound care.</td>
</tr>
<tr>
<td>5</td>
<td>Pictures taken with a digital camera. Supplement to textual notes, for introductory learning, to validate work.</td>
</tr>
<tr>
<td>6</td>
<td>Signature to verify the performance of a planned action.</td>
</tr>
<tr>
<td>7</td>
<td>Textual actions, intertwined with other actions at the bedside and the machine front in reciprocal movements.</td>
</tr>
<tr>
<td>8</td>
<td>Others actions, intervene into in movements towards the work object.</td>
</tr>
<tr>
<td>9</td>
<td>Object of work, writing on its surface.</td>
</tr>
<tr>
<td>10</td>
<td>Notes about non-standard, novel solutions to upcoming problems.</td>
</tr>
<tr>
<td>11</td>
<td>Intermediary notes, transforming them into more formal, durable and shareable documents.</td>
</tr>
<tr>
<td>12</td>
<td>Account of performed work, obtained assessment, and made measurement.</td>
</tr>
</tbody>
</table>

The “Master Plan” or “Day Calendar” (table 2, item 1) is a document with compressed information suitable for an overview of what to do for the group of machinists and the nurses respectively. In the machinist case, it is written in the managers’ office that can be labelled as a Centre of planning, see figure 6. For the workers it is available in a computer network node at the First coordinating shop floor office (a) (from now on: first office), however, a printout makes it convenient to bring it into the centre of a short meeting among the machinists somewhere on the shop floor. The document mediates the company’s management planning horizon, which doesn’t detail which individual worker shall do what and precisely when. Instead, this is taken care of by the machinist as a group that is organized
around a few machines. Afterwards when the metal pieces are finally produced, the individual worker sits down in the first office (a) and makes an accurate account of her or his machining result (table 2, item 12). The account is entered into the computing management system and is a resource that can be used for other future master plans. In the nurses’ case, they also look up the computing document and make a printout in the beginning of each work shift. The paper copy is discussed and negotiated about to find out what to do, in which order, and who shall take care of recent changes in needed work and available resources. So, initial decisions are made with support of the document that connects the Centre of planning to the activity system where the practitioners carry out their work.

In the first office (a) the combination of networked computing and a paper based document system is available for the group of workers. Standard desktop computer(s), a printer, and in the nurses’ case telephones and a fax, are together with other standard office items such as complex boards (for organizing, bulletins), mailboxes etc a centre with a vast information repository. Since the material is a shared resource it must be kept in good order. When no one is working at the desk, very little is stacked there. Instead the combination of shelves and binders makes up a very visible system, which provides an overview of what is, or is not, existing and potentially available for the group of workers. When a nurse realizes her plan of visits for the day, she makes a combination of binders, the print-out of the day calendar, her dairy, and other material for her support in visits at the care recipients home (table 2, item 2). She effectively makes a system of paper-based components and other artefacts that fits her work shift.

Movements are part of advanced on-the-ground work. The nurses and machinists keep up with a pace of performance in which the accomplishment of one task is followed with the beginning of another. Sometimes the planned sequence of actions is interrupted by an upcoming event, and sometimes two tasks merge together while other must be interrupted and resumed later, but a pulsation flow of work performance is evident in the practitioners’ movements. The nurses have to attend to the accommodations of several individuals and the machinists move between places for storage and support connected to the CNC machines. What tasks to do are made clear as a road map but exactly how the details of each task will be realized are open until the actual encounter with people and materials in places of the work environment. The nurse might occasionally, for example in the corridor, meet relatives to a care recipient of whom she wants to obtain contact information and tie them closer to the care provision. When she is dealing with drug administration, she might receive a phone call about a requested lab result or a consultation with a doctor. In the manufacturing case, a production leader or a logistics worker might approach the machinist with some urgent matter like a request for changed priority
of a batch delivery. The pulsation of events during a work shift is like movements within a current guided by a master plan.

In the execution of work both the nurses and the machinists are targeted to deal with a particular task but they have an ability to respond to upcoming changes, deviations and not foreseen actualities. This ability is strengthened with “support notes” which preserve enough information to resume a task later or to make a more sustained and sharable account about what has happened. On a slip of paper, or in the margin of an accessible document, or at the surface of something else, just a few words and numbers are written without slowing down the pace of work. The act of writing as part of movements is different to circumstances that allow sitting down at a desk and mobilizing a full range of authoring skills. But to take a few notes is necessary since the details of a short conversation or an observation, must be preserved in a reliable way. That is why the practitioners occasionally make brief textual notes (table 2, item 3), something on a surface that is not a regular document (table 2, item 9).

On-the-ground work takes the nurses into movements close to the care recipient in bed and the machinist close to the machine front. In such proximity to the work object, making notes is affected by the pace of performance that is mainly directed by treatment or transformation of the work object. That is not an optimum place for typing or handwriting. The practitioners might use gloves for protection, but nevertheless, some writing and reading might be intertwined with the main task performance (table 2, item 7). For example, at the bedside, the nurse maintains conversation with the individual while she manages to open a binder and enter a signature to verify that she has recently given an injection. This is a regular and foreseen procedure but since it is of very high importance to accurately know and share with other people, the actual writing is done even if the closeness to the object resists accessibility of documents and the making of inscriptions. The machinist does write a few numbers on the object of work (table 2, item 9), either to be absolutely clear about which machined piece is which in the set-up procedure of a new work batch, or as a preliminary measurement of a suspicious and possibly faulty machining.

Stories of what happened during the last shift are told orally in shift overlaps when the immediate responsibility of work is handed over. But also the day calendar and master plan are used as ground for building up an understanding of what is the current status and what is the upcoming things to do. The nurses themselves enter to-do tasks as items in the computer version of the day calendar. The machinists’ production account is a planning resource in the central creation of the master plan. This means that the practitioners provide themselves much of the information used for coordination of work. Short notes initially made in movements and close to the work object are further transformed into a second more elaborated paper version or into the finalised computer document (table 2, item 11). The
subsequent versions of a note become more completed and possible for other people to understand. In the established ordering of the document the note’s positioning relates to a context and the note content is expressed as a more complete record. Transformation into shareable information of what is written without much premeditation is preferable done in the first office or in an intermediary where it is convenient enough to write longer sentences. For example, the machinists keep a paper-based logbook in the second office. This artefact is intended for mainly mediation of work status within the group of machinists. Also technicians and managers might read the logbook and find reason to intervene into the group dynamics and open up a dialogue about what is going on. Those more completed and shared documents are occasionally used as a vehicle into what is happening. At a proper moment, one who has access to the documents can pick up a meaning and intervene into others actions in movements towards the work object (table 2, item 8).

Items 1, 2, 3, 7, 8, 9, 11 and 12 in the table 2 I have now explicitly referred to. The not mentioned items belong but are more general and recurrent in observations, but see the included papers.

For coordination of work activities many people at different places take part in negotiations and decisions. Much of this is made orally in more or less formal settings. Decisions to be made and the actual outcome of decision-making are most often based on and expressed in some kind of written record. Documents are made integral to management, not only in a centre of planning (figure 6) but also, as is shown in this thesis, in coordination of advanced on-the-ground work. So, what significant documents features for coordination are of most importance?

Table 3: Significant document features of most importance to coordination.

<table>
<thead>
<tr>
<th>Findings related to research sub question (q2).</th>
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<tbody>
<tr>
<td>1. Documents and other artefacts, affords clustering for movements towards the object of work.</td>
</tr>
<tr>
<td>2. Documents (includes: binders and paper documents on shelves, desks, and on the move) make possible a sharable order and indicate access authority.</td>
</tr>
<tr>
<td>3. Component format which is highly standardised: of what is visible and tangible, such as the size and colour of the document elements.</td>
</tr>
<tr>
<td>4. Components allow for highly standardised organisation as a system. E.g. on shelves (or equivalents), in containers; with labels, index registers, tabs and other layout elements.</td>
</tr>
<tr>
<td>5. Format restrain individualised appearance such as order, layout, size, colour, computer-to-paper printout (binders, the MPS system).</td>
</tr>
</tbody>
</table>
Findings related to research sub question (q2).

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<table>
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<tbody>
<tr>
<td>6</td>
<td>Document indicate authority for who have legitimate interest of its content.</td>
</tr>
<tr>
<td>7</td>
<td>Document allow for design (such as merging documents together in making a re-designed document).</td>
</tr>
<tr>
<td>8</td>
<td>Document text record that is short and precise to provide a “good enough picture”.</td>
</tr>
<tr>
<td>9</td>
<td>Tabular format affords mapping actualities with planned events (e.g. Master Plan / Day Calendar).</td>
</tr>
<tr>
<td>10</td>
<td>Document allow both reading and writing in parallel with other interactions in all the environments.</td>
</tr>
<tr>
<td>11</td>
<td>Picture validates that the job has been properly done.</td>
</tr>
<tr>
<td>12</td>
<td>Document afford bringing intermediary (temporary) office into existence.</td>
</tr>
</tbody>
</table>

In coordinating their work, the nurses and machinist are alike in that they make some document writing and reading for their own individual course of actions, while some are made for other people within the same or in an external activity system. Initial and in movements created notes, support both the individual author’s work and later in a transformed version, also others’ work. Since measurements, observations and assessments are partly based on sensitive instrument readings, for example blood pressure in a foot or a length on a machined metal piece, the quality of the reading is dependent on how it will be preserved. The readings might be made for the immediacy, or for use later within a proper course of actions, in another time and in another place, perhaps to be done by other people. This means that in a first version, a document note is connected only to one individual and it is not intended to be accessible for anyone else. However, also such a note is used as the basis for transformation into another version, which has a collective of future readers and writers.

In the elder care, the nurses put together clusters of documents and other artefacts (Bertelsen, Bødker, 2002; Blomberg, Suchman, Trigg, 1996), or to use Bardram’s (2009a) term, a bundle of artefacts, in preparations for movements towards the care recipients (table 3, item 1). This clustering is in accordance with the day calendar table and the negotiated changes necessary for the planned visits during the work shift. In the first office the machinist also puts together documents: the master plan, “the folder” with a work instruction, and sometimes an engineering drawing if it isn’t yet put up on a board. The cluster is then brought in closer proximity to the actual machine and into one of the intermediary offices (figure 6). So, the documents are either stored in their proper shelf positions and in a clus-
sical file cabinet, or they are brought along when moving back and forth at the shop floor.

A document cluster must be robust enough to be sustained during the work shift, while another new cluster must be easily made on another day. The combination of document containers (that is binders and various kind of folders), and the internal organization of those, is changed by the practitioners in order to keep up with changes in their work. Some aspects must remain, but others must be changeable. Consistently, the studied document systems are built on components that are highly standardized in size and in the ratio of their physical dimensions (table 3, item 3). Actually, this is the case both for the paper-based systems in both domains, and for the computing MPS-system at the manufacturing company. Further, it is significant that each component of the documentation system is possible to be combined differently with the other components, but still within a clearly visible and recognizable order (table 3, item 4).

In both the elder care and in the manufacturing case, the paper based document frameworks and the computer MPS-system follow a rule of simplicity. As clearly visible at the nurses’ first office, the binders and the rest of the office manifest a strikingly well ordered information system that is very much created by the nurses themselves. The size aspect is one connected with visibility and simplicity. In the nurses’ tryout of the computer based Helar prototype, they had to deal with tiny little icons and text labels. This was the case for both the prototype and the graphical part of the operative system's file representation. When the ordering of documents is obscured by alien file and folder names and of too small and fluctuating widgets, then the nurses’ authority of being in charge of the information is hard to achieve. Instead, in advanced on-the-ground work, the organizing of the documents reflects the collective character of work and that is why the appearance of structure and detail items follows a stable and simple interface. Individualized “look & feel” is not asked for, on the contrary, all that doesn’t need something unique evolve into a standard that is simple and shareable.

The computing MPS-system at the manufacturing company is developed in a similar way as an ordinary binder system. Due to the company’s preserved computing competence and the design grounded on stepwise extension and the workers involvement, the MPS shows some important characteristics that are similar with a binder system. The visible appearance is highly consistent through out all nodes of the network, both on the shop floor and in the office. The interface organization, size, colour, and layout is highly standardized (table 3, item 3 and 4) and do not allow for individual rearrangement for themselves. Instead, change of the format aspects is restrained or simply not an option (table 3, item 5). So, both the paper version and the computing MPS-system, have evolved within the practitioner's control where the organization and appearance of the in-
formation are shared with the group of people who belongs to the actual activity systems.

In the nurses’ case this recognition also supports the important separation of who has, or has not, a legitimate interest to access information. A binder on the shelf at the nurses’ first office, indicated by the organizing structure and its positioning, that only authorized people have access to that (table 3, item 6). In an individual care recipient’s accommodation, a designated binder with information about the individual person, organized by the practitioners and positioned close to the bedside, does allow for and invite relatives’ participation.

If the document format allows both reading and writing text in all environments, as paper based does fairly well, coordination is supported. To integrate text related actions in movements, the chain of action-text-action (Smith, 2005) can be maintained but the document format is highly challenged when getting close to the object of work. In both the nurses’ and the machinists’ cases, the groups of workers establish intermediary shop floor offices (“b” in figure 6) of which the “fourth office” (paper 6) are brought into existence only when actions are going on close to the care recipient or the machining of the cast metal. Some forms to fill out, or a binder or folder content to read, are documents that function at least to a limited degree in most places. Despite bad lightning conditions, no good desk support and other problems that might require the use of gloves, some office work is still possible. The harsh environment is overcome through paper sheets protected by plastic pockets, or by use of a binder that harness document features of importance to coordination (table 3, item 10 and 12).

Items 1, 3, 4, 5, 6, 10 and 12 in the table 3 is explicitly referred to, while the other not mentioned items belong in a more general and recurrent way, but see the included papers.

My answers to the third research sub-question q3: How can this study contribute to the design of coordinating support systems?, are given in the following (and in table 4): (I) To be sustained and integrated the document system must be re-designable to match changes in the work activity; (II) A new document component must be re-designable, that is compatible with the already integrated components in its appearance and ability to be combined; (III) A computing support system will better serve coordination if on the ground workers are able to co-configure the system together with specialist designers.

In the studied cases, the following document properties are the most important for the above answers. First, with recognition of mundane occurrence in office environment: the paper based systems are built around paper sheets with a standard size (Europe “A4”), to be fit into binders with an index register and a cover label. Such binders rest on shelves in modular shape and size that is easy to extend and rearrange. Further, a significant property of the re-designable document components is that they preserve
some format qualities in bidirectional paper - electronic transformations (a variation of the What You See Is What You Get, WYSIWYG-principle, with examples of various fax-scanner-printer-computer combinations).

Table 4: Contribution to design of coordination support systems.

<table>
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<tr>
<th>Findings related to research sub question (q3).</th>
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Secondly, a particular example of a re-designable document system is the computing MPS-system (Kockums Maskin AB) that is found to have similar properties with the first paper based example: Its interface has a consistent matrix layout throughout all network nodes; further, it builds on consistent character type, while size and colour of interface items are also stable and fairly simple; it is extended with content modules over several years within its format framework. A foundational principle for the organisation of the MPS is that it has one stable screen display per work organisation unit on the shop floor. This feature of the MPS-system I argue is due to the co-configuration way the system has evolved. The workers and other staff have together with specialist designers (or more accurately in this case software-computing developers) contributed to the construction in parallel to every day work at the company. How work is organised is consequently matched by the computing system.

In the studied cases are required a coordination framework that builds on a mix of face-to-face meetings, on-line communications, and the support of a documentation system. Human interaction is realised in movements at the shop floor and in direct encounters with the work object. In such interactions a document complements the practitioners’ assessment, negotiations, decisions and hands-on actions directed towards an individual’s ailment or a cast metal to be precision machined.

More developed and increased knowledge of on-the-ground work objects requires more advanced and diverse work capacities. Practitioners interaction and work performance upon such objects become more dependent on coordination. A consequence is that predetermined flow of work and detailed plans will be weaker. In other words: to give orders becomes less effective. Instead, some decisions and plans must be worked out on the shop

4 Oxford English Dictionary *designable*: “1. That can be distinctly marked out; distinguishable. Obs. 2. Capable of being designed.”
floor and involve a number of people and their joint efforts to be supported by an integrated document system. To match the dynamics of the practitioners' interaction, a documentation system must allow for re-design of some features of the system itself while other will remain stable.

Division of labour fosters skilled specialisation that in moment of work performance must be brought together. I argue that what I call a coordination framework is an essential part of an environment for practices of on-the-ground advanced work. This framework is also a part of the central management's document system as they use for central planning of work (figure 6). So, for the workers the framework has a twofold purpose: a) to reach interaction power in work close or directly with hands-on actions on the object of work, and b) to make a sufficient good alignment with a master plan and an account of performed work for the record maintained in a centre of planning (for a similar relation to a centre, or a “centre of calculation”, see Latour, 1987).

On-the-ground work requires that the practitioners are mobile and we find a reciprocal movement in which the object of work is recurrently created by the practitioners (paper 5). The nurses try to picture the ailments they will face in the encounters with the care recipients. Documents are looked up, printed, read, and discussed in office areas where the pending tasks and the actual status are central parts of mobilised resources. At the sub contracting company the machinists negotiate on who will do what during the shift based on a given and shared master plan. Intricate set-up work will be carried out in hands-on actions intertwined with reading charts and instructions. The machinists make measurements on the produced pieces. But in specific moments of work, higher accuracy is required and must be made by specialists in a special room equipped with more sensitive instruments. To realise proper alignment, to hook an action properly into a proper sequence and in connection of others’ actions, a developed consciousness is required.

In my field work, I have found that spacial mobility on the ground work is necessary to get tuned with the information systems and to mobilise and exert direct actions towards the ailment of the care recipient or the cast metal machining. But there is another dimension revealed in the practitioners movements between different positions on the shop floor. Changed context profoundly makes possible or restricts what can be done but the practitioners try to sustain coordination with help of document actions. In paper 6 we conclude that:

the AT [activity theory] idea of object-orient edness and the concept of work object highlight a double horizon as the workers in advanced practices need to attend to. To approach the object of work in the present, some specific documents are useful, to address the future of the object other document handling support an extended responsibility in time (p. 9).
Our recognition of the “four offices” at the shop floor and the practitioners reciprocal movements suggest systematic relations between document actions and on the ground work object. What documents might afford and restrict is related to the existence of a coordination framework and the practitioners orientation towards a work object. Those findings have an aspect of power relations where plans of work are taken care of by the workers. Where, by whom and how are understanding of tasks to accomplish realized in advanced on-the-ground work? Questions to be discussed in the following sections.

8. Discussion of the empirical results

The empirical result from the health care and manufacturing cases confirm that a new work order is established on some work places in the sense that the actual work is organised very much by the workers themselves. They don't wait for orders and supervision but “take instructions from” a more complicated work object. Without the support of a coordination framework, it would be much harder to maintain advanced on the ground work activities at the present high level work performance. However, the coordination framework doesn't only support the workers’ conduct, it also demands a wider responsibility. The individual worker's performance is accounted for in a detailed way and can be traced from the actual work object to what have happened back in time. Consequently, this new real work order doesn't fit reasonable well with a reduced perspective on workers as those who only deliver on discrete and clear cut tasks, or to say “completing the loops” as advocated by Denning and Medina-Mora (1995) and others. The old work organisation model according to the figures 1 and 2 doesn't hold. Instead another one is to be drawn, the coordination framework in figure 6 suggest an alternative and more updated model.

The empirical results provide both a kind of comprehensive finding in the coordination framework and connected to that, detailed findings from the observed documents and the practices which integrate them. Other research has a similar approach to what is applied here. Below is given quotes from field studies in first an on-the-ground setting and secondly in a more office-like but software computing design. Both examples are considered here because a) a focus on actualities where actions are revealed and b) an attention to documents and other artefacts integrated in work. Suchman (1997) points out that people’s abilities to interact with co-workers depend on how they see the environment:
Competent participation in the work of operations involves learning how to see one’s environment in an informed way. Whether in situations of explicit instruction or embedded within interactions among co-workers identified as peers, members’ ability to bring their differentiated expertise to bear on the situation at hand is tied to their access to each other’s activities and interactions (Suchman, 1997, p. 55).

Suchman's account from on-the-ground airport work highlights people's interaction in everyday learning how to see and access one's environment. To get the actual picture and grasp what shall be done, is an interactional undertaking. In my studies a similar statement is valid for the nurses and machinists and I also find that a document framework is central for their coordination of work, both in respect to one's own actions and to fit into others. Interestingly, also software developers, or “program makers”, make use of paper-based documents, both in individual writing code and in extensive participation in design meetings.

To write for people and for the machine – two different but intimately interlaced aspects on program creation become visible in the program makers [programmakarnas] daily practice as the continuous referral to number of pages and rows of program code in discussions about good and bad solutions to specific design problems [translation by HK] (Andersdotter, 1999, p. 36).

Further, in her study she puts forward not only the concrete size and other physical properties of standardised A4 paper sheets but also the cultural recognition of document paper and row as a practical, although not completely accurate, measure of how long it will take for a human to read. In the program makers' context, they make use of this recognition and they extend it also to a measure of how long it will take for a machine to execute the equivalent code. So, a document framework provides a content to interact about, but also a shared understanding of a mundane and practical format.

The empirical results in this thesis is the outcome of studies with a similar focus on everyday contingencies as the above examples from Suchman and Andersdotter. A difference is the attention to the work object which have some consequences. Suchman (1997) is very close in her account of actions oriented towards the object but doesn't make a point about it, instead the materiality and denomination of the work objects are summarised as a footnote. In this thesis, recognition of the work object is central and does have importance for further discussions, in particular for design considerations, see more below.

The empirical results in considerations of power relations in design

The empirical results address the theme of what it mean that many support systems, especially computational, are designed by specialists for others' use. Different strategies are suggested as a way to overcome the prob-
lems inherent in the often strict separation between construction and in a later separated stage use of the technology. In response to that, Bødker (1999) claims an implication of design and use, design must be based on an understanding of how use may develop, and how the use activities interact or may interact with other activities.

The primary practical implication is that development in and of design and use needs to be dealt with throughout the existence of a computer application (Bødker, 1999, p. 43).

So, on the one hand, specialisation foster skills advancing the technology, but on the other hand, social organisation that separate construction from deployment in use contexts will cause problematic contradictions hard to deal with. Apparently the theme of design for others' use reveal the social aspect of developing new computing technologies. The change and development of work do have implications for computing systems, Ehn (1988) addresses a double sense:

Rationalization actually affects the process of design of computer artefacts in a double sense. Not only is the form of division of labor between the labor processes of design and use an expression of this capitalist rationalization, but also the aim of design is rationalization of the labor process being designed for. An example could be systems designers that develop a production control system to be used by a planning department and that takes away planning activities from the shop floor. This is an illustration of the often applied classical method of 'scientific management' by Fredrick Taylor. This is in no way the only way of capitalist rationalization supporting the valorization process, the production of profits (Ehn, 1988, p. 98).

The empirical results from this thesis are from work contexts that have emerged in the same economy and work order as Ehn refers to. Similar rationalization of the labour process belongs to the history of Kockums Maskin AB and in particular the company's predecessors. The municipal elder care has a different background as part of public health care but also there rationalisation is now and then an employed force for change. Where is the computing designer positioned in such change? The empirical results clearly address power relations in the studied cases. Nurses and machinist who deal with document systems also take charge of design in some aspects. Interestingly, the Kockums case reveals an in-house developed computing system that is not a typical tool for rationalisation in the sense of reducing the number of employees and automating the performance of their work. To me, Ehn's statement about rationalisation is a reminder, the specialist designer does inevitably intervene in the work place and consequently there are choices to make. Attention to power relation will make more or less evident the character of the designers' intervention.

Smooth flow of work

Work activity is performed in order to contribute to an expected result. Therefore, it can be assumed as a universal human aspiration that: the individuals involved are trying to achieve an efficient and sustainable use of
their own resources. Such individual efforts are therefore in a systematic way coordinated with others efforts. The object of work always imply a resistance to be handled by the individuals’ joint operations. Because of the far-reaching division of labour and specialisation, work done in one place is necessarily linked to lots of work elsewhere. With a view to the expected results, a variety of skills and efforts need to be available, accessed and coordinated. In conditions that it works, and "things get done" for those who are actively involved, they perceive a dynamic state and a "smooth flow of work" (see also Bowers et al. 1995).

Emergence of workflow systems

A smooth flow of work requires that people, tools, support systems and materials are fitted in a practice, or rather in a variety of practices which work together. Procedures, division of labour, tool design, control over work, everything will be brought together and oriented towards the object of work that motivates actions to perform. According to various interests the introduction of an ICT system will fuel expectations for better support of a smooth or even better flow of work. The English expression 'workflow' has been coined as a generic term for ICT systems designed to both make visible but also manage to improve work processes. In particular office environments, where work has been understood as sets of repetitive tasks, work processes and modules have been identified as a basis for developing computer-based workflow technology. Development of computer systems is in such domains more or less associated with various change or control efforts of which Business Process Reengineering (BPR) and Business Process Management (BPM) are well known. The emergence of 'workflow' technology can be traced to an origin in the scientific management and industrial mass production, but as applied technology it gained its greatest impact in terms of computer systems in areas of more office-related work (Fischer, 2008). This emergence has coincided with the computerisation of office work from 1950s and the 60s, but with a more thorough application since the 80s to present time.

An established approach to the concept and application of 'workflow' technology includes, therefore, that a job is described as a variety of "activities" that are coordinated. Activities are then organised in a systematic way following a conceptual model of work. Based on the model, a computer system is proposed to both support and control the course of work. According to the model, the computer system makes clear what should be done by whom and in what order. A benefit sought for with such an implementation of workflow, is that resources in the form of people, tools and materials will be distributed timely, evenly and efficiently. If the workflow system fulfils its task, over- or under-utilisation of manpower and materials will be reduced. How well the workflow can be incorporated into work
practice appears to be dependent on the nature of the task, or rather the work object. Where performance can follow a clear routine, and where the routine is frequently and regularly occurring, that is where computer support in the form of 'workflow' seems to have the best conditions for successful use. In other cases where the performance and order of different actions are less predictable, attempts to delegate work to 'workflow' technology seems being unsuccessful in the sense that it does not directly contribute to "a smooth flow of work" (see Bowers et al. 1995).

**Usefulness of workflow**

Thus, the characteristics of work seem to be the most critical factor for the usefulness of a workflow system. In a strict definition of a workflow system, with the order and allocation of work activities primarily based on automated computer decisions, the application will be restricted to simpler forms of work. Another definition may be more open but broader in application. In our current case with Kockums Machine's in-house developed MPS-system a more opened definition may mean that even more complex tasks and more locally distributed control of planning and work can be supported by a workflow system. In this case, the computer system reaches out close to the production process and links typical office tasks with the precision machining of castings. Since the computer system for a long time has been created within the company, its development has been rubbed against the resistance of an established work practice.

The result is an almost "organic" developed system that is integrated in the activities for the company's core work objects. The MPS system makes available and stores much of documentation that holds the company's key information. The MPS system has terminals out on the shop floor and is frequently used for searching and browsing the company's master plan of production. However, some degree of freedom for CNC operators' own planning is a characteristic of this management of work. In practice therefore a combination of human work and technology are realised, were the MPS system is a central and distributed information system integrated into machinists' self-managed work processes. Work flow in this case can be described as coordinated and planned with a high degree of human decision making being part of actual work processes. People base their actions upon certain support items made accessible by the MPS system, whose data in turn are created and maintained in the daily practice of the same people in collaboration with other employees in other functions within the company.

*A pattern of moving back and forth in nurses' (and machinists') work*

In this study, on the level of individual's actions both the nurses and machinists reveal a pattern of moving back and forth between encounters with the work object and the shop floor offices. Reading and writing text is
an integral companion to other actions. Even though the nurses don’t spend all day at the bedside, very much of their time on other places are in some way oriented towards the elderly person with illnesses to be treated and possibly be turned into a healthy state. In regular office and in office like environments the nurses do preparations for encounters with the actual person, or the “care recipient” (which is a common denomination in the municipal context). After a bedside encounter is completed or temporary halted, the nurses do some post production work related to the care recipient. They put back used materials in cup boards and on shelves and again they do a kind of office work in that they enter textual information about what has been accomplished and what is proper other actions to do by herself or by her colleagues. Information and communication technologies are made integrated in their work and as we have found, the character of nurses' text actions are dependent on where in their moving back and forth they take place.

*Coordination with other people is a central aspect of the work activity*

On every workday the nurse has a distance to overcome in which she mobilises her higher psychological functions (Vygotsky, 1986) that eventually will be needed in the face-to-face and body-to-body encounters. To take care and provide medical measures it isn’t enough to react on contingencies in the actual situation. Developed methods, drugs and treatment regimes require ever more accurately performed actions while also government and state authorities demand ”secured” and recorded traces of what has happened. Repeatedly the nurses consult their shared documents as means for creating ”a picture” of the ailing individual just in time before a planned or emerging visit. Work in office like environments supports the nurses' self-managed coordination and document use. To meet the other nurses and managers is about sharing information about the actual conditions of the care recipients, to assess and orally negotiate the plan of pending visits. In a complementary way reading and writing documents serve the same purpose.

A nurse isolated from interactions with her colleagues and taken away from documents at work, will be left without much of her working capacities. When moving around, document actions are intertwined in building a refreshed understanding of the care recipients needs. Such understanding involves preparation of materials, decision-making and interaction with a number of people in different roles. The nurse maintains an authority stance which in most everyday localities is regarded as demanding the present highest rank. In that position she manage work of other people. Even if her moving back and forth takes the nurse to seemingly sheltered office-like places, most of her played out actions are oriented towards the work object (the illness of an elder) in an ongoing effort to make better treatment and reproduce healthy living conditions. This orientation is
manifested (primarily in documents) in deliberate reconstruction of the work object, a practice that can be summarised as an advanced shop floor work requiring artefact support of numerous and different kind, of which coordination with other people present or in other place and time is a central aspect. I find it crucial for the nurses to actively be part of this recurrent building of their capacities.

**What difference can new ICT make?**

On the question what difference can new ICT make, I try to discuss (work-flow and) multi-agent systems (respectively) in relation to the above cases of practitioners work. Computational entities with some degree of autonomy in a digital environment we know as software agents. When two or more agents relate to each other we speak about multi-agent systems (see e.g. Wooldridge, 2002). In research and textbook descriptions human life characteristics are often utilised to challenge design undertakings and to deliberately push forward what software constructs possibly can achieve. Concepts such as "believes", "desires" and "intentions" are established in theoretical explanations of what kind of things software agents are, or might be.

I believe such sets of words are unfortunate and misleading, at least when trying to make sense of possible multi-agent applications in settings like the nurses’ and machinists’ practice. In a survey focusing on the MABS publication series, it was found 28 papers (out of 73) that made a report about experimental agent system producing results of analysis, prediction or verification of mostly modelled human/social systems (Davidsson et al. 2007, Paper 4 in this thesis). The paper makes a comment on the modelling approach in that "ABS is believed to be better suited to model the complexity of human (and animal) behaviour compared to other techniques" (ibid).

In the survey when focusing on distinct software agent aspects that could be retrieved as common to the whole set of papers, it was found a total of 8 aspects. So, in search of agent systems as a phenomena crossing the survey, 5 out of the 8 aspects could only hold a binary value. In the remaining, one aspect hold a value on the maximum implemented number of agents in the system. The remaining two, "Simulated entity" and "Structure (of MAS)" covered 4 and 3 discrete values respectively.

This seems paradoxically but the simulated "human behaviour" was in practically all cases delimited to a few presumed human choice or other clearly defined actions simulated in a confined laboratory setting. The specific advantage with many of the simulations is a designed opportunity to observe dynamics produced by the encounters of multiple agents in the designed lab environment. My view of this is that it must be a huge step trying to move such agents from a lab setting into a real practice where human beings perform and play out the whole range of their abilities.
Agent-systems intended as real time support of human work are not likely to be human like in interactions with real human beings. Instead, multi-agent system are most successful within the boundaries of dominantly closed mechanical systems with tasks of handling deviations and unbalanced in-system conditions. They are technical applications of which optimising telecom networks is one typical example. Agent based simulation systems are also successful in laboratory experiments where social systems are modelled and an outcome is produced based on a set of input data, but still, such an isolated space is limited to be very different compared to settings of human purposeful work. Consequently, I find that when the number and qualities of variables mount to human inhabited systems the question of what agents can do, seems as way out of bounds. With design ideas of autonomous entities, agent concepts borrowed from human abilities to be "proactive" and to have for example "intentions", will stretch too far with unfortunate connotations of real human actors interacting with each other.

In the studied cases I find ground for the assumption that nurses and machinists in advanced shop floor activities integrate work performance with deliberate efforts of constructing and transforming their work object. The implication is that the practitioners need to face and deal with co-ordination problems on their path of daily and repeated movements into close and proper encounters with e.g. the individual elder with one or several illnesses, or the cast metal to be cut and drilled. When the practitioners practice is understand in this way, it is a "no support" to delegate co-ordination problem solving to machine algorithmic computation. The human counterpart to the computer as problem solver in our cases the individual nurse or machinist, will in isolation from realising coordination tasks loose the grip of core aspects of work.

The human assessment and calculation of what to do and how to proceed, is in advanced work, integrated with outwards and object oriented dealing with the surrounding world. In actions intended to transform the object of work, human "calculation" is integral to manipulating the world. When temporarily moving "backwards" from the object of work, the human seeks to recall the history of past actions in order to see the future of the object, and to create new accounts of what recently happened.

In today practices, much of its history is inscribed in a variety of documents. As found in the nurses' and machinists' cases, office work is a regular aspect of shop floor work. In other words it can be stated that ICT is made integral to advanced work practices, also on the shop floor. The nurses and the machinists themselves do the design and integration of this office and ICT support. The key finding is to differentiate in more detail when and how such office work is accomplished in practice. This offers better opportunities to validate new technologies and what kind of work to delegate to ICT artefacts such as agent systems.
On ground of the cases in this thesis I suggest a more elaborated combination of human shop floor interactions and a potential multi agent system. It would be a best match if "computing", when moving close in time and physical distance to the work object, is mainly reserved for the human individuals to perform. In moments of humans' document focused actions (ICT read and write) of such work, a software agent system is more likely to successfully provide support.

With the thesis main finding of the coordination framework (figure 6) a follow up discussion like this is better supported. The tables 5 and 6 below is a further investigation of realities between work completion and central planning activities. In table 5 humans' abilities to write text intertwined in their other actions is outlined. Even if it is a rough visualisation I argue it has consequences for what to expect of technology development. Table 6 is another aspect of the revealed coordination framework. The time aspect help to put in place the human actors' and the document systems' role.

**Table 5: Distance aspects.**

<table>
<thead>
<tr>
<th>Physical distance aspects of write support in &quot;office&quot; work on the shop floor:</th>
<th>- most distant to work object</th>
<th>- in-between distant and close to work object</th>
<th>- close to work object (unstable occurrence)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer support</td>
<td>high</td>
<td>medium</td>
<td>no (or possibly low)</td>
</tr>
<tr>
<td>Paper support</td>
<td>high</td>
<td>medium</td>
<td>low</td>
</tr>
<tr>
<td>Work object surface support</td>
<td>no</td>
<td>no</td>
<td>low</td>
</tr>
</tbody>
</table>

In table 5 it is to be noticed and emphasised that the "Computer support" category is limited to such computers that are intended to support in “office” work on the shop floor. Such devices shall not be confused with the very specialised computer that directly control the mechanics of the studied CNC machines. A CNC computer is completely integrated with the physical machinery and mainly connected to sensors detecting movements of machine parts. However, possibly such specialised computers might become even more powerful and reaching out to sense more of the machinery, but still humans’ attention will be needed. No sensor system is capable of detecting a deviance in the actual metal cutting as a result of the very predictive CNC execution. That is due to a paradox, with more precise computer control of the machine, peoples needed actions are not reduced but changed in some way. Only people, i.e. skilled CNC machinists, are able to interpret patterns of e.g. produced audible noise when the metal machining is getting out of bounds.
Physical distance aspects in table 5 explained

Physical artefacts such as paper documents and computer devices are originally made for and adapted to standard office settings. In such, light and sound conditions and the design of furniture can be taken as advantageous and stable for doing regular office work. Consequently, affordances are high and limitations low for both computer and paper based documents which will allow for smooth flow in read and write actions. In movements closer to shop floor work objects, the above outlined physical environment will change drastically. But affordances and limitations will change differently for paper versus computer interfaced documents.

In this studies (paper 5, 6) it is found that paper documents are brought to the limits of where it is possible to perform text actions on the shop floor. For example, in the machining case, each paper sheet in the instruction folder need to have a plastic cover that make the artefact durable but still possible to read, however the arrangement doesn't afford to write. Oil, grease, heavy metal pieces, tools and instruments sets harsh limitations on dealing with the artefact.

A computer device moved towards ”the bedside” or ”the machine front” will reach its limits even earlier. Lightning conditions is not on level with office standards which makes the display troublesome to read and there is not always a firm desk top to rest the hardware or to find a good support for hand and finger operations. The fragility of standard computer casing and display surface doesn't fit to an environment in which human workers need to wear gloves and hearing protection.

In health care contexts, in which practitioners are ”on the move and the go” (paper 2), there are simply no office furniture and in addition a risk of contamination hazards with carrying mobile devices around (Bardram et al., 2009, p 713). In the studied cases, the practitioners make short-lived text actions close to the shop floor objects but such occurrences of erected office support are typically unstable and a tough challenge of any affordance a document format might have.

The space in-between regular office and the places of crucial transformation actions in various shop floor environments, is however not an empty distance or ”no-man’s-land”. In our studies we found that the shop floor workers do establish office like places (paper 5, 6) ”in-between” where affordances of read & write actions are clearly restricted but to some degree acceptable to make (see also figure 6). Further, our observation that sometimes the practitioners write short fragments of text or just a few numbers, directly on either their own body skin or on the surface of machined cast metal pieces, is a significant reminder of the importance of document actions at work but also about poor affordances of regular office document formats in close encounters with shop floor objects.
Table 6: Temporal aspects.

<table>
<thead>
<tr>
<th>Temporal aspects of human shop floor activity coordination:</th>
<th>- focus on past time</th>
<th>- focus on future on a distant time horizon</th>
<th>- focus on present time and near future (within a work shift)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human subjects' abilities</td>
<td>reading and writing documents</td>
<td>contribute to plan and account documents</td>
<td>making work object transformation</td>
</tr>
<tr>
<td>Software agents, suggested abilities</td>
<td>pattern recognition in document records</td>
<td>contribute to plan and account documents</td>
<td>display patterns and deviations</td>
</tr>
<tr>
<td>Workflow systems (Denning et al. 1995 definition), suggested abilities</td>
<td>present history of triggered events in sequences of commitment loops</td>
<td>present commitment triggers on a time line forecast</td>
<td>peripheral display (Bardram et al. 2009, p.706) - of organisation perspective</td>
</tr>
</tbody>
</table>

Temporal aspects in table 6 explained

With the emergence of documents on the shop floor and close to the machines, the practitioners find support in their focus on the work object. When they physically move in direction towards the object they increasingly gets more attuned with the present time. When moving out from the closeness of the object towards the shop floor coordination offices (figure 6), they are better able to be attuned with and attend to the future of the object. They have done their immediate contribution to the transformation of the object but their responsibility doesn't end there. With coordination documents, the individual worker's identity is brought along with the future destiny of the object.

The nurse or machinist makes an account of work they have done and with that they are possible to trace back: the particular worker did that to this patient or piece of precision made metal. So, through the coordination framework, and with that "computational activities" (Bardram, 2009a,) a lot of documents are taken from "cold" (Sellen and Harper, 2002) storage and made “warm”, i.e. becoming integrated in the workers' actions. Those documents play different roles depending on the actual physical and timely
positioning relative the work object. This I argue is foundational and of importance to understand the role computing support can play for the practitioners on the shop floor. Table 6 visualises human and computing agents in the coordination framework with respect to when attention is focused on the present and future respectively of the work object. How computing agents and workflow systems might best give on-the-ground support to human agents is indicated in the table.

**Distance and temporal aspects in human orientation and attendance to a double horizon**

Individual’s mental functions are without doubt essential and they determine much of any human action. Although such inner functions inside the human body can not be observed directly, at least not in cases ”at work”, the consequential effects outside can be. However, the complex of human inner functions are sometimes assumed to be equivalent to, or similar with computational algorithms and calculations. Such imagined similarity I believe can be misleading if taken too far in attempts to create some kind of machine awareness and human-like actions in advanced work contexts. In this study the approach is to understand human interaction in records of actual performance in the material world. The findings suggest that individual humans, as part of everyday work practice, do mobilise their capacities to be realised in actions co-ordinated with co-workers actions.

Thus, the every-day work is an ongoing mobilising effort merged together with actual transformations of the world. To understand mobilising of capacities, the physical distance and temporal aspects (table 5 and 6) can help. On the one hand the full range of the individual’s sensory system serves to perceive the actualities of the context and on the other hand the more specific abilities to read and write serve contact with past time and emerging future realities. This study suggests that in the practitioners reciprocal movements relative the work object on the shop floor, the full range sensory system is most at play in close encounters and transformations of the work object, while more specific and narrow sensory flow is at play in temporary attention to documents found in various information technologies. The human abilities is thus changing with the actual physical distance to the work object and the momentarily attention to records and plans that mediate past history and future prospects.

Further, in reciprocal movements the distance and the extreme ”office like” position are changing through the course of every-day work. In the studied cases we find that the human actions can be discerned in, at least preliminary, two categories of the momentarily dominant focus in the the revealed practice. Based on that, the human awareness can preliminary be said to be either oriented towards current artefact/object transformations or attentive to historical and (distant) future realities linked to the same object and core activity of the practice (see also paper 5, 6). A pattern of
double horizon in human attention and orientation seems to be significant and of importance for design and use of document and ICT at the shop floor.

On the limits of computational entities in related research

In the drama of "human-computer interaction", I believe the above notion of double horizon of attention and orientation can be used as a preliminary human awareness model for the purpose of understanding a computational awareness counterpart. If agreed that the above idea of humans’ performance as intertwined with capacity mobilisation is a valid one, it can be concluded that computational machine entities shall not try to interfere in moments of human actions in a world such as in the studied cases. So, what kind of relation can be established between the human and computational counterparts? Will it be integrated and dynamic, or simply ordinary office desk top support brought into a non-office environment? Probably an answer turns out to suggest a rather different option than the mentioned.

One approach to learn more is to look for document related actions in shop floor environments, regardless if they are carried out with computers or not. In the following I discuss two related research undertakings where read and write actions in hospital and health care environments are in focus. In the first a prototypical and assumed "aware" computation is explored in a Danish hospital setting. The second is a case of ethnographic investigations that highlight issues of merging data of waiting time emergency rooms from several Canadian hospitals. Both research undertakings provide suggestions of how computation can address an aspect of awareness. The Danish explores a combination of a real time context detection and linking to relevant data for the same context. The Canadian suggests a computational reflection on how data computation has been carried out.

Bardram (2009b) and Bardram et al. (2009) report about activity-aware computing developed and evaluated in realistic hospital environments from an ongoing long-term research engagement. The work setting is similar to the municipal care dealt with in this thesis but it comprises more diversified work roles and probably more planned activities to accomplish on a workday: "Clinicians in hospitals attend many concurrent activities in a very mobile, collaborative, and hectic environment, while accessing a wide range of information sources."

The created application has an awareness component which is crucial for the adaptation to various environments, or "activity contexts", in which it is intended to be functional. In full scale simulated contexts at the hospital the working of the ICT system is explored of which its ability to match a "computational activity" with different "real-world activities" is evaluated. The approach is to let the practitioners themselves partly create and main-
tain the computer entities intended to be distributed on various hardware devices accessible in their core work practice located in different parts of the hospital. To be noted is that in this concrete, fully furnished and human populated simulation, the computation do not interfere into domains of human interaction but is designed to ”bundle relevant medical data like the medical record, the medicine chart, relevant clinical guidelines, x-ray images etc.” (ibid, p. 734) in a computation activity which is to be associated with and presented to the human activity counterpart.

The evaluation seems as proof of a very promising approach in which the crucial computation feature is to be aware of which human activity currently is played out. Since the setting has a changing and fluctuating character, an observed problem is to get the system switch timely from one to another ”computational activity”. It seems possible to achieve such a better mechanism and to realise an ”activity-awareness”. Although the reported research doesn’t seem to be particular sensitive to the distance and temporal aspects that is dealt with here, it is however tested in close to reality simulations with regular hospital staff as participants and players of activity scenarios. Perhaps data from the research would affirm the staff is attentive to double horizons?

In several of the Bardram examples it is argued that when the right match is achieved, a relevant bundle of resources can be made accessible at the point of care. It is further assumed that much of the overhead related to creating and putting together the needed resources can be delegated to computation. Resources as services are mentioned but in the examples nearly all items listed can be considered regular documents of different kind.

My reflection on the hospital research is that computation entities with a degree of ”awareness” seems best suited to calculate and order items, not in the human inhabited activity but within the proposed computational counterparts (see technical aspects of this in for example Tagarelli and Greco, 2010). In such a computational environment dealing with hospital and health care, data for sure belong to patients and staff. This is the content to be retrieved and regarded as documents displayed on computer screens or on paper print. The advanced computational tasks might be to process the content but the Danish case suggests that ordering and filtering into relevant bundles of documents is a key task in connection to identifying and timely switch to the actual human activity system.

The research in Schuurman and Balka (2009) addresses issues related to ”a demand for merging and integrating data from different sources into a single data set”. In several hospital emergency rooms, it is found that seemingly simple wait time data is recorded differently due to local circumstances such as where individuals’ presence is captured. Consequently the meaning of wait time is understood differently while qualities such as individuals’ health condition are found to be lost in the computational collec-
tion, ordering and calculation of time data. Nevertheless, merged data are used on central management levels and numbers read and analysed are often taken as relevant and to have "an authority that frequently supersedes their quality."

Of course it is very questionable to use corrupted data in any instance but probably even worse when used as ground for decisions that affect many peoples access and quality of care. In order to provide measures for better data quality, Schuurman and Balka (2009) try to tackle the data corruption problem and they hope "that the provision of more detailed explanations of what the data contained in a particular database field refer to could support more nuanced approaches to data analysis." Their presented methodology include a set of eight meta data fields for capturing onto logical information about data. It is claimed to "not require re-formatting of existing relational databases or meta data formats" while a database ethnography is recommended for the actual creation of meta data.

Interestingly, both the Danish and this Canadian research engagements in health care and hospital settings, suggest the combination of more advanced technology solutions with more of humans’ deliberate configuring and maintaining of the same technology. The Canadian is dealing with computational data captured on far distant places and merged beyond the limits of its local meaning, while the Danish pushes the computational sensory system to the limits of local awareness. In both, humans are required to interfere in some specific moments of ordinary computational processes where the machine input devices are regarded as not good enough.

9. Overall discussion

Denning's workflow contra an activity theory perspective on support systems for coordination of work activities

Now when the results are presented I find the two different perspectives on coordination of advanced on-the-ground work coupled to interests of who is in charge of work conduct and of development and change at the work place. To use a coordination perspective with a purpose to intervene in a work domain and change it, will require a choice in one or another direction. It is about power to control work.

Some of current workplaces require more than organising wage labour to operate relatively simple machines and tools, but a legacy of control is still maintained in a great part of manufacturing work (Gee, Hull, and Lankshear, 1996). From a management perspective a large organisation or business can be modelled with Denning’s action loop concept explained above. In Denning and Medina-Mora (1995) is given an example of a course-scheduling process administered by the student record office at a university, and further it is referred to an automated project traffic control
in an advertising agency, and an engineering change process in an IBM manufacturing plant. Even if little detail is given on the level of face to face interaction, Denning's perspective on coordination seems feasible for the re-organisation of existing work. Within the frame of a large organisation or corporation, managers are equipped with a tool to get an overview, to design a change, and test smoother operation. Some reallocation of human and material resources can be made, and some instances of not necessary sub-organisation units can be taken away, while other can be strengthened.

Although the idea of paying attention to individual speech acts (of 'request', 'promise', 'delivery' and 'acceptance') suggests a level of analysis of individuals' work, I find that Denning's perspective operates on a macro level, as from a management position. Such a perspective is useful in grasping a big picture of a process that connects many different groups and individuals. But I find it weak on the micro level where advanced on-the-ground work takes place. It can be further explained as due to an insufficient view on workers' actions as directed by a straightforward perception, as if accomplishing work is simply following a plan of predetermined consecutive steps and that the problem is to execute an effort in realising a requested delivery.

The old idea has an organising principle with emphasis on management who give orders, and workers who obey, in accordance with the figure 1 model. A very similar idea about work is prevalent in Swenson (2008) who states that: “Before anyone will perform a task, that person certainly must be informed that the task needs to be done, given the details of the particular case, and have a way to communicate the results of the activity. These are part of any human activity.” (p. 4). In line with that is given a model5 for creating a computing workflow system that presupposes the request – delivery relation. With no doubt it can work for simple labour, even though it might be a hard labour reality.

Despite that, I argue a central management position in command of today's advanced work cannot fully understand the actual status in the places of work where hands-on actions are played out. It is like an outsider's view into realities more complicated than a case of prototypical assembly line work. That is why a model like the one in figure 1 or in figure 2 is old and doesn't hold for all kind of work. Another model and figure is therefore called for. Due to required complexities of infra structure and needed operation and attention to some work objects, the horizon of central

5 The model is here compressed without details of each of the five steps: “In order to allow a process diagram to be drawn that describes human activity, we assume that the following capabilities are inherently part of a human activity step: (a) inform that the task needs to be done /.../ (b) give the details of the particular case /.../ (c) have a way to record the results of the activity /.../ (d) have a deadline for an activity /.../ (e) provide reminders about the activity.” (Swenson, 2008)
management's perspective do not reach close enough to perceive the actualities of the machines and the material (or e.g. a patient's specific illness). That is why speech acts, either as articulated requests of job to do, as given orders, or accounts of accomplished work, do not suffice to get the job done. Instead, driving forces and required capacities are generated and handled with sensitive instruments and tools by the workers who move between places of coordination and the work object to be transformed.

The activity theory perspective is attentive to the object of work, which is regarded as the most important component motivating human actions to transform and change the object's state into an outcome. Activity theory doesn't ascribe communication means (such as speech acts) as “the” driving force of making things happen.

As found in the empirical data the studied individuals clearly belong to particular contexts of work. In those they are related to other individuals, and with the integration of artefacts (of which documents are of special interest in this thesis), actions are played out and their context of work is revealed, possible to identify as an activity system. Such activity systems could be taken as equal to Denning's action loops if only looked upon from an outside position. But, from inside, the people and their artefacts are the components of a complex and dynamic system, which cannot be reduced to a few one-to-one relationships. Instead, observations of work typically reveal strings of actions of which many are supported by documents. The strings are intertwined and unfold in ways dependent on people's interactions with each other and with the material contingencies inherent in the activity.

Management cannot predict coordination, instead it is one important task among others as the workers themselves take care of, for their individual performance of work and for alignment with others' contributions. The integrated documents and the existence of coordination shop floor offices indicate this more complicated work reality. Figure 6 is then both an abstraction of an observed coordination framework and suggests a more elaborated model of advanced work.

This research as part of a suggested third paradigm of HCI

My approach might be seen as not mainstream compared to established human factors or cognitivism paradigms within HCI. With my interdisciplinary interest in peoples’ actual doing and making in the world and the workings of computing, this research seems to better fit under the umbrella of what Harrison, Tatar and Seagers (under review and 2007) argue for as "the third paradigm of HCI". They are concerned with a weak recognition for a number of approaches that actually do contribute to HCI and therefore deserve better:
Yet over the last twenty-five years a wide variety of approaches have emerged that appear to fit poorly the models and methods emerging from either human factors or classical cognitivism. These include participatory design, activity theory, user experience design, ethnomethodology, interaction analysis, and critical design. (ibid, p. 4).

Human-Factors focuses on optimizing man-machine fit. Classical Cognitivism/Information Processing emphasizes (ideally predictive) models and theories and the relationship between what is in the computer and in the human mind. The third paradigm, with its base in Phenomenology, is less reified, but no less real. It focuses on the experiential quality of interaction, primarily the situated nature of meaning and meaning creation. (ibid, p. 1).

In this thesis, the ethnographic inspired approach to field studies is interested in material phenomena that are possible to observe and make an account of. In that sense, it can be considered to have a broad perspective on the world even if its focus is directed towards artefacts in practitioners use, and in particular on documents at work. To me, with some focus guidance, this open-ended way of investigating the field seems as fruitful for contributions to HCI. Further, I agree that the approaches mentioned in the above quotation, deserve a better recognition and for that a common profile will serve well. The “third paradigm” I believe will gain in attention and become more visible and attractive to such studies on which this thesis rely on.

**Scandinavian approach – towards a renewed Nordic one?**

In a historical perspective the Scandinavian approach contributed in various and significant ways to computing. One branch was the invention and development of programming languages (Simula, Algol, C++) and another branch was the design of computing for work. Participatory Design (PD) grew out of the Scandinavian experience (see e.g. Winograd, 1996; Ehn, 1988) from joint development projects in which trade unions', workers', computing developers' and researchers' developed methods and computer artefacts. The most prominent examples were: in the early 1970s in Norway the Iron and Metalworkers Union project (NJMF-project); the DEMOS project, conducted in Sweden in the second half of the 1970s; and the UTOPIA project that (first half of 1980s) was a collaboration between Swedish and Danish researchers and the Nordic Graphic Workers’ Union.

The UTOPIA project was one example of addressing power relations at work. It involved design of computer support and professional education on integrated text and image processing. "This design was to be based on the principles of: quality of work and products, democracy at work, and education for local development" (Ehn, 1988).

In the Scandinavian style of participatory design, Greenbaum and Kyng (1991, p. 4 See also Winograd, 1996) identify four issues for design that are clearly related to peoples social relations and the question of power:
1. The need for designers to take work practice seriously—to see the current ways that work is done as an evolved solution to a complex work situation that the designer only partially understands.

2. The fact that we are dealing with human actors, rather than cut-and-dried human factors—systems need to deal with users' concerns, treating them as people, rather than as performers of functions in a defined work role.

3. The idea that work tasks must be seen within their context and are therefore situated actions, whose meaning and effectiveness cannot be evaluated in isolation from the context.

4. The recognition that work is fundamentally social, involving extensive cooperation and communication.

Kari Kuutti (1996) suggested activity theory in a kind of work oriented approach to HCI and CSCW. Developmental Work and The Change Laboratory is a related approach even though it isn't delimited to only computing design but as a tested and promising method for change at the workplace (see for example Virkunen et al., 1997).

However, nowadays the emphasis on work is gone and the notion of Scandinavian approach is partly forgotten, due to changes in society. Since work is still of fundamental importance there is nevertheless reason to continue on the Scandinavian experience, or better, to develop an approach to computing which also build on the Finnish orientation. In such an endeavour, the history of PD and workplace studies could be continued and perhaps better profiled if aligned with the “Third paradigm of HCI”. This thesis I regards as belonging to the Scandinavian and Nordic experience, and hopefully as a contribution to a continued Nordic approach to computing.

Activity theory has a potential to be a better framework for design of computing, This thesis indicates that aspects of time and place can be more developed theoretically. An activity system is connected to other activity systems and the computing technologies mediate much more and in new ways what is shared between people. Dorothy Smith and Institutional Ethnography (e.g. Smith, 2005) offer an approach in that direction, an approach that is similar to an activity theoretical understanding of coordination of actions. The Institutional Ethnography begins an investigation from the perspective of an individual and follows her (or his) work as it unfolds in sequences of text-actions-text-actions, where “text” is understood as reading and/or writing documents intertwined with other kinds of actions. The perspective has documents in focus with the intention to reveal the institutional regimes that people are involved in. The complex relations between people are seen as coordinated mainly by and through documents that instruct and make possible the activities people are part of.
Is an understanding of advanced on-the-ground work activities relevant for other ordinary work?

In this discussion the well-known multi-agent or sophisticated work flow systems can be taken as prototypical instances of the above mentioned computational awareness model. Such instances can also help to find the most appropriate areas of where advanced computing in the work place will be most beneficial. So, new technologies results in both expected and surprisingly opportunities, and with that change. Peoples’ power positions, their perceptions and capacities to deal with the world will also change.

Krippendorff (2006) provides a designer's view on human relations and technology. He argue for a “second order understanding” in design which require an individual’s ability to see or in some other way understand other peoples’ perspective on the same artefacts. The idea is that people relate to each other with help of designed technologies, and that humans act independently and motivated by the activities they are involved in. In an implicit way the following quote address power relations in general when considering design. New and advanced technology demand a renewed recognition of complex human relations:

/.../ an understanding that recursively embeds another person’s understanding in one’s own, even if, and particularly when, these understandings disagree, contradict one another, or are thought by one to be wrong or appallingly unethical. This recursive understanding of understanding is a second-order understanding. Inasmuch as human-centered design is fundamentally design for others, it must be grounded in second-order understanding (ibid, p. 66)

In a similar manner, with reference to the above discussed distance and temporal aspects of shop floor work, this study suggests that advanced computing shall not be designed to interfere and act as human agents in spaces where humans are at work. Thus, on a fundamental level my argument is that any machine cannot be considered as a human like counter part in advanced work activities. Instead, the potential is to better support the coordination of human actions if computing systems, and perhaps software agents, are oriented to deal with the digitalised information on behalf of real humans. The internal thinking of human subjects cannot be directly monitored and conducted with mechanical or computing artefacts. In advanced on-the-ground work, a computing sensory, storage and processing system cannot take the role to give orders in the human work activities. However, in other simplified and typical industrialised work, a computing system can set the rhythm and pace of work performance.

So, to remember, the studied cases are inhabited with people who are daily engaged in making meaning of complex work under change, not at least due to technology advancements, while at the same time on other places other people are still executing orders in the old industrialized way. This thesis is focused on the first group of which the reality is relatively
new because of change in work organisation from mass production to customers' involvement, and in the emergence of more advance technologies. Gee, Hull, and Lankshear (1996) do have a clear recognition of both the new and old in their investigation of the new work order:

Workers must now take responsibility, usually in teams, for whole and meaningful tasks which they understand and seek to improve. Furthermore, they must interface with technical information (e.g. statistical quality control devices) and sophisticated technologies (e.g. computers, telecommunications, robots). Gone then except, again, in the backwaters of the old capitalism are workers hired from the neck down and simply told what to do (p. 19).

Increased responsibilities comes with more advanced technology and the workers must develop and exert abilities that can not be controlled from a management centre. Other technologies and old-fashioned organisation is still the reality in many places where workers just have to obey orders. The old relations are continued, but in cases of advanced work there is a component of changed power relations. What managers previously had in their plans, is now something those workers take care of, not as predetermined hands-on tasks but as higher conscious undertakings at work. This requires more of a whole human engagement for a smooth flow in performance and in coordination of what it takes to get the job done. The question of motivation to work is addressed by Gee, Hull, and Lankshear (1996):

Leaders can scarcely achieve this motivation by trying to assert top-down control over their newly empowered workers. Newly empowered workers won't tolerate being ordered around and, in any case, it is not motivating. However, they can hardly be allowed to work (act, believe, and value) against the interest of the business, its leaders, and its shareholders. What, then, ensures trust, loyalty, and full 'over the top' commitment? (ibid, p. 19)

With no doubt, new technologies may play a powerful role at work, as introduced and made integral to a coordination framework in which the workers responsibility for actions in the present and also for future consequences of those actions are at stake. This is a reminder for all specialist designers of computing, that the outcome of their work is likely to be a component in other peoples' ongoing efforts to be in charge of their own life at the workplace.

What then about the future of people and places where support systems are used to simply control individual's work performance? Detailed studies of the concepts in workflow technologies are on-going in different and separate R & D communities (see for example Fischer, 2008). Future workflow technology is likely to be deployed in parts of health care where lots of efforts have been made to identify and model the "process" in such work. Not least, the national programs in several EU countries that intend to implement eHealth strategies, point to increased degree of standardisation and technical coordination. Initiatives to implement workflow in these
areas is expected. Will such development lead to attempts to automate human work or to support it? See for example Bossen (2006) for a critical review of a trial in health care computing.

Technology change and development of more specialised solutions, machines, diagnosis of peoples health and illness will inevitable be continued. Consequently, more work areas must be related with each other. One new specialisation will be more dependent on other complementing and supporting activities and ever more of coordination is required. With that, more self dependent and capable human workers will be asked for. Hopefully, in such a picture, design and use of better support systems for advanced on-the-ground work, can help to establish a more human and deliberate way of organising work – in respect to peoples' rich and very diversified abilities in living their life.

10. Summing up

Support systems for coordination of work can be made very differently. Regardless of that, if integrated in use they play a significant role in peoples relations. When people perform work it is said they are committed or motivated as an explanation to why they actually do their required tasks. It is also a fact the tasks people realise must be even more coordinated and this is partly because of technology advancements as the decisive force for increased specialisation and precision in task accomplishments.

A computing support system might facilitate the coordination of work but the foundational ideas for design of such a system strongly affect the feasibility of the support. If on the one hand, the workers driving force is thought as conveyed by the support systems detail plan, then only simplified and old-fashioned work can be supported. If on the other hand, it is recognised that the workers are motivated by more complex and dynamic work, the support system can be deployed and integrated if it is made redesignable and open for the workers own design contributions.

Those above statements imply that a new support system, if actually in use, inevitable enforce some and oppress other aspects of power relations at play in the work place. This understanding of power is also an aspect of this thesis contribution.

In the following I make a summary of the thesis contribution by answering the thesis research questions. First I give the three interrelated findings as answers to the overarching research question, and secondly I give the answers to the three sub research questions, which provide more detail to the first main findings.

**Overall research question:** *How are support systems for coordination part of advanced on-the-ground work and what does it mean for design of computing in such work?*
It is shown that the practitioners work to great deal rely on what I call a coordinat 
ing framework (see figure 6). Division of labour fosters skilled specialisation that in moment of work performance must be brought together. I argue the framework is an essential part of an environment for practices of on-the-ground advanced work. It is also a part of the central management’s document system as they use for central planning of work. So, for the workers the framework has a twofold purpose: to reach interaction power in work close or directly with hands-on actions on the object of work, and to make a sufficient good alignment with a master plan and an account of performed work for the record maintained in a centre of planning and management.

Secondly, the thesis recognition of power relations within and between design communities do emphasise that practitioners, that is nurses and machinists in this study, not only use but on their own initiative take part in design of the support systems as they integrate in their work practice.

Thirdly, in the practitioners'/workers' use of coordinating support systems they attend to double horizons of their activity system. It means they are, not only motivated by the actual transformation of the work object, but intermittently they realise a longer time perspective that includes the future of the same object.

The three sub research questions are more narrowly focused on documents at work. Regardless if the studied document format is paper-based or digital, it can be considered as an ICT system. The following three questions and answers are, besides the closeness to document properties and affordances, strongly related to the above overall research question. Effectively the following give more detail to the main findings.

(q1) What discernible practical uses of documents are of most importance for coordinating advanced on-the-ground work?

To be sustained and integrated the document system must be re-designable to match changes in the work activity.

(q2) What document features are the most significant to coordinating advanced on-the-ground work?

A new document component must be re-designable, that is compatible with the already integrated components in its appearance and ability to be combined.

(q3) How can this study contribute to the design of coordinating support systems?
A computing ICT support system will better serve coordination if on-the-ground workers are able to co-configure the system together with specialist designers.

Findings of discernible practical uses of documents are based on materials collected from the chosen fields. In my analysis, it appears that nurses' and CNC machinists' use of documents is related to front-line work, i.e. work with the direct care of individuals or machining of metals. These uses of the documents are in turn linked to the design of these documents. Such design is partly the product of others professional work, but not infrequently and to some extent also by those who will use them, such as the studied nurses and CNC machinists.

This thesis contribution is then summarised as condensed expressions in the above answers. It can on the one hand provide insights into coordination of on-the-ground work, and on the other hand clarify boundaries of technologies and identifying the most promising development areas for computing in the future of such work.

11. References


Paper 1.

The Wound Care Documentation Project at Municipal Elder Care

Hans Kyhlbäck, Hannes Persson

Abstract: This ongoing R&D project is about design of a peer-to-peer groupware aimed to support wound care documentation. Nurses decentralized control is recognized as a crucial factor for transition from a single paper print form to a distributed electronic case book. The use of digital photographs has been introduced revealing a developmental potential in this Swedish municipal elder care. In an evolutionary design approach the project is trying to accomplish a mapping between the work activity and the core features of the software system. An authorization layered model and peer membership rules are suggested and elaborated in the design work as key elements in a developed peer-to-peer network architecture. The article reports on utilizing ethnographic field studies and nurses participatory design work as contributions to the software development. The opportunity of improving work and learning by means of the peer-to-peer environment is discussed as additional aspects of software development work.

1 Introduction

The aim of the project is to map decentralized network solution to a decentralized wound care work practice. It will be argued that central in the work practice is the issue of the nurses’ control of their work activity, and therefore the core issue of the design challenge is to map this control aspect. Focusing on the control aspect, our approach is, first, to find out which aspects of control are central according to information captured by ethnography and participatory design methods. Second, we attempt to “build in” the same “control aspects” into the technology, fully aware of the fact that when we introduce a new powerful technology new circumstances emerge and, consequently, a new work practice will occur.

1.1 Sharing and Remembering Wound Care Information

The Wound Care Documentation project is an ongoing project established since one and a half year in the actual work practice of nurses in a Swedish municipal elder care. So far the use of a digital camera and the task of taking digital photos of wounds have been introduced and accommodated to the nurses’ documentation work. In conjunction with initial field studies, a stand-alone software called “Hedvig” was designed and tested at location as a prototype for a future digital wound documentation system (Kyhlbäck, 2002). Currently users and developers cooperatively construct a decentralized network solution to a decentralized work practice. The special features of digital images are perceived as a promising technique that will be integrated in a new way of sharing and remembering information related to wound care treatment.

The design approach of this project is not to invent a large size and self-sufficient system intended to compensate human work. On the contrary, it sets off small and simple to find a way of supporting intelligent human work. The aim of the intended
software is not to automate human actions as a kind of an agent system but provide a technological space that facilitates wound care measures and the organizational memory of provided treatment.

1.2 The Challenge of Introducing a Network Solution

Thus, the Wound Documentation Project is facing a challenge of introduction a distributed network solution in a health care work practice. New network technology may result in distrust, non-acceptance and frustrating experiences for the health care personnel. What seems to be an important reason to failures of deployment is the human’s lack of control of the technology. In their book *Information ecologies* (1999) Nardi and O’Day describes how the activity in an operation room at a hospital was affected by the introduction of a central monitoring system where the neurophysiologist could monitor several operations at once from his office. The introduced system fed all the data of interest to neurophysiologist outside the operating room, including operation room audio and video, in addition to the instrument data. As they write “It was an invasion of privacy. It threatened the sanctity and balance of the social practices that made the difficult work of neurosurgery possible” (1999, p. 178). The authors claim that the “remote broadcast changed the nature of communication inside the operating room in significant ways” (1999, p. 179). They no longer made jokes or talked about their weekend plans. This maybe seems harmful but as the authors states “the banter and fun in the operating room provided social cohesion in a stressful situation that required meticulous teamwork” (ibid.). The personnel who were monitored had no control over who had the access to watch the records of them. It was even so that anyone who got access to the computer network was able to see the broadcast from the operating room. This feeling of being out of control can demolish most introduced systems. As Nardi and O’Day point out, the introduction of a new artifact inevitable will lead to changes in the current work practice, and in some cases it leads to the emergence of a whole new practice. The new technology makes things possible that were not possible before and therefore affect the activity in the work setting where the artifact was introduced. By the deployment of such a central artifact as our designed peer-to-peer groupware system, the daily activity in the elder care is likely to be affected.

1.3 The Mission and Suggested Concepts

The mission of our R&D project is to support, and avoid making things worse in the elder care. We hope that our contribution will help to make the work activity more sound and flourishing at the same time as we understand that our peer-to-peer system is not the one and only solution to problems of well-being for the care recipients and the health care staff. We have identified a set of goals for what to accomplish in making real our over-all mission for the R&D project. In the developmental work we consequently have created or selected a number of measures for realizing how to accomplish the implementation and deployment of our: decentralized network solution to a decentralized wound care work practice. Our design work focus on a transition of a paper print case book to make a distributed electronic version. The ubiquitous Internet is a technological grounding on which we build an implementation of our designed peer-to-peer groupware. From findings of ethnography on how the local team work is
organized, we try to map by means of our suggested concepts for this peer-to-peer groupware. The *authorization layered model* realizes our understanding of core characteristics of wound treatment documentation. Some parts of the information are not needed for assessment and analysis of a particular wound healing process. Leaving personal data out will make it possible to share anonymous information with personnel in the periphery of the work practice. In making a distinction between different information content, we find a way to distribute information and in effect the system might promote learning on a distance to the actual work practice. The authorization model is followed up by the *peer membership rules* and found as a sufficient match to actual division of labor in the health care practice. Those concepts are key elements in our peer-to-peer network architecture which is currently developed further in our R&D project. In developing an *ontology* (Fensel, 2001) we might find an artifact that facilitates communication among nurses and software designers, as well as a product to be utilized in our design.

1.4 Allowing the Nurses to Maintain Control of Wound Care Information

However, for now this article reports on an on-going project where the peer-to-peer groupware is planned to be deployed allowing the nurses to maintain control of wound care information content in a digital environment. The software under development will allow for the nurses to first invite themselves as members of a specific network community, or more precisely, to a peer group as described in following paragraphs. The nurses and other personnel provide wound care tasks as motivated by the individual care recipient’s need to get her or his wound healed. For those mostly elderly people in the municipal special accommodation, it is painful and takes a lot of patience and time to successfully treat wounds. In this writing we refer to wounds in general but adhere to descriptions like: “chronic wounds such as pressure, diabetic and venous ulcers” or “non-healing” alternatively “hard to heal” leg, foot and pressure wounds that need recurring treatment. The municipal wound care work is characterized by skillful assessment and giving ‘hands on’ measures at the care recipient’s home.

1.5 Integrated and Unified Case Book

A supposition of the R&D project is that the nurses will learn and feel familiar with the peer group software and further get confident about adding more people to either be full members of the group or only as restricted “to just look” at some specific parts of the information. The idea of the extension of the documentation artifact is to let people look and learn and this is found to be a secondary motive for the Wound Care Documentation project. In supporting documentation work an integrated and unified case book is asked for as the central artifact. A nurse in the municipal elder care and member of the Special County Wound Treatment Group pointed out: “There is a need of a unified documentation. Today we have a number of home-made case books” (interview May 2002). Additionally, the General Practitioner Ruth F. Öien that has developed a work practice on pinch grafting at a primary care centre in a neighboring municipality, highlights the importance of improved education in a recent doctoral thesis: “Monitoring standards for assessment of ulcer aetiology through repeated ques-
tionnaires and educating medical staff seemed to assure more accurate diagnoses, a prerequisite for effective leg ulcer treatment” (2002, abstract).

1.6 Evolutionary Design Approach

The methodological approach of this project is to develop the system in an evolutionary way as inspired by the Scandinavian tradition of participatory design work. The idea is to integrate feedback from the field continuously into the design process. Nurses and software designers and engineers currently interact to get work practice experiences and the design made more specific and fine tuned. The technique of using mock-up’s, that is low fidelity prototypes of user interfaces, is a way of facilitating communication between end users and designers. This approach of our R&D efforts seems well suited to applying new technology to an established human work practice. According to Tom Gilb the evolutionary process “… is particularly suited to complex technology, fast-moving environments, large scale projects” (1998), this approach seems to make sense also in our project. Analysis and design is in a way adapted to the articulated needs as picked up by ethnographic studies and joint design sessions. Further on, delivered software will be tested and evaluated in the real work setting of the end users.

2 Wound Care in a Swedish Municipal Health Care

In municipal elder care within special accommodations, people live and receive bodily care and help with ordinary things to do in a home, and in some cases they are given medical care treatment. About 500 individuals live at eleven special accommodation units in the Municipality of Ronneby. For all of those, a total of twenty-three nurses provide medical care treatment. They work as generalist with many different tasks to carry out, and a particular task is to provide wound care treatment. Use of computers is not prominent in this work-at-home-setting while the municipal elder care requires a lot of “human touch” and sensitive attention to the elderly in need of help and proper treatment. Bandaging and dressing of a wound is a routine task that involves assessment, decisions and co-operation between all involved people. The task is far from trivial but a time consuming work concerning life of a human being and the particularities of a specific wound.

2.1 Nurses on the Move with the Bag on Wheels

Quality of treatment is dependent of mutual understanding which is built when nurses, doctors and other personnel cooperate. Learning about the individual care recipient in general and about a specific wound is an every day issue of wound treatment. Embedded in the infrastructure of the work practice are artifacts as the case book. In the today paper version it contains heterogeneous information about the individual’s personal data, status of health, diagnosis and instructions of the specific wound treatment and also written notes on periodically taken measures. The personnel learn about the development of individuals and of the healing process as close and intimate aspects of life as such. New practices, new medicals and specific wound treatment tools and ma-
As the health care work is regulated according to national legislation, it is argued to extend the local infrastructure and connect it to adjacent health care institutions and to governmental bodies in the administrative and political system. In trying to realize such extension there is however a lot of baggage to deal with. Information is often thought of to be made available in other locations than where it is created. We believe that it is first necessary to consider the information and communication technology in the primary location. In Figure 1 is indicated the nurses work as on the move and making visits to several homes of elder people on an ordinary day. Each nurse have a “bag on wheels” in which is found four to five ordinary loose leaf binders containing paper prints of information, a diary and some medical equipment. The actual content of the bag is about planned care service to provide for elderly people as the nurse pay a visit to. Information about wound treatment is only a part of all this paper work. Deploying wound documentation software will not in itself replace the use of a bag on wheels.

We believe this work might be supported by an enhanced and computerized Wound Treatment Documentation System. The use of a digital camera and digital photographs as a part of the documentation work is introduced among the nurses since about one and a half year ago. Fully aware of the risk of reducing freedom of the course of actions of the health care workers while they are dealing with a very rich and diverse
reality of elderly care, we try to make a computer support system successful by a sufficient match between the construction of a computer peer-to-peer system and the world as perceived by the end users.

3  Design of Network Architecture

When designing key elements of the system architecture we adopted three levels of authority, *apprentice* (Lave and Wenger, 1991), *credential member* (Brookshier, 2002) and *group manager*. We deliberately deviate from the conventional term user and from now on suggest the terms above. These terms would be in better accordance with the common vocabulary in the context of the actual work practice. We use the term peer as a generic term when we don’t want to distinguish their level of authority. Those levels, or identified sorts of health care personnel, make up our peer membership rules.

3.1 Distinction between Different Levels of Authority

This distinction between the different levels of authority is a direct mapping of the relationships in the work context. In the local work setting a nurse is a member of a health care team. In the application the team is mapped into a peer group and the nurses in the team are mapped into credential members. The nurse that is “the responsible nurse” (“PAS” is the Swedish acronym) for a specific care recipient is flagged as group manager and has the power to let other persons join the group (i.e. become credential members). To make sure that the peers in the system receive the same privileges as in their local work setting we introduced the model of authorization layers (Kyhlbäck, 2002, also see Figure 2). This model determines which person is authorized to see (and modify) information about a specific care recipient.

![Fig. 2. Model of case book authorization layer.](image)

The 1\(^{st}\) layer is the protected information that only the credential members have access to. The information in the 2\(^{nd}\) layer is for both credential members and apprentices. However, the PAS might give or prevent the apprentice’s access to the 2\(^{nd}\) layer information due to the individual care recipient’s wish.
It is the PAS that determines which peer is a credential member or which peer is an apprentice (all peers in the system are without access until a PAS let them into their group). As can be seen in Figure 3, a peer can be both a credential member and an apprentice, although not within the same peer group.

At the first degree of extension peer 3 is an apprentice (indicated by the arrow) concerning care recipient A (“cr A” in the figure), but a credential member concerning care recipient B. At the second degree peer 2 is a credential member in the peer groups for both care recipient A and B. Peer 4 is an apprentice in the first extension but in the second has become a credential member in the peer group for care recipient A while peer 5 still has a non access position concerning information on both care recipients. Consequently, peers within the system who are not appointed as credential or apprentice members for a specific care recipient, are treated by the system as having no access at all, they are only potential members to be invited by the nurses in the work activity.

![Figure 3](image)

**Fig. 3.** The WoundDoc system at two different degree of extension reflecting the dynamic character of peer membership rules.

As can be seen in the Figure 3, *WoundDoc* is the group that contains all sub peer groups building up the system. Each peer group within the main group WoundDoc corresponds to the concept of a virtual private network (VPN) (Stallings, 2000 and Brookshier, 2002). The WoundDoc group is a part of the default World peer group (Brookshier, 2002). By the nature of the information handled by the system all network traffic and data are encrypted. Encryption together with the introduced authority model helps maintaining the status as a secure VPN.

### 3.2 Distribution of the Administration Task

This system model sketched above distributes the administration tasks to each PAS. The system therefore becomes less dependent on central administration authority. The role of the latter will be restricted only to assign a PAS to each care recipient and reassign a PAS to a care recipient when necessary, making sure that each care recipient has a PAS all the time. The municipal nurse unit manager (MnUm) has the responsibility for this task today in their local work setting, and therefore we have introduced another level of authority in our system: the MnUm. The tasks and the role of this peer are derivable from the local work setting and mapped into the system. The MnUm is actually passing over the control of the system to all peers flagged as PAS. Consequently it is the PAS who get the distributed (decentralized) control over the system.
3.3 The Information Owners Control

The PAS get control over which peers are credential members or which are apprentices regarding “her” peer group(s). The benefit of this solution is that it is the information owners (PAS) her/himself that maintain control over who is authorized to access the information. Information in the 2nd layer of a specific case book is all an apprentice might get access to. It is totally de-personified and could make no harm, except if someone has access to the 1st layer information containing personal particulars. The purpose with letting this 2nd layer information as partly available is to support the learning process within the organization: other nurses can read care treatment instructions and see images of critical wounds and learn by other nurse’s experience. That’s also why we decided to name this level of authority apprentice.

Since the PAS now get the control over the specific peer group it is up to her when letting other peers into her peer group. It is expected that the peer groups gradually will expand over time. What’s important is that the control of this expansion is distributed to each PAS and not to some central administration authority.

4 Design Considerations Facing Work Practices

A problem of today practice with use of a single paper case book is that it is casually not accessible when it is asked for. This is due to the contradictory character of the information about sensitive and taboo issues. Wounds are not something the care recipients are likely to talk about with somebody else and even less something to show and make visible. It is essential to respect privacy and follow legislation about secrecy. That is why the paper case book is only made available for authorized care personnel. Partly because the municipal nurses are on the move and pay visits to several individuals in different special accommodations on every day, the paper case book might not always be available. The sensitive information content is secret and because of that less available. As a work-around, the nurses, therefore frequently write notes on “post-it” pieces of paper and for a while put them in their pocket. Later on when there is some space in time, the nurses update the paper case book with help of those “post-it” notes. To remember is that on an ordinary working day, the nurses plan a number of visits to provide several kinds of treatments, of which wound treatment is only one of them. Typically the nurses try to keep up with the plan but are now and then interrupted by events that “pop up”. The nurses are most of the time on foot making rapid shifts of focus and instant switches between different services. In respect of wound treatment, things might be significantly changed if a high level of privacy is maintained and access to a reliable information system is improved by means of a peer-to-peer computer network.

4.1 Crucial to Provide for Nurses Decentralized Control

The crucial design task for our peer-to-peer groupware is then to provide for decentralized control. A paper case book is stored in an ordinary loose-leaf binder of A4-size. It is an artifact with physical properties for long accepted as secure in the municipal health care. We expect that if the software fulfills functional requirements for smooth and stable performance and a decentralized control, then the computer artifact also can
be regarded as safe and reliable. All of this can not be foreseen in advance but might be created, provided the nurses in the first place are able to experience that they are at least in the same control of the digital case book as with the today’s paper version. If they have control of who will access what, it will be possible to create and share information on the computer network. The nurses, in particular the PAS, create documentation to support their own day-to-day actions but as the information owners they fulfil an agency in the interest of the individual care recipient. The relationship between a recipient and a provider is socially constructed and if the health care matters are carried to an extreme, the recipient is in his or her full right to refuse care treatment. In the same manner, the individual might refuse documentation about her or his wound to be made available for others than a select few. This is also supported by Swedish legislation that explicitly states that information across health care institutional boarders have to be carefully approved. The individual care recipient has to actively confirm approval as a condition for distribution to adjacent hospital care system or any other health care authority.

4.2 Other People might be Members and Peers

The municipal nurse carries a key role in maintaining an intimate and trustful relation as a first hand partner in providing hands-on treatment, as well as a mediator to other potential care providers. If the responsible nurse is able to instruct on proper treatment, assistant nurses and relatives might be involved in the actual wound care treatment. The wound care case book might also be subject to such a cultural constructed health care practice and other people than nurses might have a legitimate interest to become members and peers in appropriate peer groups. Obviously, doctors in the primary care system currently have interest in both the care treatment and in the case book. In the municipality in question, there is an agreement to divide nurse’s responsibility on the municipal organization and doctors tasks of mainly making diagnosis and prescriptions on the primary care organization. The doctors come at planned visits to the special accommodations and fulfil a role as a “patient responsible doctor” (“PAL” is the Swedish acronym). Following the rules, there are one PAS and one PAL on each care recipient. The today’s paper case book is then available for the adherent PAL at a visit but it is not available at the primary care location, which is the “home” of the doctor’s ordinary working time. With our network solution and the individual’s approval, the digital case book might be accessible for the PAL at the primary care locations as well. The nurse (as a PAS), given the control of the peer group, might then experience that the relationship with the care recipient is not violated even if the case book is made available in other locations. This possible extension to the primary care has to be carefully considered in deployment of the software.

If the peer-to-peer system will meet an initial acceptance by the nurses, and in compliance with their agency also by the care recipients, several peer groups will be dynamically constructed. On the designed condition the PAS invites and adds her nurse colleagues who replace her at time when she is not on duty. Such flexibility to form peer groups match the current working teams that provide wound treatment for an individual at the special accommodations. The added members of a peer group are those that have the day-to-day primary responsibility for provision of care. They will have full access to the case book which is needed to follow rules of making notes on period-
ically taken measures of wound treatment. Those notes make up a history of the healing process that also might be further enhanced by digital photos integrated into the electronic case book. Taking pictures with a digital camera is already experienced as a promising technique to enhance wound documentation and is already part of the work practice.

4.3 One Peer Group on Each Individual Suffering of a Wound

In deployment of the peer-to-peer system, a peer group will be created for each individual suffering of a wound, and consequently, the number and size of the peer groups will reflect the practice of those that are close to the individual care recipient. The nurses are as employees obligated to follow the conduct of a hierarchical line organization but there is usually no practical or legal reason to share treatment information with e.g. any superior manager. The provided health care work is inherently decentralized in respect to its location to peoples home and how it is culturally developed and motivated by the needs of the individual care recipient (Westerberg, 2000). As our ethnographic studies reveal, the municipal personnel are employed by a large organization comprising one principal authority, however, in respect to most work practice tasks, they are members of several culturally developed activity systems (Engeström, 1987). A municipal nurse might be a designated “patient responsible nurse” (PAS) and as such carry a key role. Around the individual are other people involved in providing care treatment. Rules and artifacts are to be followed or utilized – all referring to the care recipient as the central and communal object of an activity system. For short, the municipal elder care as an official line organization is one large system, but seen as activity systems, there are many decentralized working teams defined by each individual care recipient. Provided that the peer-to-peer system will be accepted and the PAS will be given the decentralized control of the software, we expect that the added peers to each peer group will match the actual members of each activity system. A successful deployment will in a first phase be constructed by the nurses and matching each care recipient as the object of each decentralized working team. In a second phase, also the adherent doctor as a PAL will be added to the appropriate peer group, provided that legally difficulties in crossing institutional boarders are overcome.

4.4 Design Principles for the Graphical User Interface

In our project we emphasize the visualization aspect of the electronic case book. The diversity of information types range from check boxes to free text descriptions including digital images of the wound in question. The graphical user interface is being made to follow design patterns that clearly divide one coherent concern on one distinct display. As the interface is visualized in full authorization mode on a standard desktop screen, it shall also be clear that the information is about only one specific care recipient. Name and other information that reveal the identity is therefore not necessary to blow up for everyone to catch at a glance. On the other hand it is stated as a requirement that a significant part of the interface shall display names and some representative object for each credential member in the actual peer group. It is expected that visualization of all authorized peers support a user experience of the interface that confirm which particular wound and care recipient that is the common object of the group. Ad-
ditionally, there will also be indicated which one of the peers that is the PAS with power to manage membership in the group. These design principles for the user interface is set up to promote a functional requirement to display only one case book for one care recipient at a time and in effect also support a user experience of a decentralized control of the peer-to-peer system. This design make justice to object oriented software concepts that we believe will serve the purpose of integrating the user interface and the software system into the mature social activity systems.

4.5 The Scale of the System

Following a guiding-star of humans conduct over an advanced technology, our project utilizes the Internet infrastructure and provides it as a support system to be controlled by the members of a purposeful human work practice. Peoples decentralized distribution of power to accept membership, refuse or restrict access to resources is not a task to automate. Given the foundational principle to support and not reduce peoples conscious work we believe a successful approach allow the end users to learn and get familiar with the new system. If the members of the municipal elder care control what, when and who to be integrated and made connected to the potential of a large technology system, the scale of it will be balanced to the needs and perspective found in the local circumstances of a decentralized work.

Starting in very small scale we expect each peer group of credential members to grow to a size that match the culturally matured activity systems. It might take some time to get to a balanced situation. It will involve breaking principal organizational barriers between the municipal care, primary care and specialist hospital care. By the time when members learn and accept the peer-to-peer groupware they might be encouraged to let size grow in terms of making anonymous information available for apprentice peers. The very existence of the software within the frame of the municipal elder care will make people in adjacent care systems interested, and probably some will insist to share text and images about the wounds. Provided that the care recipient allows his or her information to be shared, it can be made available for the apprentice peers in the system. It is then possibly for apprentice members to “just look” at those parts of the information as we define belonging to only the 2nd layer of information in the electronic case book (see Figure 2). Probably a doctor only needs this anonymous part of the information to be able to make advice from a distance. Students of health care are another group that might have a legitimate interest to look at a series of digital images that reflect the healing process of a wound. We believe the peer-to-peer groupware have the potential as a wound care documentation support system and possibly it also open up for new and improved ways of learning and performing work.

5 Holding it All Together

Internet infrastructure provides a horizontal zone of expansion beyond the organizations local intranet. Already today the underlying network platform makes it possible to connect to the system from anywhere in the world, as long as the computer has an
Internet-connection. We use the worldwide Internet to connect our peers. The built-in mechanisms in the system together with the JXTA-platform enable us to shape a virtual network of geographically distributed clients. The figure below is a general model of how geographically distributed computers and networks establish a virtual network.

![Diagram of virtual network](image)

**Fig. 4. General model of mapping between physical and virtual networks (JXTA press kit)**

In our model the WoundDoc main peer group containing all the dynamically created care recipient groups represents the JXTA Virtual Network layer in the picture above. It is this boundary (group) that delimits the peers from the rest of the peers in the default world peer group. The municipal fiber network connecting all the special accommodations in Ronneby represents the physical network in the figure. The fiber ring obtains connection to the global Internet for the public authority buildings within the municipal. As mentioned the access to the WoundDoc system is via Internet, the fiber ring is only used to provide the computers with Internet access. This enables other networks to connect to our virtual network such as the county computer network in Ronneby primary care or at the hospital in Karlskrona or even a dial-up modem connection from the home of a relative as long as the computers got an Internet connection.

JXTA is a set of open-source protocols for building peer-to-peer applications. The following description of JXTA is from the introduction of the JXTA protocol specification:

The JXTA protocols are a set of six protocols that have been specifically designed for ad hoc, pervasive, and multi-hop peer-to-peer (P2P) network computing. Using the JXTA protocols, peers can cooperate to form self-organized and self-configured peer groups independently of their positions in the network (edges, firewalls), and without the need of a centralized management infrastructure (Project JXTA, 2003).

In this particular project we use the Java implementation of this API. JXTA gives a potential of unlimited numbers of peers but the decentralized control delimits the actual number of members in our WoundDoc application. With a match to a relevant activity system a particular peer group in our system will be self-organized and consequently it will find its proper size. Nurses and doctors belonging to different principal institutions do have the individual care recipient as their common object and therefore they

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1. [www.jxta.org](http://www.jxta.org)  [https://jxta.dev.java.net/](https://jxta.dev.java.net/)
2. [www.sun.com/aboutsun/media/presskits/jxta/](http://www.sun.com/aboutsun/media/presskits/jxta/)
will become members of the same peer group. Barriers between institutions might be overcome with thanks to the JXTA technology and a match motivated by the common object will balance the size and extent of the peer groups. This dynamic relationship between the humans and the technology seems likely to holding it all together.

5.1 Design of a Digital Case Book

In the course of our evolutionary design the scope and content of the current documentation work is questioned by the nurses as a result of our interest in the paper case book. It is now regarded as a “home-made” variant of a case book adopted five years ago in the municipality. The case book now in use has an origin in another municipality’s elder care and it has been disseminated in various forms to several municipalities. Still, it is a point of departure for our design of the digital version, but as a result of our presence in the field, another paper case book was brought up by the nurses: a one-page form, originated from primary care wound treatment work at nearby primary care (Öien, 2002). At location in Ronneby elder care, the nurses made editing work with handwritten markings and notes on both paper case books with the intent to feed information into or wound documentation project. The expected outcome is that the planned software will realize a more uniform and integrated documentation form. Interpretations and compilations of this empirical material are considered as valuable for the developed design.

To be noted is a potential conflict between concepts developed in two different work cultures, that of municipal care on the one hand and primary care on the other hand. A direct translation of the Swedish word "journal" (a word found in both title names of the paper case books) associates to the legally and legislation ruled understanding of a medical record. This is not perfectly valid in our case when the wound care documentation shall not be regarded as a medical record in such a strict legally sense. Instead it is a systematically used tool for documentation of municipal wound care treatment and intended to mediate necessary information among those who provide wound treatment.

Our developmental design work is prepared for and allow for new material to be adopted as we now try to merge the most appropriate parts out of two different paper case books. The nurses in the municipal elder care have an active participating design role together with our team of software developers. However, a possible and typical risk of introducing computer artifacts in a work practice is to standardize too much and in effect restrict the existing work culture of providing health care. At the special accommodation, social relations develop in the intimate interactions between the care recipient and the nurses. Vocabularies develop to facilitate “hands-on” actions and communication. The case book serves the interest to maintain remembering and assessment of wound healing among those that directly take part in the treatment activity. To find a balanced way of making a unified case book but not reduce too much of established work culture is an issue of great importance for the health care work.

5.2 Ontology Design supporting a Balanced Standardization Work

We believe that the development of an ontology might work as a bridging process of shared conceptualizations between members of the health care and the developers in
order to understand the task at hand. Our approach to ontology design might be different to much other work in the health care domain. We are not satisfied with a simple reuse of a possible available ontology. To avoid a drawing board product we find it essential to make an ontology grounded in a real work setting. In our case we have access to experiences of health care personnel with specific knowledge in wound documentation. An ontology seems as a potential rich artifact that might be developed in joint sessions with both nurses and developers taking part in cooperative work. We expect that ethnography and participatory design to develop an ontology, will effectively help in mapping between the real world practice and a formalized representation. To anchor ontology design in the real work setting seems beneficial even if there is a ready made version produced somewhere else to use as a point of reference. For sure, our project requires learning to successfully integrate the peer-to-peer system in the municipal elder care. To meet the request of enhanced learning of wound treatment, ontology design might mirror the work practice in making explicit the concepts of wound care documentation. Through interaction between developers and members of the health care, a balanced standardization in work can be agreed upon. The nurse’s participation in merging the actual paper case book together with the one brought up from the nearby primary care is the primary point of departure for the development of our ontology. In parallel, this ontology will feed structure and concepts into the ongoing design of the electronic case book.

6 Discussion

In the continuation of the Wound Care Documentation Project there is planned a trial period with testing and evaluation of the peer-to-peer system in the real health care work setting. A lot will be in a research interest to observe, and more empirical data have to be analyzed for next phases of R&D work to do. At the moment, we are able to summarize the R&D challenge of designing a decentralized information system solution to a decentralized documentation work. As also can be seen in Table 1 we summarize our mission to accomplish a contribution to support a desired development of municipal health care work. In this article we have suggested and discussed some key design issues that might explain how to realize our mission, of which the most important computer science issues are also depicted in Table 1.

In a number of small activity systems, nurses decentralized control of wound care work is depicted in the first three cells of first column in Table 1. We consider privacy of the care recipients as a fundamental concern to respect in any distribution of the information. Sharing an electronic case book is then possible and improved learning might be supported in wound assessment and care treatment. Privacy is also required for any attempt in making information accessible across institutional barriers. In the rightmost column of the table we indicate peer-to-peer grouping in a self-organized way as an over-all sufficient solution. Web technology and use of the ubiquitous Internet infrastructure we believe opens up for novel designs. The project’s implementation of the software is built on a combination of general available technologies and our particular concepts of authorization layers; peer membership rules for credential, apprentice and group manager members and the separation or loose coupling between personal data and specific wound treatment information. Ontology design we expect as a
supportive method to facilitate our central task to map a technological solutions to a health care work practice. Future work will reveal the fulfilment of the projects expectations on the design and deployment of a peer-to-peer groupware in a wound care documentation work.

Table 1. Mapping a decentralized solution to a decentralized care documentation work

<table>
<thead>
<tr>
<th>What to accomplish:</th>
<th>Wound Care Documentation</th>
<th>How to accomplish:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supporting sound and flourishing elder care activity systems</td>
<td>Mapping of technological solutions to health care work practices: ethnography, participatory design and evolutionary software development</td>
<td>Peer-to-peer grouping in a self-organized way implying decentralized software control</td>
</tr>
<tr>
<td>A recognized decentralized work practice</td>
<td></td>
<td>Peer membership rules for credential, apprentice and group manager members</td>
</tr>
<tr>
<td>Nurses in control of wound documentation work</td>
<td></td>
<td>Separation or loose coupling between personal data and specific wound treatment information</td>
</tr>
<tr>
<td>Privacy for the care recipients</td>
<td></td>
<td>Authorization layers</td>
</tr>
<tr>
<td>Learning in wound care</td>
<td></td>
<td>Ontology design</td>
</tr>
<tr>
<td>Crossing institutional barriers</td>
<td></td>
<td>Use of ubiquitous Internet infrastructure</td>
</tr>
</tbody>
</table>

7 References


### 8 Internet resources


What does it take to replace an old functioning information system with a new one? A case study

Hans Kyhlbäck, Berthel Sutter

Summary
Purpose: To investigate the case of a municipal wound care practice and the process of designing a specific computer documentation record system. In carrying out our kind of action research, creation of the system that integrate digital photos, was supposed to remake the old wound care documentation system and transform it into a more advanced and unified tool.

Methods: Ethnographic studies were conducted before and parallel to the design work. Nurse practitioners were involved in design and actively determining essentials of the computer artefact. Developmental Work Research (DWR) is the framework against which data from the work practice and system development where analyzed and interpreted.

Results: First, an old-fashioned information system within health care work will not successfully be replaced by a new one, unless the new is better “as a whole”, that is, better supports work practices of a range of occupational and professional workers. Second, when designing information system for the public sector, system designers will almost always face dilemmas based on a contradiction between central, high level interest and a local level work-practice perspective.

Discussion: Our study reveals that the work practice of the municipal nurses is characterized by three distinctive features: High mobility, the need for face-to-face interaction in different locations, and a great variety of artefact usage. This implies that a new information system has to be “better as a whole” dealing with those characteristics.

Keywords: Activity theory; Information storage and retrieval; Medical informatics; Wounds; Wound treatment; Interface size

1. Introduction

In this paper we report about design for nurses’ work practice in a socio-technical context of Swedish health care. Typical for the municipal elder care in this case and pertinent for the task of giving wound treatment, is the nurses dependencies of high mobility, social interaction and utilizing a vast diversity of tools. The mobility of the nurses stems from the fact that they need to meet a lot of patients in the patients own housing (After this sentence we preferable write ‘care recipient’ and not ‘patient’ to recognize the work domain of our case as a municipal, or community, health care for people living in their own home but receiving help and care from the public sector). The features of the work practice of the nurses necessitate encountering the care recipients face to face (or “body to body”). Within the scope of their work practice, the nurses realize a capability of designing and redesigning their standard set of artefacts in order to get the every-day work done in a proper way. In our case study, a new In-
formation and Communication Technology (ICT) system, a digital case book for the wound care was to be developed. This was carried out in a joint project using the Developmental Work Research (DWR) approach (a kind of action research) in which an evolutionary system development practice was incorporated. DWR is a methodology comprising ethnographic investigation, reflection on the history of the work and designing solutions to identified need problems. This methodology for creation of a new tool, such as a computer system, includes gathering of qualitative data to be analyzed and used as raw material utilized as input in the transformation of the investigated work practice. Nurses, computer system developers and researchers joined in an activity for analysis and design of a new digital case book. The outcome was a rough prototype of the to-be-designed system (named HELAR).

In the further presentation of this paper we first reflect on experiences of the developmental work in terms of the delivered prototype HELAR, and, second, we make a critical investigation on the technical design as deployed in the work domain of the nurses.

In the Method section we shortly present DWR as applied in our case and we also provide a brief presentation of the ethnographic tradition in software and computer design.

Our two claims also address the underlying force in working life and we want to discuss tensions and contradictions (discontinuities in Bertelsen & Bødker [3]) as conceptual tools in a further developed approach grounded on DWR. For the matter of Object-Oriented System Development of computer systems we recommend the DWR approach to be inspired by and as we believe a successful way to deal with identified problems of designing new sociotechnical systems.

In his seminal work on the structure of scientific revolutions, Thomas Kuhn pointed out that a paradigm would not be abandoned just because it faces many anomalies. A further condition must be met: an alternative paradigm, regarded as better, must be available. Something similar seems to be valid for the replacement of an old-fashioned, albeit functioning, socio-technical system. A better one has to be presented, received and realized in practice. This would in our case of wound care practice, as it seems, require new software and hardware made to be immediately accessible to all the nurses in performing their everyday work.

2. Materials and Methods

Our approach of DWR emphasizes the importance of material artefacts and concepts central to a local work practice within the target domain. In our case of wound care, nurses brought about their current version of paper based documentation work as well as a corresponding artefact from a specialist hospital work in a design session intended to create the digital case book. In order to deeply understand the driving force of change and transformation of work - ethnographic studies were conducted before and parallel to the design work. By that: researchers and system designers closely followed the nurses in their daily work practice. The investigation of municipal wound care was accomplished by taking notes, shooting digital photos, collecting material artefacts in use and making audio recorded interviews. Using the DWR approach in order to understand, follow and facilitate work we also connect to a tradition of doing ethno-
graphic work and utilize the investigation results as input to the design of a computer system development. Lucy Suchman and her Work Practice and Technology Group at Xerox Parc are probably the most well known and prominent founders of the tradition of bringing ethnography to design of computer systems [14].

Our methodology, DWR, might open up for a more systematic involvement of practitioners in work-oriented design of computer artefacts. DWR has a focus on innovation systems at the local level and can be labelled as a kind of “action research” or “interactive research”. It is grounded in and takes an activity theory perspective as a framework for guidance and analysis. The principles of DWR can be summarized like this: “First, a collective activity system can be taken as the unit of analysis, giving context and meaning to seemingly random individual events. Second, the activity system and its components can be understood historically. Third, inner contradictions of the activity system can be analyzed as the source of disruption, innovation, change, and development of that system, including its individual participants.” [5] p. 63. In this kind of action research learning, development, and research are basic elements for both practitioners and researchers. Learning as a by-product of participation in any activity is about learning of actions and strings of actions. One learns what is given in the culture by participating in the culture. Occasionally, spontaneous innovations occur as actions in response to challenges in work practice. Another feature of DWR is the mutual collaborative efforts between researchers and the practitioners from the activity to be developed.

Evaluation of the wound care digital case book (prototype system HELAR) was made through participatory work in making case book entries and integrating digital photos on the care recipients’ wounds. The character of collected evaluation data is mainly qualitative, but in terms of “usability” it is not only “soft social business” but adheres to established engineering practice. No questionnaires are made because we prefer close interaction between nurses and researchers, which provides domain expert perspective and direct experiences of trying to make sense of the development outcome that is produced. In the evaluation interaction, sessions were audio recorded, digital photos taken and notes written in a manner that comply with ethnographic field work methods. The evaluation data is analyzed and interpreted against the framework of DWR as building on principles of activity theory [5].

3. Results

3.1. Features of municipal wound care activity

In a small municipality in south of Sweden elder care is given to about 450 people living in eleven special accommodation units where they receive help with many kinds of every-day things, like getting dressed and taking medicine. A number of assistant nurses, twenty-two nurses, managers and other personnel work and provide round-the-clock service. Wound treatment is only one out of many things the nurses take care of. Only a few individuals suffer from wounds that are hard to heal. Nonetheless, it is a very painful, time demanding and a taboo issue to experience. Each wound is a unique challenge of getting hold of a process and making it into a progressive healing and well-being. Both planned and emerging treatment tasks of a great diversity are neces-
necessarily provided in close contact with many individuals, where each situation needs assessment, communication, decision making and sometimes hands-on work. Our study reveals that municipal nurses work practice can be characterized as heavily on the go and on the move.

Clusters of artefacts [2, 4] are constitutive of most work practice. The artefacts are brought into the activity, made accessible and often re-designed to make a better fit to work to be done. When needed they are grabbed and in a systematic way made use of in actually performing work. Set up and configuration of each cluster take into account that the artefacts make some operations and actions possible but restrict others to be made. In the actual case there are medical materials, medicine and aids for remembering and documentation of provided care. Furthermore, there is a specific clustering of artefacts selected at each working shift: a set of medical instruments, a diary, a note pad and or a deck of small slips of paper, four or five ordinary paper binders, all of it packed into a bag on wheels, one for each nurse. This bag-on-wheels is the current mobile IS in use by the nurses.

The typical everyday documentation work in municipal elder care looks like this: As soon as possible in conjunction with a performed action, the nurse makes use of any table or a furnish detail to place their slip of paper, diary or checklist in order to document with a pen. If needed the binders are consulted, before or at the actual moment of giving treatment. Short notes on slips of papers are temporarily put in the nurses’ pocket or the notes will be found in the note pad. At some planned or emerging situations on the shift, the nurse drawbacks to a little sheltered place and there she makes a final proper documentation. They transfer their first hand notes from the slip of paper into the regular paper forms stored in the binders. In other words, those artefacts, brought along and accessed when needed, form an extensive mobile information system that is designed and redesigned by the practitioners themselves as a part of their municipal care work activity. Thus the nurses actively construct the nearest sociotechnical context of their own work. As the everyday practice is characterized by intensive interaction with care recipients and other health care staff, their technical support systems have to be available for immediate access.

Work actions in elderly care are typically an unforeseen mix of planned events and dealing with a diversity of emerging cases, following that the nurses have to embody a vast set of operations in performing an action that is sufficient in each and every situation. Most actions and operations are dependent on artefacts that are familiar to the nurse and that constitute parts of the socio-technical system. Since the practice involves a diversity of people to interact with and also demand an ability to shift location for meeting the care recipient in her or his home, a nurse must bring along necessary artefacts contained in the bag on wheels. Closer to the target location, artefacts are put on a tray and in the pockets. Other artefacts, specific for each individual care recipient, are found in a cup-board at each individuals home. To make those needed tools, medicine and other materials ready at hand, the nurse have to choose tools and items and in effect she makes a redesign every time at the location of where she provides health care.

So, what characterizes the socio-technical system of wound care work is in our case three things: First, the nurses are on the go and on the move, second, they are in-
teracting face to face and in different places with a lot of people, and third, they use a variety of artefacts, the combination of which they not seldom design themselves. The bag-on-wheels contains the set of artefacts most needed and provides one access point to those at home of the individual care recipient as well as allowing for rapid shifts between various places. In the municipal elderly care, the bag-on-wheels obviously is still a working mobile information system.

3.2. A growing motive for a new socio-technical system

Wound treatment has significantly changed during the last decades, from, in many cases, something not very much to hope for, to today’s situation when a wound is systematically diagnosed and a more advanced treatment is provided [16]. Due to the change, the potential to initiate a healing process has become the guiding principle. Each wound is dependent not only on direct treatment measures, but to a large extent on the over-all living conditions of the care recipient. Daily habits of moving the body and keeping up with a balanced diet are inescapable components of treatment, a concern for all people of importance to the individual. Providing daily care requires a good understanding of treatment materials and methods and so does affecting and possibly, radically changing someone’s living conditions as a whole. The municipal nurses are in work practice the main responsible for giving direct treatment but also supervising others. As life and time passes, a good memory is needed to be shared among the group of nurses that substitute each others as key members of the wound treatment activity. To better mediate care recipients’ wound history and healing progress, the nurses need an improved documentation artefact. A nurse in the municipal elder care and former member of the Special County Wound Treatment Group pointed out: “There is a need of a unified documentation. Today we have a number of home-made case books” (interview May 2002). Maybe the same could be said about similar documentation artefacts for a number of other treatment tasks the nurses are responsible for, but what regards the complex character of wound treatment it is obvious that demands of remembering, assessment and information sharing among all involved in giving care are urgent.

Those experienced short-comings of the documentation artefacts, and the introduction of digital photos on wounds, coincide as the motive for our case, a process of redesign of the old socio-technical wound care system and transforming it into a more advanced and unified tool. The design of a new specific computer system integrating digital photos was supposed to play an important role, possibly by exchanging the paper forms in the trajectory of the wound healing treatment. Some major issues for documentation work are to support assessment of the status of a particular wound and refinement of a shared memory among the practitioners. For every wound the course of the healing process is dependent on measures that have been taken and further on can be applied. If, for some reason, the documentation is not available or insufficient in some sense, the assessment lacks information and work becomes harder. In that case, the emergence of digital photos contributes to an imagined vision of a complemented and richer documentation of the nurses’ work. Several properties of a wound might be captured in a convenient way by a digital photo. A series of photos that document the wound status over a period of time might be easy accessible and provide information that clearly visualizes the change of the wound.
An anomaly in today’s practice is experienced because the binders with information are not always accessible for all nurses in all situations. In our R&D project, the vision of a distributed digital system was partly made real in producing the new ICT system, a digital network case book for documentation of wound treatment (the prototype HELAR). On a time scale, Figure 1 roughly depicts the background of the developmental work and software design.

In evaluation of the prototype HELAR, some problems of integrating the new artefact in the work practice were revealed. Typical for the nurses is that they are generalists in providing a vast number of different care treatments tasks of which some are planned and others appear as urgent cases. The division of labour among the nurses is mainly based on allocation to a set of accommodation units where about 30 to 50 individuals live in their own flat.

One nurse is assigned the formal responsibility for a number of individual elderly tenants but they form a group of 3 to 4 nurses substituting each other on the same care recipients but on different work shifts. In conjunction of this organization, the documentation work as a whole is shared among the groups of nurses that usually are related to each others. The system of different paper forms, collected in ordinary binders, stored on shelves and put in bag-on-wheels for transportation, is in a way “home-made”, that is, designed by the nurses themselves. As such, the everyday practice will be affected by changes in one or another end of the cluster of artefacts made as integral to the activity system. So, if the nurses were forced to switch to a new digital wound care documentation system, the whole set of remaining paper forms would still be there, requiring the nurses to keep up with the old ordinary binders, with pencil write reports by hand and at the same time learn to use the new digital system and adapt it to the local activity system. We encounter an upcoming contradiction between the old and a new way to document work that takes more time and an extended set of skills to perform. The benefit would probably not, even if we could disregard the pro-
totypes’ shortcomings when seen in isolation, outweigh the cost caused by the new case book. To make a feasible switch, it seems as it will be needed, at one time, to exchange most of the paper document work with an all-embracing computer system.

3.3. A new ICT system - possibilities and problems

When our design project started, there were only about four network connected standard desk-top computers, available for the nurses at an administration centre where most nurses meet at the beginning of a work shift. Only a few standard computers were network connected and possible to make use of at the care recipients’ accommodation units. All those computers were not of the latest manufacturing model but second hand equipment, out-dated in administration work and later transferred to the nurses’ domain of health care. Consequently, for a major shift to a large new software system, it would also be needed to upgrade and extend the number of computer hardware units. In an evaluation of such a shift it would be possible to compare the resulting efficiency in terms of accessibility at the location where the nurses write and enter documentation information. The existing mobile bag-on-wheels system allows for documentation forms to be available close to the care recipient’s home. A computer network would not to be expected to be available on that many places, if restricted to standard desk-top computers. We can foresee a contradiction between the old systems’ accessibility in different locations and the network systems, which are spatially restricted mainly to administration centres. A possible computer solution might be mobile devices, but it would then confront us with another contradiction between the size of a standard paper form that roughly comply with a standard desk-top screen and the size of mass produced hand-held computers. Particularly when it comes to digital photos on wounds, the height and width do matter, “one-size do not fit all”, but a convenient hand-held computer with not to small screen and keyboard could be a solution.

Security matters are also an important aspect of this documentation work. Information on wounds has to be restricted to only those who have a legitimate interest and are involved in providing treatment to the care recipients. Each nurse is the formal responsible for a number of individuals (PAS is the Swedish acronym for this role) and in that position she is the one that sets up new documentation paper work containing references to physicians diagnosis, descriptions on treatment and she maintains proper reports on current status and also reports on taken measures in the provided health care. Documentation contained in a number of ordinary binders are artefacts that have a physical, three-dimensional property. In the hands of the nurse, there is no doubt where the information is and who has access. The nurse is in full control and can protect unauthorized people from getting access but at the same time she has an interest to share the information with her colleagues. At some occasions this problem is contradictory when another nurse must take some not planned actions and the documentation is not within reach. But a problem emerge in transforming the paper forms into a digital computer network because established routines and rules for access are jeopardized. The nurse with former control of each paper within her sphere of control is now experiencing that “it is in the computer”. That means a digital sphere with a number of individual accounts and access relations, all of which is not established and controlled by the nurse herself. A key aspect of the HELAR prototype was the attempt to map the nurses’ control of the paper work into the digital case books. The same nurse with
formal responsibility for a care recipient was, through a particular software design solution, also the one with superior control of the digital wound care documentation [8]. This design was in accord with the nurses’ way of preserving security matters but it does contradict the way control is established and maintained in the prevailing power paradigm of client-server network architecture. A solution to that problem might be specific software that implement another kind of control, as in the HELAR prototype, not with a single centre of power, but designed so that it realize a competing order compared to the structure of underlying operative system.

Another dilemma when replacing the old paper based system is one of power relations and parallel ways of organizing municipal health care [15]. A new system requires decisions about scarce economical resources to be taken by officials and politicians on a high level in the hierarchical line organization. The vertical relation builds on the central authority’s main responsibility of allocating health and elderly care on equality terms and fulfilling imperative obligations towards the individual citizen according to the social welfare legislation. Those on top have a rational of keeping up with a budget and as good as possible distribute resources to those who need help and health care. Looking at the every-day practice of nurses, assistant nurses, other personnel and family relatives who locally provide those services, there is not the same visibility of their parallel, horizontally oriented organization. The locally based horizontal organization is the necessary glue that holds together the given resources. Many things, especially taboo problems such as wounds and wound treatment are secured and protected in the interest of the individual. A high level manager has no identified right or reasons to access information about for example a particular wound. Managers and politicians on high and central positions are making decisions on overall issues concerning the care recipients in both ordinary housing and in special accommodations, they are not supposed to deal with a lot of every-day work tasks. All this is agreed upon in the Swedish municipal tradition, even if not all or even most of things are formally described and negotiated about. This roughly explains why changes dependent on budget decisions, such as introduction of a large-scale computer system, have to address what is knowledgeably to and in the interest of those in central positions. A matter like an improved wound care documentation system is likely to be regarded as something remote and of minor importance.

In the end, on a level of over-all design, we are able to summarize what it takes to replace an old paper based with a new computer system in municipal elder care. Close and detailed observations are a way of getting the practitioners’ voice being heard. Respecting their experience of realizing work is a basis for our problem analysis and way of designing solutions. We find that a design project that takes the unit of the practitioners’ work practice as a conceptual framework for the specific design product is in a better position of making the to-be-designed artefact an integral part of the activity system that is to be transformed. In the case of municipal wound care, we suggest that a further initiated system development process has to consider following aspects:

- The practitioners’ participation in the software design is a necessary way of getting a comprehensive understanding of the need problem, which in turn is a prerequisite to make a better artefact replacing the old one(s).
• The software development process organized as a part of a re-design of the local activity system(s) is a way of incorporating the most essential pros and cons of the older artefact(s) in use.

• Power relations between stakeholders in the target domain have to be addressed and investigated as a component of the developmental process. This affects the set up of the design and allows us to not forget the practitioners’ work-related interest in realizing care to the elderly in need.

• To fit the mobile character of the nurses’ work in municipal health care, it is of great importance to provide convenient and immediate access to the new artefact close to the location of the care recipients’ home.

• To take advantage of digital photos on wounds it requires not to small graphical interfaces.

• Security problems are partly solved in preserving the nurses’ superior control of the information.

In next sections our evaluation shifts to a focus on more detailed and technical design issues revealed in the wound documentation prototype.

3.4. The short-coming of the new ICT system

The system development process in which HELAR was designed will not be described in this paper. (But see [8, 9].) Suffice is to say that the prototype HELAR was constructed as a network distributed case book in an attempt to make a more unified wound care case book. Two main features of the system was a kind of peer-to-peer network architecture (See for example [12] about the peer-to-peer concept) and a picture archive system integrated in the digital case book on wound care treatment. The network distribution of the case book is not yet tested but the prototype is available on one of four network connected computers at an administrative centre. Aspects of the computer prototype’s interface as well as storage and retrieval of written reports and digital photos are currently evaluated in the work practice of the nurses.

Despite the fact that security issues and other properties of the nurses’ work have been mapped in creation of this particular software, our observation reveals a contradiction between a mind set that permeates software development and the essential qualities of the work practice of the nurses. This we find is due to the usual bias at constructing large scale systems satisfying central and high level interests and in effect supporting aspects of resource allocation, follow up and control. An all embracing computer system getting into every-day working life is a paradigmatic case in a retail store where computing is straight forward to apply on sales of commodities. In a municipal elder care there is also an obvious computation potential on charging the care recipients for provided care or for calculation of salaries and wages, but it is a more complicated and problematic issue when it comes to computer support for health care.

In our evaluation we find examples of computer interface design consistent with typical deskwork practice in banking and other business areas. Nurses and their colleagues might have white collars but they are typically not sitting at a desk or at a counter. As we already have pointed out, the work practice of the nurses are features
by high mobility, close to patient interaction, and discretion in use of a variety of artefacts. Here we will elaborate on that.

The software HELAR is only accessible “in the computer” that in our case is a standard desk top machinery available only in the administration centre. At this site digital photos can be handled in conjunction with text from information in the digital case book. Some of the observed difficulties are about recognition and making connections between different devices on a “simple” level of artefact-artefact interaction. To do those things right, the nurse has to be seated like an office white-collar worker, taking the time to get familiar with small icons, virtual menus, buttons and other standard widgets. In the developmental work project, a routine of taking the memory card out from the camera and in next step plug it into a card reader attached to the computer was designed. It makes picture transfer more convenient but some joints in the cluster of software artefacts in the computer are still a problem.

Fig. 2. Evaluation, cut outs 1-4 from computer interface.

The joints between the HELAR prototype and other window components belonging to surrounding operative system are things of trivial character. However, when getting into detailed testing and making use of some of those joints, it caused problems hard for the nurses to overcome. Figure 2 is a set of four cut outs from four photos of the computer interface. These are shot during evaluation when a nurse struggled with “getting the digital images into the computer”, that is, to choose the good enough wound photos and get them stored in the HELAR prototype.

Cut out no. 1 (Figure 2) is a smaller part of one of the HELAR case book views that is constructed for entering written notes and possibly taken photos from a periodically given wound treatment. The arrow pointer is moved over a tiny little “button” and the intention was to access the photos stored on the camera memory card attached to the computer. Labels, buttons and text were considered as rather small requiring very precise mouse movements to hit the right areas at the screen (the display properties was set to standard resolution of 1024 by 724 pixels). In succeeding to open the window component of the surrounding operative system, the next problem was to re-
cognize the right logical unit. In cut out no. 2 the pointing arrow is close to a scroll bar button to the right. The small size of the button indicates the large number of logical units to choose from in the opened selection box, many of them hidden below the bottom of the visible box.

This particular task of navigating between logical units, and at a proper point getting “deeper” into the folder structure, reveals a demand for remembering an extensive structure of units, folders and files. In cut out no 3 the memory card is located and a number of image files and additional folders are displayed. The file names are automatically generated by the camera. While the names only follow a numerical order it is hard to make sense out of a set of photos. A feature for preliminary inspecting a photo is accomplished through “selecting” and “clicking” at a filename. A smaller image of the photo is then displayed to the right in the window, see cut out no. 4. A crucial judgement must then be made by the nurse, to either skip or finally chose the photo to store it in the case book. Still it is a matter of size, the relatively small image in the intermediate “storage”-window (Cut out no. 2-4) does not make full justice to the photo quality. When finally stored the photos are at a size that allow for two photos side-by-side in the case book view for reading and looking at information created at two different treatment occasions (Figure 3).

![Fig. 3. The HELAR prototype, photos side-by-side in a case book view.](image)

### 3.5. Reading and writing when on the go and on the move

What we have learnt is that size matters, especially when it comes to integrating photos in a documentation system. It is a challenge, probably harder to deal with than often expected because we believe we are very well acquainted with photos in our ordinary family life. This is what Bertelsen and Bødker identify as a discontinuity, or a contradiction, between interpretation and implementation [3]. In the present working life context, we interpret the idea of utilizing digital photos as a promising possibility of
turning them into tools for supporting the work practice. But when actually trying to implement these ideas of integrating the digital images into a computer system, we inevitably close much of the perceived possibilities because the programming code constructions need to end in unambiguous statements acceptable for the machine execution. In the process of dealing with this contradiction, a very crucial trade off must be made between on the one hand opening up for a maximum size of a photo, and on the other allowing for other widgets, necessary for making sense out of a two dimensional screen display.

Photos on wounds do have valuable properties in terms of colours and shapes. To make justice to those properties, the display size is important. In addition, as the above task of photo storage reveals, size of text labels, buttons and other widgets also matters. The nurses are not able to accomplish such a smooth performance in navigating and hitting the right spots on the standard screen as they have proved to do when actually shooting the photos with a standard camera at the care recipients’ home. Probably the interface constructions can be made more logical and perhaps a better file-choosing-window could be designed, but a problem that permeates both the HELAR prototype and the operative system is a preferred size on a possible scale of width and height for all kinds of widgets and text that the interface is built on. If sitting at the desk top computer all day long is the reality for computer system developers, one small size on the scale is appropriate, if being on the go and on the move – as the nurses are - a larger size is required. This is a problem in architecture and building construction, recognized within other areas but not well grounded in computer system design. Look for example at needed size on road signs, where the text sizes have to match people’s perception constraints when moving at high speed. About the same fundamental principle of choosing the right size within a scale appropriate for humans activities is acknowledge in town renewal projects [6] and we think it can be applied to computer design as well. What we now clearly have understood, is that it is a size problem that gets worse when the target domain practice differs from the design practice of computer system developers.

Another aspect of supposed “trivial” character is revealed in the joint case between different systems as described above. The extensive structure of logical units, folders and files is something learnt long ago, and directly a matter to deal with on several occasions every day for desk top workers (like system developers). They have an easy access to some kind of mental model of this structure. For the nurses it is hard to recall or imagine such a clear “picture” and to make it as “embodied” and easy to reach when needed. The nurses are typically not sitting at desktop work and that is why they experience breakdowns when forced, for example, to find the small scroll button, scroll the view, read and correctly interpret the meaning of short small text labels. The whole matter gets even worse when the computer interface differs in some aspects compared with last experienced occasion, or when an unintended mouse click cause a window to collapse, change size or in some inexhaustible way alter its appearance.

### 3.6. Intermediate solution for storage of photos

As a parallel practice, the R&D project designed a file name standard and routines for storage of digital photos shot in conjunction with periodically given wound treatment. To get independent of a possible success of the HELAR system, the photos were taken
care of in an alternative way. The technique with a specific memory card reader attached to the computer was taken further and the task of using the file management application was tested. For now, this seems promising and not necessarily a redundant task in preparing for a future more integrated digital documentation system. Guidance for this parallel task was to use as simple and established software as possible. This meant to use the general purpose file manager of the operating system. Unfortunately, at the initially stage of trying to performing the task, the nurses were confronted with a too rich interface. The display contained nearly a countless number of visual two-dimensional widgets. The matter was also complicated of the not so obvious names and structural relations to several logical units for file storage. A set up display is not stable, but on the contrary, in some automatic way it is often changed in arrangement and appearance of different items. Despite the fact that principles are stated in Design Patterns for Graphical User Interfaces, the computer is crammed and the size of components and text labels are still too small. Metaphors of desk top computing gives a reference to office work, but in speaking of a desk, it seems as covered by too many and sliding items. The nurses would probably benefit from an interface following the Limited Selection Size design pattern. The principle is stated in the published definition:

Experience and usability testing have shown that when a selection interaction confronts a user with too many related items from which to choose, users slow down or become temporarily confused. Guidelines for designing user interfaces usually recommend a limit in the range of seven, plus or minus two, items to be displayed at once [7].

Several computer games with command control features are designed with only a restricted number of buttons to push, examples in accordance with the design pattern cited above. The nurses would for sure be happy with an interface more in line with such games. Instead they experience software consistent with office deskwork and desk top computing. In this evaluation, the creation of more text and other information in the activity system, reveals a tension between being seated at deskwork and to be on the go and on the move in a non office like environment. Perhaps solutions inspired by game and design pattern could ease such observed tensions. However, the nurses keep up with storage procedures in order to preserve photos that are still valuable for the documentation work, and for sure the nurses will become more skilled and trained in handling the computer systems.

3.7. To sum up the evaluation of the new system

To sum up, we find the ongoing transformation of the socio-technical system of the wound care project that we present here promising. Nevertheless, the project is facing a problem. When the ICT subsystem was designed, it was too much influenced and dependent on size standards and metaphors of office work and desk top computing, and it did not meet the distinctive features of municipal wound care practice: high mobility, face-to-face interaction with care recipients, and variable uses of a variety of artifacts of their own discretion.
4. Discussion

What we now have investigated turns out to be a part of a work practice domain that is very complex in terms of interaction, artefacts and mobility. In the first place the nurses are those with main responsibility for providing health care on a day-to-day basis. Through ethnographic studies, participatory design and participatory evaluation, we find evidence for choosing some essential characteristics of the nurse occupational work, as important to assess in order to explain experienced problems of the complex and demanding task of replacing an old information system with a new ICT system. For reason of clarity, we depict in figure 4 and 5 the demands on nurses’ work by comparing it to other occupations and professions. We have also other human work studies as ground for our comparison\(^1\).

![Diagram of required technical performance and human-human interaction]

Our assessment can be criticized as not valid for some individual workers, but it is made taking into account what at least is needed for conducting typical work in an acceptable way. For example, in figure 4 a machine operator is depicted relatively low on both scales of human-human interaction and needed technical performance skills. The linear scales are not divided in units but the arrow ends are thought of as the minimum requirements in the “low” end and maximum demands in the other “high” end. In figure 5 we compare in a similar way demands for mobility and complexity of artefacts in use. In both figures the nurse is found in the most demanding quadrant I.

A description similar to those presented in the figures has been the result of a national research study initiated by the Government of Canada — the Essential Skills Research Project in 1994:

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\(^1\) Additionally, as researchers we are teachers and, one of us have experiences from fifteen years as blue-collar worker in manufacturing industry, first as unskilled machine operator and later as educated industrial electrician.
To better understand the importance and relevance of Essential Skills, particularly how they relate to different occupations, the researchers created occupational profiles for nearly 200 different occupations. Each of these occupational profiles shows how each of the nine Essential Skills (Reading Text, Document Use, Numeracy, Writing, Oral Communication, Working with Others, Continuous Learning, Thinking Skills, Computer Use) are used in a specific occupation and at what complexity levels.2

The complexity or difficulty of tasks is rated on a scale from 1 to 5, with 5 being most complex. Building on such profiles, figures like ours no 4 and 5 can be made more precise weighing numerical measurements on skills. However, for the purpose of this writing we do not need such precision.

Fig. 5. Required mobility and tool diversity and complexity.

The finding we can present is that nurses’ work is essentially different to the work of office workers and machine operators. Typically, computer systems have mainly been designed and successfully been deployed in work domains populated with workers from the quadrant III of our figures. Also typical for the education area of computer science and software engineering is the orientation of text books that draws heavily on machine automation problems with examples of vending machines, ATM’s and similar. The history of developing computer systems is dominated by a motive for automation and where it has been realized, we find paradigm examples in “one- or a few-buttons-push machines” deployed mainly in a correlated work practice area of quadrant III in both figure 4 and 5. Of course, this is not particularly surprising. A technical development starts in an area that is most suitable for the technology as such. But today demands on new and better technical solutions require rethinking a lot of what is needed in those other.

2 the Essential Skills and Workplace Literacy Initiative http://www15.hrdc-drhc.gc.ca/eng-lish/general/Story_Initiative_e.asp
Donald Schöen has taught us about what he calls “reflection in action” as one characteristic of professionals work in complex and less clearly defined practices. He explains why formal computational models generally fail because they do not suit work where practitioner exerts a diversity of skills in dealing with “complexity, uncertainty, instability, uniqueness, and value conflict” [13] (p.18). Examples of architectural design, business management and criminal justice are professions where the practitioners reframe a situation and in reflection, the practitioner make use of skills acquired in earlier work with similar problems. In many ways, we think his lessons also apply to nurses’ work in demanding interaction with people and urgent cases. Possible computer solutions supporting more complex and advanced activity systems, as for example municipal wound care, require us to take the practitioners daily work seriously.

Taking the practitioners seriously in order to find computer system suitable for more complex work practice, we find it important to do ethnographic studies and investigate the ground for forces of change in a local activity system within the work domain. Our method points in the direction of exploring observed tensions and contradictions as resources for design of new solutions – let it be either redesign of practice or creation of new technology. The DWR approach implies research in the field, in close contact with practitioners at work. This is true for the gathering of key artefacts in use, but also when it comes to development of computer system. The methodology invites us to do participatory design and participatory evaluation of the new artefact. For more advanced solutions we recommend a qualitative approach. The Multiview [1] or the ETHICS approach [10, 11] might be an alternative, but as the latter method builds on questionnaires addressing the practitioners only as individual agents in the entire organization, we believe it is a kind of an opposite approach, perhaps suitable for other purposes and business interests.

To work in a standing position and being on the go and on the move, or work in sitting position at deskwork, makes an obvious difference. Currently in our case of the municipal elder care, because of decisions on a high and central position, a major ICT system (named Magna Cura) has been deployed in the municipality since about one
and a half year. It is mainly designed for administrative purposes and for the management of community care in a Swedish municipal context. It can be regarded as enforced on the personnel from an above power position. To some extent, also the nurses in our case are obliged to integrate parts of this vast, all-embracing system into their work. The particular task of creating wound care documentation is not (yet) opened up for in the Magna Cura system. However, the nurses have been directed to utilize the system for other similar documentation work. In addition, some new computers have been purchased, installed and exchanging the older ones in the nurses’ administration centre. In some respects, this has been for good and the nurses have become more familiar with computing, but certainly it has a cost. A question is if the nurses now are forced to become more of typical office clerks as part of their work practice. It might be a significant challenge to the nurses’ work experience, to remain in standing position or to be seated in a remote location (Figure 6 might be a reminder).

It is still an open question if the designed first version of the ICT system HELAR can be redesigned so that it becomes a central part of a new socio-technical wound care system or if the technology it stands for has to be abandoned. In our wound care case, the nurses might find a better sociotechnical system to exchange their “bag on wheels”-system and the researcher might gain insight in refined methods and theory. Perhaps computers available when standing on foot and closer to the work practice in the different accommodation units will be a good match to a more advanced activity system of wound care treatment.

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References


Who is involved in HCI design? An activity theoretical perspective.

Hans Kyhlbäck, Berthel Sutter

Abstract
The aim of the paper is to discuss the conception of design in the field of human-computer interaction. From an activity-theory perspective, three aspects of design issues in HCI are stressed. They are, first, a broader conception of what it means to design and which artefacts are to be designed; second, a more molar unit of analysis than merely the design of the computer system, including an extended time frame for the design process; and, third, taking designers most often neglected, namely the practitioner, seriously. Our method is to take a detailed case study as our point of departure, where the case begets the concepts, and at the same time works as a test bench for the generated ideas. Thus, methodologically we ask what a detailed case might tell about design related to HCI.

Author Keywords
Cultural-historical activity theory, specific and general design, object-orientation of design, wound care.

ACM Classification Keywords
D.2.1 Software engineering: Requirements/Specifications – Methodologies (e.g., object-oriented, structured). H.1.1 Models and principles: Systems and Information Theory - General systems theory.

Introduction: HCI and beyond

When modern text-books present the field of HCI they often underline that the phenomenon of human-computer interaction is rapidly changing – because of new technology and new user habits – and that the book tries to grasp the suggested change and look ahead of what might come. Some representative text-books quotes go like this:

This new edition of Human-Computer Interaction is not just tracking these changes but looking ahead at emerging areas. [7, Preface]

New influences and strands have been incorporated – broader social science, networking, media, information management, and artificial intelligence. HCI has become the focus for a new view of what computing is about. [6, p. xxxvi]

Our book is called Interaction Design: Beyond Human-Computer Interaction because it is concerned with a broader scope of issues, topics, and paradigms than has traditionally been the scope of human-computer interaction (HCI). [18, p. v]
Preece has even coined the expression “interaction design” in order to make clear that one must go “beyond human-computer interaction” as the phenomenon of HCI, so far, has been conceived.

The authors emphasise the importance of the user and user-orientation of a HCI approach but when they pose the question of who is involved in HCI design, like [Preece p. 8] and [Dix p. 4f] explicitly do, they nevertheless leave the “user” aside. Why is that? One reason could be that in HCI the user has replaced the worker from the former Scandinavian approach to participatory design.

In the Scandinavian approach to participatory design during the 70’s and 80’s, there was a radical political strand concerned with cultural and political consequences of the computerization of society [8]. Some decades later, as pointed out by [1], that spirit had changed and the initiative to a broader computer design involvement had moved away from Scandinavia. If one acknowledges that practitioners need to be involved in HCI or in “interaction design”, it would not be easy to forget them. Taking the involvement of the practitioners seriously, it must imply involving their work practice as well, or else, on what basis would they be involved? The practitioners are experts in their use-domain, in their activity. If one counts with practitioners instead of users, it would be obvious that the work practice (including the artefacts in use) of the practitioners has to be taken into account.

As digitalizing and computation continue to permeate evermore diverse fields of working life, the motive gets stronger to involve the practitioners in the transformation of their work practice. In such an endeavour it is perhaps needed to go “beyond HCI”. At least it necessitates a re-thinking of what it means to do software design, a multi-disciplinary and multi-interest trade [13]. According to activity theory, this re-thinking will be based on an analysis of tensions and contradictions inherent in design project.

To reflect on design and system development, Bertelsen and Bødker provide an interpretation of the concept of discontinuities [3]. It is a comprehensive term for recognition and investigation of differences, divergences, and contradictions, as they find fruitful to deal with in the creation of systems for the future. They pose that discontinuities can be seen as resources for design and they identify “three basic classes of discontinuities: between experience and desire, between parallel rooms, and between interpretation and implementation.”[3, p. 410] Human activities are not static but for ever changing and driven by contradictions as the determining factors of their historical trajectory. We find the discussion important to continue and further develop for an improved HCI approach - addressing a world of more diversified and complex problems to handle.

A number of “use” and “user”-influenced fields connected to HCI are concerned with research on, and design of, computer based systems for human work practice, e.g., computer science and software engineering. Different approaches seem to get along reasonably well and complement each other in the actual practices of system development. While some concepts and general-purpose artefacts have become popular, and may unite design practitioners, we still witness a severe lack of theory when it comes to what to start with. We believe that a methodology which systematically ap-

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1 One of the critics of Preece, [16], poses the question how far beyond HCI “interaction design” really is.
proaches the need problem in a domain can fill a theory gap between the everyday use of artefacts and the highly elaborated design process of software and hardware. In the literature, several examples are presented comprising a start phase, followed by analysis, design, implementation and evaluation phases in a software process model. What is not successfully dealt with in most software development and interaction design approaches is how to go about in the start phase, something which is crucial for efforts to understand the domain and making well-informed guesses about the future. Ethnography that informs design is an established set of methods used in many contexts (e.g. [4]), a set of methods that we also include in our approach. In other cases, however, the “actors in a domain,” i.e. the practitioners, are perceived as some kind of containers of goals that possibly generate requests of appropriate machine operations in the to-be-designed system. At this level of human interaction, such individual actions are regarded as sufficient for understanding the domain and for getting input to the well-oiled developmental process. For example, in [15] the start phase is described as a requirement workshop where people “brainstorm” for the purpose of finding the primary actors and their use-goals. We find this a too narrow perspective of the work practice of many problem domains where a software system potentially might be the solution to the stated problem. To hope for an elementary business process at the level of “user tasks performed by one person in one place at a time in response to a business event” [15, p. 60], as a sufficient conceptual tool, is at risk of missing the historical background and dynamic features that cause the need for a software solution.

A wider conception of design

Predominantly, design is understood as a very specific activity, and in HCI this is certainly the case. We want to see a broader conception of what it means to design and which artefacts are to be designed.

According to the perspective we take, “cultural-historical activity theory” (CHAT), all things are regarded as historically transformed. The same holds true for activities. They are being transformed historically. For example, in some analyses by [8] and [20] the distinction between learning (and instructing) as a general activity and learning (and instruction) as a specific activity has been pinpointed as crucial. Here we will make the same claim for design, namely that, it is a point to distinguish between design as a general activity and design as a specific activity. Petroski has expressed the idea:

Just as we all have a sense of health without being physicians and a sense of justice without being jurists, so we all have a sense of design without being engineers. [17, p. 25]

One form of design is design as a general activity, another form is design as a specific activity. General design occurs when people, as part of the activity they are involved in and contributing to, design and redesign their environments and the everyday artefacts they are using. The credo “to design is human” is valid for all people, but as a specific activity design encompasses only experts. In other words, design as a general activity is an aspect of human activity. When you work, you design. When this aspect of work has been turned into the object of work in itself, the result is design as a spe-
pecific activity. In the paper we will use the awkward term specific-design in order to distinguish it from general design.

<table>
<thead>
<tr>
<th>Designer</th>
<th>Kind of design</th>
<th>Designed artefacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specialists (i.e., software developers)</td>
<td>As a specific activity</td>
<td>Information systems or another IT artefacts</td>
</tr>
<tr>
<td>Practitioners</td>
<td>As a general activity</td>
<td>Everyday in-use artefacts</td>
</tr>
</tbody>
</table>

Figure 1. General and specific design activity

There is another aspect related to design that is important in this context and that is: the artefact that mediates an activity should not be thought of as singular. There is always a cluster of artefacts involved in the process of mediation [2, 4]. This ought to be a memento for professional designers. When they design an artefact to be used in a work practice, they ought to be aware of a fact that scholars of CHAT have called attention to (e.g. [11]), a fact that tends to generate misunderstanding between designers and users, namely that an artefact being designed is a common object for the designers, but is a potential tool for the user/practitioner in his/her later work practice. From the perspective of the practitioners, an artefact designed by specialist designers is not the artefact. It is only from the specialist-design perspective the artefact has that privileged position. The object of their work (the becoming computer artefact) is for the practitioners that will use it, a tool that hopefully will improve the work practices. Figure 1 shows the idea.

Let us sum up our distinction between general and specific design. General design is design with the object of the activity in mind². Specific design is design of artefacts to be used in an activity. The artefacts that are being designed are, in the perspective of the general designer, tools to be used in the activity. From the perspective of the specific-designer on the other hand, the artefact that is being designed is an object of the specific-design activity. In other words, an artefact, which on the face of it is the same regardless of perspective, differs in meaning depending on which role it has in the activity system.

Unit of analysis

The second aspect that we, from an activity-theoretical perspective, would like to point out as important to HCI is the need for a more overall unit of analysis than merely the design of the computer system. We suggest that the “activity system”, which is constituted by the activity of work, is a proper unit of analysis. A way to de-

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² In the paper we are interested in the general design that the nurses as practitioners do. But of course our reasoning also applies to the general design that specific-designers (software designers) perform when they redesign their own design activity in order to promote their specific-design activity and make better products for their customers. This general design activity of the specific-designers has been dealt with by Gargarian [12], who calls it “environment design”.
scribe an activity system that we have found useful is by means of the “triangular model”, which is developed by Engeström [10] and based on cultural-historical activity theory.

Immediately below we will give a condensed presentation of some core concepts of CHAT pertinent to issues of design. Later on we will present a case in some detail where those concepts are used. Hopefully that will be sufficient for the reader to follow our argumentation.

From a CHAT perspective, all activities are object-oriented and artefact-mediated. Let us briefly explain what that means and begin by addressing the idea of object-orientedness. CHAT holds an activity to be determined by its object, i.e. the focus of the activity, its transformation of an initial state (“raw material”) into an outcome, while guided by many stakeholders’ voices of imagined possibilities.

The object of the design session is some “raw material” (e.g. an old artefact) and an idea of its improvement. In the design process the raw material is transformed and the idea transubstantiated into, say, a computer system and its use within the activity system of wound care.

Next, what is the meaning of activities being artefact-mediated? Humans need some vehicle (pivot) to perform an activity. The vehicle is something man-made, an artefact, which is previous human activity fossilized, and as such it “invites” or affords some kinds of actions. That is, the vehicle used to perform an activity, is hinting at what to do. At least, the vehicle makes some things possible at the same time as it restricts others.

The artefacts make possible, they are cultural prostheses. Without the prostheses, certain kinds of activities are not within the scope of the ability of the person(s). The activity is being mediated by artefacts - in short, that are the CHAT meaning of artefact-mediated activity.

To sum up. If we claim that the unit of analysis should be “the activity system,” there is a need to specify what constitutes an activity system. What is the common object of the activity, who is involved, and what are the major instruments that are mediating the activity? Before we try to answer those questions, let us here confine to say that the formation of an activity system, motivated by the development of a computer system (the object), has to comprise computer designers as well as practitioners. It has to unify the activities of specific design and general design.

Method

The method we have used for this paper can shortly be described in the following way. As researchers within the perspective of cultural-historical activity-theory we have used and developed the developmental work research approach originating from Engeström [10] and formed a joint-venture project with nurses in municipal wound care. This joint-venture project has been running for tree years, and, together with the developmental work activity conducted by the nurses prior to the project, it constitutes the case that we are presenting.

Letting the CHAT perspective face the practice generated by the joint-venture project with respect to human-computer interaction and design is our “method.” The case project has generated conceptualizations that have been elaborated within the theoret-
ical framework of CHAT. At the same time the case functions as a test bench for the concepts and theoretical perspectives.

The case study

The case that will be presented here is a joint venture project aiming at developing a digital wound care documentation computer system

Background

A Swedish health care reform in 1992 entailed that more and more people are now being cared for in municipal institutions. In ordinary housing, assistant nurses give home help service and in special accommodations for elderly, the municipalities also provide medical health care up to doctors’ responsibility. The county councils, a principal authority besides of the municipalities, are the organiser of primary care at the local levels and also of most hospital treatment. Led by these authorities, legitimate nurses have an extensive responsibility for everyday health care work where they co-operate with other professionals and the patients. The work of the municipality nurses typically has a long-time perspective coping with all kind of diseases. In such work practice, several nurses and assistant nurses develop activity systems that more or less involve the care recipient and close relatives in giving help and treatment. When a case of emergency occurs or the care recipient for other reasons is in need of specialist treatment, the staff of the municipality turns to doctors in the primary care or at hospital.

From our case of wound care treatment in Ronneby, a small municipality in the south of Sweden, we get an insight in work practice of the nurses in elderly peoples’ home. We can also see traces of general design actions made by the nurses themselves. Historically there have been significant changes in understanding and treatment of wounds that are hard to heal. In the eighties, about a third of wounds in the region where not examined, no proper diagnoses were made and subsequently there were no treatments given. The care was made mostly with a hope of not worsening the situation for the care recipient. Lately, care improvements have changed this very much hidden world of wound cleaning and bandaging and turned it into a matter of professional concern.

In order to provide proper treatment, the nurses have to have knowledge about previous wound status of the patient, what have been done and what diagnosis had been made. For the purpose of keeping up with a good understanding of each particular wound and for sharing with colleagues, the nurses document facts about the care recipient, the wound diagnosis and the regular treatment. Gradually, a need for an organizational memory support system has emerged. Such a system might offer support to actions to be taken, but also provide historical information relevant for authority’s follow-up on the quality of work. Consequently, the change in the conception of wound treatment, as a potentially successful healing process, pushes for new tools, materials and practices to be developed. In parallel with the understanding that a lot more can be done to improve the wound care practices, the need for documentation of work has clearly been recognized by the nurses.
In the late nineties two municipal nurses from Ronneby attended a university distance course on wound care treatment. A practicing nurse at a hospital was involved in the course sharing a lot of her successful experience from a special project. She was tied to the infection care unit but had gathered her colleagues at the hospital and educated them in wound treatment. A number of patients were lucky to get their wounds remarkable better off, apparently because of the nurse’s teaching and instructing efforts. As a consequence, the developmental and learning activity soon was formalised as a specific project. Another result of her work was the design of a wound documentation form (“the three-page form”). This artefact is a kind of less formal medical record, specifically addressing treatment of wounds. The form was presented for the nurses from Ronneby who then adopted it in the Ronneby municipal elder care. Since then, 1999, it has been used in the special accommodations for elderly people, not as a doctors’ record but more like a case book for support of everyday work and documentation of provided treatment.

Nurses and design

Influenced by the successful work of the hospital nurse, the municipal nurses adopted her specific three-page paper form. Where nurses encountered a greater number of patients suffering from their wounds, they integrated the three-page form into their binders system containing documentation forms for many other treatments tasks. In other parts of the municipal elder care where only one nurse provided wound care, it was sufficient to only add the third page of the form.

Figure 2 General and specific design in and for municipal wound care work

As the healing process was more considered as something to improve, an interest raised to follow changes of the size and other visible properties of each wound. A traditional analogue camera was borrowed and a few photos were made for the main purpose of documenting the progress of the wound treatment. The photos in a way com-
plemented the paper forms but didn’t cover very much of the longer time of months or
even years that a treatment might last.

In this stage of the process of the development of their wound care activity, the
nurses got in contact with our research group at the university, which become the start
of a long-term joint-venture R&D project. By that we came to know the general
design activity of the nurses and establish a collaborative developmental work prac-
tice.

A digital camera was the next artefact that the nurses, now as part of the R&D pro-
ject, tried out with a hope for easier handling of each photo. The elaboration on how to
use the camera brought the nurses closer to the computers available at an administra-
tion centre. A relatively small number of digital photos were stored in the computers
and paper print- outs were now attached to the regularly used system of wound care
paper forms to complement the handwritten documentation.

Along with more attention to issues of wound healing, the nurses introduced new
bandaging and other materials as well as novel treatment techniques. The paper forms
functioned as a resource for instructions and keeping records of status and provided
care. Added to similar paper forms, the nurses made a comprehensive design by means
of a special “bag on wheels” holding papers and binders together, one for each nurse.
In fact, the “bag on wheels” is still (2004) a working mobile information system in
daily use in the nurses’ work practice. The extent of the documentation in their work
practice is displayed in the number of binders at the shelf of their office, but also in the
need for the bags on wheels into which the nurses put their selected binders at the
working shift. Also, an estimation of the average percentage of time nurses spend on
wound treatment is 10 to 20, and the over-all documentation work has been estimated
to be of the same amount. At a low-technology level the nurses themselves design
their own artefacts in choosing what have proved to be useful for them. They take
away what is not needed and incorporate what makes sense in their sociotechnical en-
vironment. However, as time is passing some old rules are changed due to new find-
ings, e.g. according to former knowledge the rule was to make a cleaned wound dry
and expose it to free air, but today’s practice is to preserve it in a moisture condition.
Such changes in practice of course demand changes of artefacts in use. Figure 2 is an
attempt to a rough summing up of the design activity of the nurses.

The design project case

During five months in spring 2003, four nurses from the municipal elder care in Ron-
neby actively contributed to the design of a computer system, a process that resulted in
a software prototype. The nurses met and worked together with a team of 17 software
designers and developers, and collaboratively they designed a digital wound care doc-
umentation system named Helar [14].

The digital photos integrated in documentation work opened up for the idea of a
computer- based wound care system. This idea was soon realized in the R&D joint
project between the nurses and software developers at the university. In the project the
Helar system was designed for the nurses at the same time as the nurses contributed to
design of the computer system. In participatory design sessions the paper forms that
currently were in use were brought in as a starting point and also a paper form from a
hospital specialist wound care was considered as a ground for making the software
documentation. In the design process, the specific items in the forms were examined, excluded or integrated into a more unified form distributed on seven “views” or panels to choose depending on what task to perform. Therefore, one might say that the Helar transformed paper forms from municipal and hospital care, merged and, in addition, was designed to include digital photos as a special picture archive. An essential feature of Helar, which thus can be regarded as a digital case book\(^3\), is the ability to view and compare two photos on one screen display. The time dimension of the healing process is expected to be covered by those photos, because the idea is that they are to be shot in conjunction with periodical taken measures. Another foreseen advantage with the digital documentation system was the creation of a more unified case book, which was easier to share between the practitioners, but still keeping up with security interests.

Figure 3 The “raw material” for the PD session work: three case books in paper format

The first PD session lasted for 70 minutes and was held in a specially furnished “Mock-up room”. Sitting at a table, the participants gathered around typical mock-up materials, i.e. paper, pencils, glue, scissors etc, but in the first place, the actual paper forms, the wound documentation case book was created. The meeting was audio recorded and all utterances are transcribed.

What was the task of the PD session and what happened there? The task was a task of redesign. In the whole software design process, the paper-based case books were transformed into a computer system, which also included photos of wounds. The outcome can be seen if one compares Figure 3 (the five pages of the three case-books of which some were, and still are, used by the nurses) and Figure 4, the first view of the computer solution. In this first PD session, the raw material, the concrete object to work on, existed in the form of the three wound-care case books (a total of five paper pages). And the first step towards the final outcome was the paper case books, with annotations and crossings as well as notes written by the nurses or taken by the designers, plus the audiotape documentation and some digital photos.

\(^3\) The concept *case book* is chosen to distinguish this as a support system for the work practice and not as a formal medical record as used in hospital and primary care.

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Which was the contribution of the nurses? As an answer, let us first give an overview of what happened in the PD session. We have, based on the audio log, listed 41 “tracks” that make up the session. With track we mean a theme or a thread initiated by one of the participants and which is followed up by other participants. Some of the tracks are rather close to each other because the participants went back and picked up issues already discussed. There are many tracks and many themes dealt with in the PD session, but for the present discussion mainly the two first tracks are of interest, and we will focus on themes they brought up. The first track is a kind of negotiation of what is the object of the PD session and of the specific-design activity. The second track is a joint outlining of the framework of the (specific) design object.

**Two themes in the PD session**

One crucial issue in the PD session was the joint construction of a shared object of the PD activity. Without a common ground among the participants, the efforts put into the session by the participants will not be collaborative and successful. Thus, an interesting question is how (and if) the shared object of work is established in the session and how it is established. The start episode (“Track 1”) provides an empirical base for an answer.

/---/

**Designer1:** But perhaps it is like that all case books have something valuable, something you want to keep. In that case it is important that we get to know.

/---/

**Nurse3:** It is a little advanced, it was a little too much. Don’t you think? (She refers to one of the case books, the one that can be seen in the centre of Figure 3.)

**Nurse2:** Mm, it is the one that Rut Öien (a physician in the county specialised in wound care) uses.

**Designer2:** One thing to think of is to try to pick out the titbits from each and try to get them on paper so to say. Everything you think primarily this is something we really use. (…)

**Designer1:** And there may be issues that are missing, that aren’t covered by these case books but which you think are important.

/---/

**Designer2:** Eh, something that can be a standard for all of you.

/---/

**Nurse1:** Is it this one you have used /name of Nurse3/?

**Nurse3:** Yes, it is the one that I use very much. I have one can say never had time, but I have thought, and it was not that very good. Eh, I think that mainly, really, it is like our papers for the moment, but we will anyhow move to ehm

**Designer2:** Magna Cura (an administrative computer system)

**Nurse3:** Magna Cura, exactly. So, we are not going to use that either. /---/

**Nurse3:** But now I don’t think it is of immediate interest.
Designer2: Is there a wound care documentation system in Magna Cura?
Nurse2: No
Nurse1: No, I don’t think so
Nurse2: No, there isn’t. So this we have to have in addition.
Designer2: Yes
Nurse2: Thus, we shall not mix it up.
Designer2: (inaudible)
Nurse2: The concepts I mean. No (overlapping)
Designer2: Because in the same way you do with the other care planning documents (omvårdnadsplanerna) in your binders, the wound care case book is complementary to that.
Nurse2: Precisely
Designer2: Like our application will be complementary to Magna Cura.
Nurse2: Mm
Designer2: You can say so
Designer1: Mm, so, this … It is only the wound care case book you shall consider today.
Nurse2: Mm mm (overlapping)

What can be seen in the start of the PD session is a negotiation that takes place about what kind of artefact shall be designed in the project. The nurses have brought heavy arguments for their work practice perspective and in a concrete way placed them on the table in the design room: the three forms that are in use in their practice. So, this is the starting point for the negotiation process where the object of the design activity is outlined.

The second important issue of the PD-session is the contribution the nurses add to the design of the product. In PD it is taken for granted that the software designers will have something substantial to supply, because they have insights in and knowledge about the hidden machinery of computers and software. It is also acknowledged that “users” – in principle – have competence to offer, but the question is always how this competence may be externalised in the design of the product. For our case, the audio log of Track 2 provides the data:

Nurse2: It strikes me, the first thing I will like to face when reading a wound care case book is the name of the patient, date of birth, the body …
Designer1: It would be great if you wrote that here (hands over an empty paper)
Designer2: Or make a drawing
Nurse2: Ah, but it is little of this (refers to the <B-M> case book on the table)
Nurse1: This is a beginning, I completely agree with /name of Nurse2/ about that.
Nurse2: It must be like that, where the person lives …
Designer1: Yes
Nurse2: and telephone number connected to the address so to say. And the body – and there it should be possible to point out where on the body, if it is feet, legs, arms, back, shoulder or wherever, that you put a little marking dot: “There is a wound!” As well as patient responsible doctor and nurse. It has to be on the first page.

Nurse1: Yes, I agree with you about that. It must, it’s what one starts out from.

Nurse2: Yes.

Designer1: So that is what you would like to face, the first you...

Nurse1 and 2 in unison: Yes!

Nurse2: It has to be the entrance gate in some way.

In the second track of the PD session is discussed how the introduction view to a separate case book of the Helar prototype should be designed. From their experiences and from what they found most workable from the three case books that were to be redesigned and placed in front of them on the table, the nurses picked out features and composed a comprehensive picture, which they called the “entrance gate.”

Figure 4 The introduction view to a separate case book in the Helar prototype.

The entrance gate that was strongly suggested by the nurses in this initial phase of the PD session, is also what, with minor adjustments, become the final outcome of the specific-design project. Figure 4 shows how it came to look like in the Helar prototype.

The activity system of wound care development and design

After three years of R&D experiences of artefact design in wound care and half a year of a specific software design project in the same domain of work, we have got a better picture of who to involve and how to improve HCI and also how to go beyond HCI of today. Nowadays the process of software development is an established way of producing computer artefacts. Work practice characterised of a great diversity of tasks and interaction between people in many kinds of roles, of which the municipal care is a
good example, have now reached a point when practitioners put a claim on software and hardware to be designed in a way that fits well into the main flow of work. The whole and particulars of a domain’s inherent features, and also the need for a specific-design activity to make sense in a transformed domain of the future, cannot sufficiently be captured in a formalised document, e.g. a functional list in a requirement specification. It has to be systematically worked through in a process where practitioners and specific-designers interact for a considerable period of time.

In the Helar design work the nurses took a responsible role for the case book items to be put together and changed in a more comprehensive way, and, in addition, allowing for digital photos to be integrated and supporting the long-time perspective that is typical for this kind of care work. The software designers took another role as main responsible of the form issues of the case book and in leading the sessions to result in further work of the physical design of the software. The participants formed an activity system motivated by the common object, the digital case book to design, and they established a division of labour mediating their respective role towards the common object. As a significant feature of the activity system, the currently used paper forms were brought in, mediating the nurses understanding of and design of the digital case book. The participants created mock-ups (handwritten and painted pieces of paper put together) that effectively mediated the design sessions. Further on, computer prototypes were tested bringing the design into functioning software. Finally the development work reached an end in the delivery of the Helar prototype.

A point to make about the division of labour between the nurses and the software designers is that in the initial design sessions, the nurses maintained an authoritative role as responsible for the material content of the specific design. Their focus was mostly on the design and re-design of their own work practice despite the fact that the stated purpose was the actual design of a computer system. The software designers on the other hand were mainly occupied, in interacting with the nurses, with form aspects of the design and the technical constraints and possibilities of the product. In later sessions when the design had developed into a run-able prototype the software designers tended to take more space focusing on technical features of the prototype. [5] have reported on similar experience: “Discussion in a prototyping session often focuses on the interaction with the computer than on how work is organized around the computer” [5, p. 215]. The interaction and division of labor in a diversified activity system, gets us into essential features of specific design. If such joint design practices recognize the way the work of the domain practitioners is organized, as activity systems, we are sure that the domain experts (the nurses) may have a good opportunity to contribute to the design of computer systems.

From our presentation of the design activities conducted by the nurses as a part of their work activity, and given the new dimension by their involvement in the joint-venture R&D project, we hopefully have made clear why the activity system is an appropriate unit of analysis for HCI.

Discussion

What we claim in the paper is that a revisit to the Scandinavian approach of participative computer system design in order to actualise its cultural, political and professional
spirit is a way to forward the HCI perspective and practice. In doing that, we also have given it an important turn. It is not only we, the HCI researchers and computer-system designers, who invite the practitioners to contribute to the artefact design. Although there are good reasons for the involvement of the practitioners – quality, empowerment, democracy of working life – there is more to it. It becomes visible when the concept of design is broadened to include design as a general activity, and design of clusters of artefacts as an aspect of everyday work practice. When a long-time perspective is added, it even becomes obvious that the practitioners have the initiative in the broader design process. In the long run, they are the main designers: only on certain occasions are they inviting researchers and specific-designers of computer systems to help to design computer systems to support their work activity.

For the specific purpose of a software developmental process, as for understanding of HCI in general, we believe that cultural-historical activity theory bridge the gap between the need problem and the way to design an appropriate computer/software solution. Crucial for this approach, we find the unit of an activity system and the common object as the guiding theoretical framework. It might provide a good start phase of the design process, and a perspective of work practice that is sensitive to dynamic features in human interaction. Thereby system designers will be better prepared to find the intrinsic and hard-to-capture causes to the perceived problem. If the practitioners’ general design work is recognized, the artefacts in the present domain will be utilized in the software process as an essential resource for transforming initial ideas into a future product (see also [4]). To get things right in the sense of maintaining a proper perspective on human interaction, software developmental processes need a more theory-elaborated unit of analysis on a level not as narrow as “the one person performing in response to a business event unit” or as scattered as “the whole organization”. A unit on the level of the practitioners’ activity system we think is the most fruitful in supporting interaction between the practitioners (“general designers” and “domain actors”) and the software designers (“specific-designers”). By means of that we think the need problem will be captured in a more advanced way, suitable for solutions to be incorporated into the domain of the work activity of the practitioners.

What is then possible to achieve in design, can human-human interaction be designed? Artefacts can be designed, that is clear. But the meaning of “interaction design” is far from obvious. In a strict sense interaction, inter-actions, cannot be designed. Interactions are situated, they are emerging, they evolve as parts of communicative exchanges. Blueprints and other plans may be used, but they are not determining the interaction [19]. However, artefacts and clusters of artefacts can be designed and redesigned, so that they, if relevant, they afford and restrict interaction. In other words, indirectly and with a great portion of roughness, interactions can be influenced. That is the meaning we put into the expression “interaction design.”

Another approach addressing the context of the practitioners, their artefacts and the object-oriented way work is accomplished, might result in guiding tools for the designers supporting a better understanding of the actual actors and a richer analysis of the problem. We believe a theory grounded model will help in two ways: first as a conceptual tool for elicitation of the most appropriate classes of objects in the domain and their associations in order to understand the problem on a level that embraces the social aspects of work, second such a tool also guides in setting the stage for the prac-
titioners and the designers’ interaction during the software developmental process itself. All of this requires practical try-out and evaluation if our methodology and suggested extension of HCI and software development will prove to take advantage of a more theory inspired way of designing.

In the case we have presented, much of the HCI design was created in the special activity system that however could have been more furnished and supported by analysis work in utilising the theoretical activity model itself. In such a case, more on surrounding system of everyday use might have widening the perspective of the design work. Potentially more aspects can be dealt with, selecting the most important objects and issues as well as underlying forces of change that can be found in the domain, provided the activity system is more theoretically elaborated. What goes on prior to a specific-design starts, why it was put on the agenda, and who and what matters for the inception phase of the software development, are questions we claim are important to be put on the agenda for HCI. If the specific-design work acknowledges the practitioners’ general design in their domain, we find it likely that the design product more easily can be incorporated in the long-term activity system and become a mediating tool for, in this case, the nurses’ wound treatment work oriented towards the care recipients. Such a wider perspective, we suggest, might give the impression of a too rich world of objects and relations, but considering the great diversity of social interaction and the vast number of artefacts in a municipal elder care work, we believe that a specific-design can handle current HCI issues and develop them further. What is required is that the gap between the need problem and a particular solution is bridged by a theoretical framework that unites both general and specific designers.

Conclusion

In sum and for short, what we have argued for in the paper is: Fine that design has developed to be specific, fine that we now have system developers, designers and HCI specialist, but don’t forget that the specific-designed artefacts have to be taken care of by the general designers, the practitioners, in order to get impact on the work practice it was intended for. And don’t forget that the practitioners may contribute substantially also to specific-design.

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Applications of Agent Based Simulation

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Abstract. This paper provides a survey and analysis of applications of Agent Based Simulation (ABS). A framework for describing and assessing the applications is presented and systematically applied. A general conclusion from the study is that even if ABS seems a promising approach to many problems involving simulation of complex systems of interacting entities, it seems as the full potential of the agent concept and previous research and development within ABS often is not utilized. We illustrate this by providing some concrete examples. Another conclusion is that important information of the applications, in particular concerning the implementation of the simulator, was missing in many papers. As an attempt to encourage improvements we provide some guidelines for writing ABS application papers.

1 Introduction

The research area of Agent Based Simulation (ABS) continues to produce techniques, tools, and methods. In addition, a large number of applications of ABS have been developed. By ABS application we here mean actual computer simulations based on agent-based modelling of a real (or imagined) system in order to solve a concrete problem. The aim of this paper is to present a consistent view of ABS applications (as they are described in the papers) and to identify trends, similarities and differences, as well as issues that may need further investigation.

As several hundreds of ABS applications have been reported in different publications, we had to make a sample of these. After having performed a preliminary search for papers describing ABS applications that resulted in about 50 papers, we identified one publication that was dominating. About 30% of the papers were published in the post-proceedings of the MABS workshop series [1, 2, 3, 4, 5] whereas the next most frequent publications covered only 10%. We then chose to focus on the MABS publication series and found 28 papers containing ABS applications (out of 73). Even if we cannot guarantee that this is an unbiased sample, we think that selecting all the applications reported in a particular publication series with a general ABS focus (rather than specializing in particular domains etc.), is at least an attempt to achieve this.

In the next section, we present the framework that will be used to classify and assess the applications. This is followed by a systematic survey of the sampled papers. Finally, we analyze our findings and present some conclusions.

2 Evaluation framework

An ABS application models and simulates some real system that consists of a set of entities. The ABS itself can be seen as a multi-agent system composed of a set of (software) agents. That is, there is a correspondance between the real system and the multi-agent system as well as between the (real) entities and the agents. We will use the
terms “system” and “entity” when referring to reality and “multi-agent system” and “agent” when referring to simulation models. For each paper we describe different aspects of the problem studied, the modeling approach taken to solve it, the implementation of the simulator, and how the results are assessed.

2.1 Problem description

Each problem description includes the domain studied, the intended end-user, and the purpose of the ABS application.

**Domain:** The domain of an application refers to the type of system being simulated. We identified the following domains after analyzing the sampled papers:

1) An *animal society* consists of a number of interacting animals, such as an ant colony or a colony of birds. The purpose of a simulation could be to better understand the individual behaviors that cause emergent phenomena, e.g., the behavior of flocks of birds.

2) A *physiological system* consists of functional organs integrated and co-operatively related in living organisms, e.g., subsystems of the human body. The purpose could be to verify theories, e.g., the regulation of the glucose-insulin metabolism inside the human body.

3) A *social system* consists of a set of human individuals with individual goals, i.e., the goal of different individuals may be conflicting. An example could be to study how social structures like segregation evolve.

4) An *organization* is here defined as a structure of persons related to each other in purposefully accomplishing work or some other kind of activity, i.e., the persons of the organization have common goals. The aim of a simulation could be to evaluate different approaches to scheduling work tasks with the purpose of speeding up the completion of business processes.

5) An *economic system* is an organized structure in which actors (individuals, groups, or enterprises) are trading goods or services on a market. The applications which we consider under this domain may be used to analyze the interactions and activities of entities in the system to help understand how the market or economy evolves over time and how the participants of the system react to the changing economic policies of the environment where the system is operating.

6) In an *ecological system* animals and/or plants are living and developing together in a relationship to each other and in dependence of the environment. The purpose could be to estimate the effects of a plant disease incursion in an agricultural region.

7) A *physical system* is a collection of passive entities following only physical laws. For example, a pile of sand and the purpose of the simulation may be to calculate the static equilibrium of a pile considering forces between beads and properties within the pile considered as a unit.

8) A *robotic system* consists of one or more electro-mechanical entities having sensory, decision, tactile and rotary capabilities. An example is the use of a set of ro-
bots in patrolling tasks. The purpose of the simulation could be to study the effectiveness of a given patrolling strategy.

9) **Transportation & traffic systems** concern the movement of people, goods or information in a transportation infrastructure such as a road network or a telecommunication network. A typical example is a set of interacting drivers in a road network. The purpose of a simulation could be to create realistic models of human drivers to be used in a driving simulator.

**End-users:** The end-users of an ABS application are the intended users of the simulator. We distinguish here between four types of end-users: *scientists*, who use the ABS in the research process to gain new knowledge, *policy makers*, who use ABS for making strategic decisions, *managers* (of a systems), who use ABS to make operational decisions, and *other professionals*, such as architects, who use ABS in their daily work.

**Purpose:** The purpose of the studied ABS applications is classified according to *prediction*, *verification*, *training* and *analysis*. We refer to prediction as making prognoses concerning future states. Verification concerns the purposes of determining whether a theory, model, hypothesis, or software is correct. Analysis refers to the purpose of gaining deeper knowledge and understanding of a certain domain, i.e., there is no specific theory, model etc to be verified but we want to study different phenomena, which may however lead to theory refinement. Finally, training is for the purpose of improving a person's skills in a certain domain.

### 2.2 Modeling Approach

The modeling aspects are captured by the eight aspects described below.

**Simulated Entities:** They are the entities distinguished as the key constituents of the studied systems and modeled as agents. Four different categories of entities are identified: *Living thing* - humans or animals, *Physical entity* - artifacts, like a machine or a robot, or natural objects, *Software process* - executing program code, or *Organization* - an enterprise, a group of persons, and other entities composed by a set of individuals.

**Number of Agent Types:** Depending on the nature of the studied application, the investigators have used one or more different agent types to model the distinct entities of the domain.

**Communication:** The entities can have some or no interaction with one another. The interactions take place in the form of inter-agent communication, i.e., messaging. Here, we defined two values to indicate whether communication between agents exists or not.

**Spatial Explicitness** refers to the assumption of a location in the physical space for the simulated entities. This can be expressed either as absolute distance or relative positions between entities.

**Mobility** refers to the ability of an entity to change position in the physical space. Although the real world entities may be spatially situated or moving from place to place, this fact need not be considered in the simulation if its inclusion or omission does not affect the outcome of the study.
Adaptivity is the ability of the entities to learn and improve with experience that they may acquire through their lifetime. Two values are defined to indicate whether the simulated entities are adaptive or not.

The structure of MAS refers to the arrangement of agents and their interaction in the modeled system to carry out their objectives. This arrangement could be in one of the following three forms: peer-to-peer, hierarchical, or recursive. In a peer-to-peer arrangement, individual entities of the modeled system are potentially interacting with all other entities. In a hierarchical structure, agents are arranged in a tree-like structure where there is a central entity that interacts with a number of other entities which are located one level down in the hierarchy. Whereas, in a recursive structure, entities are arranged in groups, where the organization of each group could be in either of the forms above, and these groups are interacting among each other to accomplish their tasks. The three types of MAS structure are illustrated in Fig 1.

Fig. 1. Peer-to-peer, hierarchical, and recursive organization of a MAS.

Dynamic: If the modeled entities are able to come into existence at different instances of time during a simulation, we regard them as dynamic.

2.3 Implementation Approach

The implementation approach used is described in terms of the following aspects:

Platform used: The software platform is the development environment, tool or language with which the ABS application is developed. The platforms provide support to different degrees for the developers so that they need not worry about every implementation detail.

Simulation size describes the number of agents participating in the implementation of the ABS application. If the number is different between simulations or is changing dynamically during a simulation, we will use the largest number.

Scale: The size of data used in the actual simulations has been divided into limited/partial or full-scale data. The full-scale data represents data for a whole system, while the limited/partial data only covers parts of the system.

Input data: The data used in the experiment can either be real data, i.e. taken from existing systems in the real world, or data that is not real, i.e. artificial, synthetic or generated.

Distributed: ABS applications, depending on the size and sometimes the nature of the application, may require different execution environments: a single computer, if the
number is small or several computers in a distributed environment, if the number of
agents is large.

Mobile agents: Agents executing in a distributed environment can be described by
their mobility, as static or mobile. Static agents run on a singular computer during their
lifetime. Mobile agents, on the other hand, are able to migrate between computers in a
network environment.

2.4 Results

The classification of the result of the approaches will be in terms of maturity of the re-
search, comparison to other approaches and the validation performed.

Maturity: ABS applications can have varying degree of maturity. In our framework
the lowest degree of maturity is conceptual proposal. Here the idea or the principles of
a proposed application is described, but there is no implemented simulator. The next
level in the classification is laboratory experiments where the application has been
tested in a laboratory environment. The final level, deployed system, indicates that the
ABS system actually is or has been used by the intended end-users, e.g., traffic man-
agers that use a simulator for deciding how to redirect the traffic when an accident has
occurred. If the authors of the paper belong to the intended end-users (researchers), we
classify the application as deployed if the authors draw actual conclusions from the
simulation results regarding the system that is simulated (rather than just stating that
ABS seems appropriate).

Evaluation comparison: If a new approach is developed to solve a problem which
has been solved previously using other approaches, the new approach should be com-
pared to existing approaches. That is, answer the question whether ABS actually is an
appropriate approach to solve the problem. Such an evaluation could be either qualit-
avative, by comparing the characteristics of the approaches, or quantitative, by different
types of experiments.

Validation: In order to confirm that an ABS correctly models the real system it needs
to be validated. This can be performed in different ways, qualitatively, e.g., by letting
domain experts examine the simulation model, or quantitatively, e.g., by comparing
the output produced by the simulator with actual measurements on the real system.

3 Results

In table 1 the framework is summarized. Table 2 shows how the papers were classified
according to the framework. If a paper does not explicitly state to which category the
simulator belongs but there are good reasons to believe that it belongs to a particular
category, it is marked by an asterisk (*). If we have not managed to make an educated
guess, it is marked by “-“.
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## 4 Analysis

### 4.1 Problem description

The results indicate that ABS is often used to study systems involving interacting human decision makers, e.g., in social, organizational, economic, traffic and transport systems (see Fig. 2). This is not surprising given the fact that qualities like autonomy, communication, planning, etc., often are presented as characteristic of software agents (as well as of human beings). However, as (some of) these qualities are present also in

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other living entities, it is interesting to note that there was only one paper on simulating animal societies and just two involving ecological systems. Very few papers are found on simulating technical systems, such as ICT systems, i.e., integrated systems of computers, communication technology, software, data, and the people who manage and use them, critical infrastructures, power systems etc. The aim of such models might be to study and have a deeper understanding of the existing and emerging functionalities of the system and analyze the impact of parameter changes. (The only paper on simulating technical systems concerned robotic systems.)

In more than half of the applications, researchers were the intended end-user. As can be seen in Fig 3., the most common purpose of the applications included in the study was analysis. However, no paper reported the use of ABS for training purposes indicating that this may be an underdeveloped area.

4.2 Modeling Approach

The simulated entities are mostly living things, indicating that ABS is believed to be better suited to model the complexity of human (and animal) behaviour compared to other techniques. However, it should be noted that in some applications there were entities not modeled and simulated and implemented as agents. Hybrid systems of this
kind are motivated by the fact that some entities are passive and are not making any decisions, especially in socio-technical systems. The model design choices for some of the aspects seem to be consequences of the characteristics of the systems simulated. After all, the aim is to mirror the real system. These aspects include number of agent types, only about 15% of the applications had more than three different agent types, spatial explicitness (60% do use it), mobility of entities (50%), communication between entities (64%), and the structure of the MAS where a vast majority used a peer-to-peer structure (77%). However, as illustrated in Fig. 4, there are some modelling aspects where the strengths of the agent approach do not seem to have been explored to its full potential. For instance, only 9 of the 28 papers make use of adaptivity, and just 7 out of the 27 implemented systems seem to use dynamic simulations.

![Fig. 4. The distribution of modeling aspects.](image)

### 4.3 Implementation Approach

Nearly half of the papers do not state which software were used to develop the ABS. In particular, it is interesting to note that the two papers with the largest number of agents do not state this. Of the agent platforms and simulation tools available, none is dominantly used. In fact, many of the simulations were implemented with C++ or programs developed from scratch. A possible reason for this may be that many ABS tools and platforms make limiting assumptions regarding the way that entities are modeled. The number of agents in the simulation experiments is typically quite small (see Fig. 5). In 50% of the papers the number of agents were 61 or less. The fact that most simulation experiments were limited covering only a part of the simulated system, may be an explanation for this. The reasons for this are seldom discussed in the papers but are probably lack of computing hardware, software (such as proper agent simulation platforms), or the time available to perform the experiments. Moreover, there may be a "trade-off" between the complexity of the agents and the number of agents in the experiments, i.e., that large sized simulations use relatively simple agents whereas smaller simulations use more complex agents. However, further analysis is necessary before any conclusions can be drawn.

Many of the simulation experiments are conducted with artificial data, typically making simplifying assumptions. This is often due to reasons beyond the researchers'
control, such as availability of data. As a consequence, it may be difficult to assess the relevance of the findings of such simulations to the real world problems they aim to solve. It seems as very few of the simulators are distributed, and no one is using mobile agents. However, these issues are seldom described in the papers.

![Fig. 5. The frequency of different simulation sizes (number of agents).](image)

### 4.4 Results

We have not encountered any ABS applications that are reported to be deployed to solve actual real world operational tasks. The examples of deployed systems are limited to the cases where the researchers themselves are the end-users. The cause of this could be the fact that ABS is a quite new methodology, or that the deployment phase often is not described in scientific publications. As illustrated in Fig. 6, less than half of the simulations are actually reported to be validated. This is particularly striking as it is in most cases the complex behaviors of humans that are being simulated. Also, comparisons to other approaches are very rare.

![Fig. 6. The frequency of different types and evaluation.](image)
4.5 Limitations of the Study

Although the conclusions drawn from our study are valid for the work published in the MABS proceedings, a larger sample is probably needed to verify that they hold for the whole ABS area. There were a number of interesting aspects that we were not able to include in our study. For example, regarding the problem description, the size of the actual problem, i.e., the system being simulated would be interesting to know. Typically, only a partial simulation is made, i.e., the number of entities in the real system is much larger than the number of agents in the simulation. However, in most papers the size of the real system is not described and often it was very difficult for us to estimate the size. Another interesting aspect not included in this study is the modeling of entities. The representation of the behavior and state of the real world entities should be sufficiently sophisticated to capture the aspects relevant for the problem studied. We initially categorized the ways of modeling the entities in the following categories: Mathematical models; Cellular automata; Rule-based (a set of explicit rules describe the behavior of the agent); Deliberative (the behavior is determined by some kind of reasoning such as planning). Unfortunately, there were often not enough information in the papers concerning this aspect. Related to this is the distinction between proactive versus reactive modeling of entities, which also was very difficult to extract from the papers due to lack of information. Regarding the implementation, we wanted to investigate how the agent models were implemented in the simulation software. We found examples ranging from simple feature vectors (as used in traditional dynamic micro simulation) to sophisticated software entities corresponding to separate threads or processes. However, also in this case important information was often left out from the presentation.

5 Conclusions

The applications reviewed in this study suggest that ABS seems a promising approach to many problems involving simulating complex systems of interacting entities. However, it seems as the full potential of the agent concept often is not utilized, for instance, with respect to adaptivity and dynamicity. Also, existing ABS tools and platforms are seldom used and instead the simulation software is developed from scratch using an ordinary programming language. There may be many reasons for this, e.g., that they are difficult to use and adopt to the problem studied, or that the awareness of the existence of these tools and platforms is limited.

Something that made this study difficult was that important information, especially concerning the implementation of the simulator, was missing in many papers. This makes it harder to reproduce the experiments and to build upon the results in further advancing the state-of-the-art of ABS. A positive effect of our study would be if researchers became more explicit and clear about how they have dealt with the different aspects that we have used in the analysis. Therefore, we suggest the following checklist for ABS application papers:

1. Clearly describe the purpose of the application and the intended end-users.
2. Indicate the typical size of the system (that is simulated) in terms of entities corresponding to agents.
3. For each agent type in the simulation model, describe
   a. what kind of entities it is simulating,
   b. how they are modelled (mathematical, rule-based, deliberative, etc.),
   c. whether they are proactive or not,
   d. whether they are communicating with other agents or not,
   e. whether they are given a spatial position, and if so, whether they are mobile
   f. whether they are capable of learning or not.
4. Describe the structure of the collection of agents, and state whether this collection is static or agents can be added/removed during a simulation.
5. State which simulation (or agent) platform was used, or in the case the simulator was implemented from scratch, what programming language was used.
6. State the size of the simulation in terms of number of agents.
7. Describe how the agents were implemented; feature vectors, mobile agents, or something in-between.
8. State whether the simulator actually has been used by the intended end-users, or just in laboratory experiments. In the latter case indicate whether artificial or real data was used.
9. Describe how the simulator has been validated.
10. Describe if and how the suggested approach has been compared to other approaches.

Future work includes extending the study using a larger sample, e.g., include other relevant workshops and conferences, such as Agent-Based Simulation, and journals such as JASSS, in order to reduce any bias. Another interesting study would be to make a comparative study with more traditional simulation techniques including aspects such as size, validation, etc.

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The Role of Paper and Digital Documents in Bedside Nursing Activities

Hans Kyhlbäck

Abstract. As part of a long-term study, this is a sample from research with focus on documents in on-the-ground work. In this article, the role of documents in preparation for and in bedside nursing activities is highlighted. Nurses' work in this municipal elder care is co-ordinated and enabled with help of documents of various kinds and level of completeness. Through a detailed analysis of the creation and transformation of the documents, it becomes visible that nurses themselves to great extent prepare and plan their visits and the actual care that takes place at the bedside. However, what the applied perspective help to reveal is a purpose of the documentation work to enable and strengthen the nurses’ capacity to provide best care. The presented research has an Activity Theoretical approach in which collaborative work systems are studied. With ethnographic observations, the nurses’ document actions are found to be oriented towards the central work object that is understood as the most determining component of the chosen unit of analysis. This article summarises findings and discusses consequences for improved future versions of paper and digital documents in bedside nursing activities.

Keywords: bedside; nurse; document; shop floor; unit of analysis; Activity Theory.

Introduction

This article focuses on the role of documents in Swedish municipality nursing activities. Findings are based on a selected study where the researcher closely follows and observes a nurse’s work for half a day. With minute observations, data is gathered and contributes to a series of similar studies from a longer research project initiated in 2001, and that is still ongoing (see Kyhlbäck & Sutter, 2004 and 2009). Discussions about work place studies in human factors, work science, and for example human computer interaction, address the questions about which methodological approach to go for and what advantages different theoretical frame works might have. In this study it is assumed that the detailed account of observed work and the showed role of documents, make it possible to present a picture of bedside nursing activities. As a by-product, this is also an illustrative example of choosing ethnography and an Activity Theoretical (AT) perspective for work place studies (Engeström, 1987).

Salmon et al. (2008) put forward that in human factors, a more recent theme to emerge is to take ”the overall system itself as the unit of analysis rather than the individuals within it.” This is in line with an AT understanding of human work as an activity in which individual subjects are interrelated in a systematic and historically developed way. A study in the field would then ideally capture what is going on from several subjects’ view in their activity system. From the perspective of the AT framework the group of people (in this case: nurses, other staff and patient relatives) are always oriented towards the object of work. Further, this is understood as the most de-
termining component of the activity system that is the framework’s unit of analysis. With focus on and close observations of one nurse’s actual work, the unit of analysis is possible to deal with through her performed actions and the role that documents play. The approach seems rewarding since small resources for research can be productive if peoples’ work is taken as a systemic whole, in which the contained components actually are related in a highly dynamic way. Furthermore, it is to be emphasised that this study is not the only one, but part of a number of similar and related studies in the same municipal elder care.

The selected domain is where elderly people live in special accommodations organised by the municipality. They live there because attention to their well-being is needed around the clock. It is mainly nurses and assistant nurses but also relatives who provide help and medical treatment. The elderly might stay for only a couple of weeks, or they do live for some more years - often until the end of life.

My purpose with gathering empirical data is to investigate the role of documents in bedside nursing activities at the home of the elderly, how the documents are made up, how they coordinate people’s actions, and how they contribute to the actual activity. According to AT, human actions are motivated by inherent needs in the object of work. In this case, the elderly who receive care and attention are the central objects, or more precisely: their identified and documented health problems. Thus, the needs of each one of those individual elderly trigger the nurses and other people to develop and maintain a practice of specific care treatment that involves attention, help and providing comfort.

Even though other people contribute to the provided care, one nurse is the central staff member - not in one but in several of those activity systems. Each care recipient resides in an apartment that is the private sphere where most of the nurses’ bedside encounters take place. In this study, the housing units have about 10 and 40 apartments respectively, but there are also rooms for mutual daily living such as eating and watching TV. In addition the staff have work related spaces of which at least one is a smaller office look-alike room.

Since all care is potentially motivated by the elderly’ needs, it is sometimes questioned why the staff don’t spend more time in direct treatment – at the bedside. This is a concern in my study. See also a recent study by Hendrich et al. (2008) as recognition of what nurses do in office and at the bedside (on-the-ground type of work) environments. To be remembered is that an ailing elderly person mostly lies in bed, which makes work getting into a very private and intimate sphere. The specific needs to take care of can for example be related to problematic wounds that are hard to heal, or it might be even more serious conditions such as a cancer disease that calls for palliative care in the very last months or weeks of a lifetime. The nurse is responsible for performing specific treatment actions but also to plan, follow up and co-ordinate several others’ work. She must be prepared for planned actions but also to be responsive to other urgent things to do.

In the following it is shown that nurses are dealing with a great variety of documents. They both read and write, and not only that: the nurses also make the documents integrated with other resources at work. It is clearly visible that text actions are part of the coherent strings of actions the nurses do perform. Documents are mediators of the nurses’ actions. It means that text stands in between and connects to other
people and artefacts in the activity. Following is that work performed in office spaces serves as support for actions at the bedside. The multitude of places and events in which documents are initially created, to be transformed later, indicate the complex relationships in the nursing activities. Its no wonder that there is a proper and systematic order of documents, and document related artefacts the nurses share within their group and with other related people. In the Discussion section it is concluded that the nurses are not only “users” of documents or information: they are also designers of both content and considerable part of what that holds it together.

This article tries to answers the questions what roles do paper and digital documents play, and what does a case study of nursing activities tell about design considerations aiming to support such work? It is organised as first a short outline of nurses' document use, then is given a detailed account of a nurse's office work, and next we take another look into on-the-ground work when the same nurse visit care recipients in their apartments. It is found that nurses use a wide variety of interrelated documents, which they transform in an intriguing and complex way. The second thing is that documents support an ongoing creation of the nurses’ capacity. Additionally, related to the perspective of making design: a contribution of this study is that it makes clear that design of documents is an activity the nurses do and also something that computer specialist might do for them. In last section of this article, the applied unit of analysis and the above mentioned design issues are discussed and concluded. However, we will start by giving an account of the method used in the study.

Method

When following nurses and making ethnographic accounts, I have tried to capture nurses’ practice through their use of documents. In this half-a-day of observations, I "followed as a shadow" (Sachs, 1993) while taking field notes and a great number of digital photos. In addition, this field data is used as ground for follow-up interviews. Later on in a sheltered place, the photos are shown in a stimulated recall session where the nurse explains her work recently carried out.

In the course of my research conduct I scrutinise a few illustrative examples of documents as part of a nurse's work. Those are connected to a pair of particular documents I find useful as the starting point on our way to unravel complex relations between documents/texts and human actions. When the nurse enters into a resident’s home we get into intimate particularities of the care recipients life. Since the text documents of the practice are documents in the researcher’s records, series of digital photos and field data preserve and mediate some aspects over time in the nurse's interaction with the care recipients, relatives, assistant nurses or doctors.

I have categorised the half-a-day observation into 24 numbered episodes that together count a total of 166 minutes, see table 1. Those two hours and 46 minutes is the time of my observation when I managed to use camera and/or making filed notes. For example, during transportation between nurses’ Staff facilities and the housing units V and H, no field records were made and the passed time do not qualify for a discrete episode. But, when the nurse's actions have fulfilled a coherent set of tasks, or when she has made a significant task directed towards an individual care recipient, an episode has been identified. In table 1 the letter E is for episode, C is the column for indi-
individual care recipients D, L, I, K and R that are central in the episode and who are identified by me; M is for duration in minutes and P is the number of photos from the field observations.

Table 1 Episodes during the half a day of observations.

<table>
<thead>
<tr>
<th>E</th>
<th>The nurse's actions and documents in the episode (E)</th>
<th>C</th>
<th>M</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>At Staff Facilities (episodes 1-14), read Day calendar, write fax</td>
<td>D</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>Handling papers, phone, the Boxboard</td>
<td></td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>3</td>
<td>Read Day calendar, log on computer</td>
<td></td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Write Medical record</td>
<td>L</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>Write in Day calendar</td>
<td>L</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>Write about close relative and personnel, record notes, use of Post-it no. 1</td>
<td>L</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>Phone call, write Post-it no. 2</td>
<td></td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>Read and write record (overlap episode 9)</td>
<td>D</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>9</td>
<td>Phone, write the Boxboard (overlap episode 8)</td>
<td></td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>Write fax, shredding post-it</td>
<td>I</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>Write Medical record, erase calendar rows</td>
<td>D</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>12</td>
<td>Read Medical record</td>
<td>K</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>13</td>
<td>Write Medical record</td>
<td>K</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>14</td>
<td>Boxboard, Dairy, packing bag</td>
<td></td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>15</td>
<td>At Housing V (episodes 15-18), conversation, Dairy</td>
<td>x</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>16</td>
<td>Visit, distribute medicine</td>
<td>I</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>17</td>
<td>Phone, writing post-it (3), Report book</td>
<td></td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>18</td>
<td>Dealing with Delegation binder</td>
<td></td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>19</td>
<td>At Housing H (episodes 19-23), signing list</td>
<td>D</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>20</td>
<td>-- Break time</td>
<td></td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>21</td>
<td>Housing H, office space</td>
<td>R</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>22</td>
<td>Writing Medical record</td>
<td>K</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>23</td>
<td>Visit, injection, conversation and signing list</td>
<td>K</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>24</td>
<td>Visit, distribute medicine</td>
<td>K</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>25</td>
<td>Visit, distribute medicine</td>
<td>y</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

In table 1 the episodes are chronologically ordered, but transitions from one to another is not always distinct. Nevertheless, episodes 8 and 9 are clearly overlapped which is indicated in the table. First episode is in the morning in an office area in the Staff Fa-
cilities. After extensive “paper work”, the nurse Beatrice travels to the Housing V that is an ordinary housing unit for elderly people. After a couple of visits and meeting an assistant nurse, she goes to Housing H with palliative care residents.

During the episodes I have recognised five elderly by name that are clearly addressed by the nurses actions, and additionally two (x and y) without clear identification (for me). A total of 225 digital photos together with my hand written notes make up the field data. During 22 minutes after lunch the same day, the nurse commented upon twenty selected photos in the stimulated recall session. In table 1, episodes 2, 6, 9, 10 and 14 clearly involve notes on a piece of boxboard and the post-it note no. 1 (in the following when that document is refereed to I will simply denote it as the post-it).

I have used those basic documents as entry points for much of the following account and analysis. Even if not visible on all the table rows, those two artefacts are related to most of the nurse's office work on this work shift. It should be noted that the “Medical record” in the table, is maintained only within the municipality. It is a document required according to the Swedish health care legislation (HSL, in Swedish: Hälso- och sjukvårdslagen), but shall not be confused with the other type of similar record maintained by the County Council organisation.

Results

Short outline of nurses' document usage

In the beginning of a work shift the municipal nurses meet in a regular office located in an administrative staff facility. There the nurses make a print out of a planning document called the Day Calendar. The digital version of it is stored in the Magna Cura computer system, a large size administration system for mainly municipality use. The calendar is a list in table format for the day’s planned tasks such as injections to thin out the blood after a fracture, a task of general review, to follow a doctor’s visit, or to distribute drugs in medicine boxes. If for example a colleague within the nurses' network is on sick leave, the others have to take care of the tasks planned for her.

On diverse times and places, the nurses themselves issue entries to the Day Calendar. Now, in the immediacy of performing work, the nurses together decide about the final division of tasks to do. The calendar mediate what have been distinctive things to take care of and nurse Beatrice, my informant I have followed, comments about a particular use: “because of it I might have to make a question to the doctor. The easiest way to reach him is through the fax in the morning. During the day he will call back. Then we have a conference chat. This procedure is a well functioning way to work.” Further she explains that frequent use of fax technology makes it possible to overcome geographical and organisational gaps between the patient responsible doctors and the municipal nurses.

The doctors belong to the County Council, that is another principal authority, but in a special agreement they serve, make diagnosis and decisions for treatment of the elderly at municipal accommodations. It is agreed that the doctor shall come on a visit once a week but much of the nurses' and doctors' co-operation is through fax and telephone calls.
Each nurse has an ordinary paper based as an accompanied artefact through the work shift when moving around. An example of its use is from a phone call when nurse Beatrice was driving home after work. The Boxboard attached to it provides us with one of two reference points in the following account (see the Boxboard and the Post-it in figure 1).

Immediately at arrival, and still in the car, the Boxboard was handy at reach for Beatrice to make the note on. It was shortly afterwards attached to her diary with a paper clip. This is one example of how notes are caused by emerging calls to her mobile phone. She scribbles a few letters, and afterwards, the meaning of them might be re-entered into another document, on a piece of paper or in the computer system.

Actually, Beatrice's diary is a versatile artefact. It does not only hold entries inside. Attached outside is the Boxboard and inside the front cover is a smaller list with phone numbers of importance and another list with a work schedule for her colleagues and herself. The written content on the day-to-day ordered pages in the diary is also diverse, for example notes about a pending call to a daughter of a care recipient, the nurses' work schedule, an elderly's making contact with the dental care, for special foot treatment, an alert note about a possibly arrival of a new care recipient, and more. Although, with reference to the Boxboard, Beatrice summarizes the artefact cluster in that "the most important end up on the outside". So, with this overall picture of nurses' use of documents, let us take a closer look at Beatrice’s everyday work activity.

The nurse’s office work

Out of all the episodes of the shift, I have selected a few for a focused perspective in which writing and creating documents are directly connected to bedside nursing, that is, episodes in which the nurse makes planned visits in care recipient’s apartments. In the empirical data the two artefacts, the Boxboard and Post-it note, are located beside
Beatrice's Day calendar and the diary, her most basic documents. We will see how she uses them for transformations of text into more elaborated and complete documents.

In this and next section we will look into episodes 1, 2, 5, 6, 10, 14, 22 and 23 listed in table 1. The handwritten notes on the Boxboard and Post-it note are clearly visible in the digital photos but in this account they are translated to English and converted into machine letters. Because of privacy reasons identifiers in photos are masked (see figure 1) and further, in this writing all individuals' names are exchanged to fictional ones. Each note on the Boxboard is numbered into 9, later 10, rows that equal the original document. In the list with numbers 1-9 below, do notice, the particular document is not finally settled, the document will change in the course of the nurse's work.

(1) Inga ESR Call lab.
(2) NA? Appr. Creat
(3) dehydr. value
(4)
(5) Call Melinda [phone no.]
(6) [mobile phone no.]
(7) Fax Jocob Daisy's urine ?
(8) Leonardo inj. 13/9
(9) DN Halla Mary-Anne [phone no.]

Starting in the office staff area, the Boxboard and other document artefacts are put on the desk. The Day Calendar is negotiated about and Beatrice proceeds with office work. Regular tasks of giving injections are listed in the calendar and together with the reminder on row 7 on the Boxboard; the nurse finds a reason to go on with a written question. She transforms the note into a new one in another document. Actually, the short note expands into more complete sentences when Beatrice writes the question to the responsible doctor. This is her hand written text on the fax form:

To: Dr. H. Jacob From: Beatrice Palm
About Daisy Bengtsson [soc. security number]. On the whole no more urine production,
appr. 100 ml last 24 hours. Continue Furix 80 mg inj.?
Best regards / Beatrice

After sending the fax, Boxboard rows 1-3 imply that Beatrice shall make a phone call (episode 2). By that she receives wanted complementary data, and fills out on the Boxboard (see below list on rows 12 - 14 and also the new row 10 with a K-haemolysis answer). Later, in episode 5, Beatrice proceeds with her use of the Boxboard since on row 18 there is a note preparing for the future date, September 13th.

(10) K-haemolysis
(11) Inga ESR Call lab.
(12) 138 NA? Appr. Creat
(13) dehydr. value 2,43 79
She makes an entry about Mr Leonardo into the computer version of the Day Calendar that will help to coordinate the nurse's work on an upcoming day. However, also the yellow Post-it (rows 20 - 27 below) belongs to the cluster of artefacts put on the desk. Now its information becomes integrated as a supplement to the previous stored information in the computer system. By some reason, we can recognise a redundancy in the Boxboard and Post-it, in particular see from Post-it the note (20-21) and last (25-27, an arrow on the Post-it point from Charles on row 27 to phone no 3 on row 25). Based on that Beatrice makes a more complete “picture” of who is who and of importance to Mr. Leonardo.

In the transformation, paper based documents becomes digital. The nephew Charles Clark is added to the list while earlier Leonardo's record only held the name of a good friend. In this way, the list of people mediates what is and might be some of Leonardo's social network. The digital document is established by the responsible municipal nurse as a result of her investigation and creation of knowledge about him.

Mr. Leonardo is a new care recipient that now belongs to Beatrice's sphere of responsibility. For treatment of him, the district nurse in the area of his ordinary housing and this municipal nurse are formally recognized in the Magna Cura system as affiliated and responsible staff. Beatrice's entry states that Mary-Anne is the nurse under County Council jurisdiction and that she herself is the patient responsible nurse (PAS = Swedish acronym for patient responsible nurse) during this period of living at the municipality facilities. In the computer, Mr. Leonardo’s social network is an important piece of information but there are also dated records of the status of his conditions.

Municipal nurse colleague Lizette made the last one: “Is feeling sick now in the morning, has got suppository at the hospital in similar situations. Half an hour later Leonardo feels better and asks for breakfast.” In episode 6 nurse Beatrice adds a new writing under category Nutrition: “Feels a bit sick sometimes. Receives T Postafen 25mg to take by himself when needed.” Actually, she transforms one keyword on row 22 (the above list) on the Post-it into a complete statement in the digital document. In next moment she read row 23 and writes under category Pain/sense impression:
“Some pain in his back and legs. Receives K Oxynom 5mg to take 2 by himself when needed at pain breakthrough.” After that, she leaves that part of the computer system devoted for Mr. Leonardo.

In episode 10, Beatrice is ready to make a second fax message to another doctor. It is about coordination and a shift of formally responsible doctor between a private clinic and a County primary care unit. The complemented information on row 14 (and 32 below) on the Boxboard is used as ground for a more complete note about Mrs. Inga’s current status:

To: Dr. Pinetree        From: Beatrice Palm
About Inga Eriksson [soc. security number] who is actively listed on R-by, not the private clinic C any longer. Dr. S. Svensson at private clinic C will fax sample value to You. Among other things ESR is rising 195 at 5/9, 179 at 31/8 […]
Best regards / Beatrice

After sending the fax, she destroys the Post-it piece of paper together with another white one ripped from her notepad.

During the course of making “paper work” at the office area, the Boxboard is a material reminder from writing actions the nurse has done on other places, but her current work progression also leaves evidence. When a row on the Boxboard is dealt with in a satisfactory way, she marks it through with a couple of lines. The progress of work is visible because of the added lines while it is still possible to decipher the meaning of row 35-37:

| (28)  | K-haemolysis          |
| (29)  | Inga ESR               |
| (30)  | Call lab.              |
| (31)  | 138                    |
| (32)  | dehydr. value          |
| (33)  | 2,43                   |
| (34)  | NA? Appr. Creat        |
| (35)  | 79                     |
| (36)  | ESR 179 ESR 194        |
| (37)  | Call Melinda [phone no.] |
| (38)  | [mobile phone no.]     |
| (39)  | Fax Jacob — Daisy’s urine? |
| (40)  | Leonardo inj. 13/9     |
| (41)  | DN Halla Mary-Anne [phone no.] |

When episodes 1 through 14 now are completed, Beatrice logs off the computer and leaves her desktop work. Some of the binders and other material are put back on the shelves and on their other proper places. A number of artefacts including the diary, and still the Boxboard, are brought together as a new cluster of artefacts and all are packed in her canvas bag to be at hand when moving around. She is leaving for first an elderly and then a palliative care housing unit. In the next section we will look closer into episodes 22 and 23 from the visit at the palliative care unit.

The nurse in bedside actions

During this half-a-day observation, one planned visit to Mrs. Kathleen, involves a blood thinning injection (episode 22). After giving the injection, Beatrice is standing at
the bedside talking with the resident. At the same time she prepares for signing the injection list. It is a regular procedure in order to confirm that prescribed measures have been taken. Even though the Day Calendar explicates that the injection shall be made and also when and who is responsible, there is a A4-size binder containing a signing list on a designated paper form for those particular injections.

The artefact is called the Contact Binder (or sometimes the “care recipients binder”) and, in register categories, it holds among other documents the signing list. The binder is supposed to follow the care recipient and shall not be put somewhere else but in Kathleen's facilities. A similar record of signs is regarded as belonging to the formal municipal medical record stored in the computer system. Thus we might have a redundancy of information of which I will elaborate a bit more in the following sections. Beatrice has to put her sign in the proper place and when she writes, there are clearly visible, on the same document, her and other staff's earlier sign inscriptions to be simultaneously read. Close to Kathleen's thighs, Beatrice places the Contact Binder with the list to rest on the bed.

When Beatrice is on a visit, most of the time she pursues to talk with the care recipient and other people who might be around. She continues talking and in parallel she performs other things like giving the injection. Though she temporary directs her talking towards the assistant nurse, she seems to maintain contact with Kathleen lying in bed. Her communication is going on, and at the same time she manages to grab the binder, places it on the bed, opens and navigates to the proper index section, finds the list and makes her signing entry.

The Contact Binder has its storage place on a sideboard in the same room as Kathleen has her bed. On the sideboard there is also another binder of less institutional character that is called the Life Story Binder. Family relatives do take the initiative or are encouraged to put together a sort of life story. In Kathleen's case, it tells about her husband, children and other family relatives, where she was born and raised, her school and occupational life. Among written stories there are photographs and similar artefacts from special events of importance to her. When the nurse puts back the Contact binder to its proper place she simultaneously keeps up talking and her head is directed towards the woman in bed.

A matching sign entry about the injection will soon be made in the computer system when nurse Beatrice is back at the office room. The nurses does not need any new scribbled note in between, it is a planned task of which one item is in the previously printed Day Calendar sheet. In the following episode 23, Beatrice distributes drugs into a medicine box. During her counting of pills she receives a mobile phone call. At the moment there is no paper slip within reach. The nurse simply makes a short note on the back of her left hand, and later she comments: "it is a support note." Interestingly, she seemed reluctant to explain this note further due to its non-regular document format.

**Overview of documents in use**

As we see, the nurses moving about will leave traces in written text that appear in a variety of documents. To get a better picture of the content of text and the role documents as text holders play, we need a comprehensive over-view. In table 2 is listed the
observed and recalled documents the nurse integrate in her actions oriented towards the care recipients.

Table 2. Documents in nurse’s actions oriented towards bedside work.

<table>
<thead>
<tr>
<th>Document type</th>
<th>Where the document is integrated</th>
<th>Document type</th>
<th>Where the document is integrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Day calendar (paper)</td>
<td>Any place</td>
<td>12 Day calendar (digital)</td>
<td>Office area</td>
</tr>
<tr>
<td>2 Post-it, Box board</td>
<td>Any place</td>
<td>13 Medical record HSL (digital)</td>
<td>Office area</td>
</tr>
<tr>
<td>3 Note on skin of hand</td>
<td>Any place</td>
<td>14 Social record SOL (digital)</td>
<td>Office area</td>
</tr>
<tr>
<td>4 Notepad</td>
<td>Any place</td>
<td>15 Report Book notes</td>
<td>Housing unit, staff area</td>
</tr>
<tr>
<td>5 Diary</td>
<td>Any place</td>
<td>16 Epikris resume</td>
<td>Housing unit, staff area</td>
</tr>
<tr>
<td>6 Telephone list</td>
<td>Any place</td>
<td>17 Work schedules</td>
<td>Housing unit, staff area</td>
</tr>
<tr>
<td>7 Work schedule list</td>
<td>Any place</td>
<td>18 Contact Binder/Signing lists</td>
<td>Resident's apartment</td>
</tr>
<tr>
<td>8 House Binder/ fax copies</td>
<td>Any place</td>
<td>19 Contact Binder/When needed list</td>
<td>Resident's apartment</td>
</tr>
<tr>
<td>9 House Binder/ medicine list</td>
<td>Any place</td>
<td>20 Life Story Binder</td>
<td>Resident's apartment</td>
</tr>
<tr>
<td>10 House Binder/ epikris</td>
<td>Any place</td>
<td>21 Medicine card, Medicine packing</td>
<td>Resident's apartment</td>
</tr>
<tr>
<td>11 House Binder/ delegation list</td>
<td>Any place</td>
<td>22 Respirator instructions</td>
<td>Resident's apartment</td>
</tr>
</tbody>
</table>

The nurse is the only one who writes or reads documents 2-5 (table 2), but those in turn will provide ground for the creation of other documents to be shared with her colleagues. On each housing unit there is one corresponding House Binder. Since some of the nurses are organized as belonging to one or two such houses, the binder is sometimes referred to as “her binder”. Usually the binder is stored in the nurses’ office in the staff facilities but is carried around on a planned visit to a care recipient.

Computers have been used during the last ten years, but the commercial Magna Cura system was introduced in 2003 and has been operated since then. The system is built up around administrative tasks and has been extended with more modules of which one is specialized to meet documentation requirements as stated in the Swedish health and medical legislation (HSL) of which also municipal nurses have to make documentation work pertaining to medical issues. To be noted is that other events of
importance to the care recipient shall nowadays also be documented in a similar record system according to the Social service act (SOL).

Out of those computer entries that the nurse makes, the most are within the HSL medical record and some in the SOL record (table 2, item 13, 14). In effect, writing the computer records generate entries in the Day Calendar (table 2, item 1). Despite some attempts with hand-held devices, the computers are only stationary ordinary desktop computers restricted to typical office areas. In each house, documents are stored in connection with a staff area for rest and meeting events. Those are about history of care treatment and records of current work (table 2, item 15-17). Regularly the nurse reads through and might add notes, a practice that facilitates coordination and communication between staff and the patient responsible nurse.

Each resident is a regular tenant in one or two rooms with small kitchen that make up a complete apartment and the resident’s actual home. In that space, nursing documents are stored in mainly the Contact Binder. Most people involved in giving care make some use of this particular artefact. The Life Story binder's main purpose is to facilitate development of social relations that is also considered of great importance for the practice of medical treatment.

The most prominent documents in daily use are then covered in the table 2, however, there are some others as well but not listed here because they do not appear frequently in every-day actions performed by nurses. They are more like over-all statements about the organisation's purpose and goals or they are official documents with formal decisions about identified needs and corresponding measures the municipality is responsible for.

To summarize the overview, we see some documents that follow the practitioners in and out of office areas and residents apartments. Of those, some are of intermediary character and often only used by the sole author, the nurse. Other documents are made more readable and durable in order to support the author's or her colleagues’ future work. Some textual information appears in multiple documents, a necessary redundancy because the document holder preferably is of paper material. It is obviously an advantage to make some information available in specific localities, in particular when the nurses' work is about to mobilise and coordinate also close relatives and friends who can help and give some treatment. Other documents support the interaction between the nurses in the municipality and doctors and other people present in other institutions.

Support in creation of nurses’ capacity

During the work shift, the nurse has planned visits to do in the residents’ apartments but she is also prepared to carry out emerging and more urgent actions when something else comes up. The office area is a starting point but not the place for core activities in nursing. Approaching care recipients is an ongoing part of work in trying to be as prepared as it takes to get close to the individual in a proper way. “Getting close” is supported by projecting the care recipient as an individual and as someone with specific needs of medical treatment.

Beatrice explains her way of making documents for her colleagues with a purpose of supporting a good picture of “her care recipient”. In making intermediary and finally more durable texts, she builds up resources for her own use in the actual meeting
of a care recipient. There are always particularities in a proper treatment of each individual and for example: in the palliative care it is a priority to be sensitive to breakthrough of pain. Text in documents reveal a history that help to imagine the future a bit more predictable when for example a pain killer can be timely given.

The nurses' movements are directed towards close encounters with a number of individuals in their own homes. To manage in nursing activities, the practitioners create resources that have a transient character. Each visit to a care recipient is more or less "built up" like a temporary housing construction. In metaphoric terms, the nurses are continuously setting up their scaffolds materials and skills it takes even though these are less visible. We can also think of their work as creating bridges, from a starting point often at an office area, over and into the proximity or even very close to the individual human. Bridges are created "in real time" during the approaching movement when the "good picture" becomes alive in consciousness and in body-to-body interaction. Such bridges are ephemeral and they need to be recreated in the next encounters, during the shift or on another day/night.

The recreation I find is very much dependent on text of which meaning more or less easily can be brought forth in the picture. Or if we like the "bridge" constructions: each bridge section connects to the following. Bridgeheads and abutments are made of text on which the ephemeral bridge span can be built. So, it takes much of investigation to make visible the nurses “construction work”, of which their intermediary documents such as paper slips and post-it notes are short lived and soon outdated.

Text is thus central to nursing activities integrated in and supporting actions towards the ailing individuals. Movement close to the individual but also away from more office like environments puts a lot of challenge onto the document formats meant to hold the text content.

**Office preparation for bedside work**

During the day or night shifts, the nurse now and then makes or answers phone calls. If it is about something to share or remember over a longer period of time, a first writing is usually made on a small post-it-note or a similar "short-term document" which has an initial or intermediary character. Later it is used in making a more comprehensive entry in a collaborative document, for example contained in a resident Contact Binder, the staff Report Book, or the computer document system. When a final entry is made, it is about a work task that can be strikethrough on the intermediary document. Thus a completed status of, for example, a consultation with a distant doctor, is clearly indicated.

A detailed account of a phone call reveals that the conversation includes the obtaining of specific data such as measured values or particular identifiers of people in question. Conversation goes on with focused interaction through listening and speaking. At the same time information data is fixed with the help of inscriptions of letters that make a very short text, shaped to be understood idiosyncratically by the actual author, and probably only within a not too long time period. The text is not intended to be shared and need to be re-written and transformed for a particular audience that is mostly the nurse's colleagues. This kind of writing starts with only a few letters that shortly afterwards expands into complete sentences, even if specific abbreviations are used.
Beatrice stresses that entries in a shared document shall be as short and precise as possible: “Let's say my colleagues work on a night or on a weekend, then they need to get a good enough picture of my care recipients in order to provide the right measures.” Her writing to be shared is made with the purpose of supporting all the nurses engaged in providing care close to the individual. The document text needs to be fully understandable but not too extensive. When a colleague shall try to make a “good picture” through her reading, time is limited. Such writing of the nurse has the professional collective as the readers, much in a similar good order that Heath & Luff (1996) report about when doctors’ record entries in connection with patient consultations are considered. The written statements shall be possible to read in a mutually agreed way serving a common professional need.

One reason why the first inscriptions are short is that the obtained data is not yet complete enough; the work with creating understandable information is ongoing but interrupted and later resumed. In episodes 6 – 8, Beatrice makes office preparations based on earlier short notes on the Post-it. It is about a nephew’s name and phone number. The nurse actively tries to find good information about any relative of importance and had, when passing by, recognised someone on a short visit. At the moment she manages to get a little but not all needed data to make an entry about. Later when a new opportunity occurs, the small task is renewed and more complete data is written on the actual post-it. Her actions are emerging and interlaced, and has been characterised as on the move and on the go, see Kyhlbäck & Sutter (2009).

The AT perspective helps to sort out nursing activities that might be thought of as “messy” at a first glance. The paper and digitally stored information is sometimes an artefact to share as one consistent overview of all the pending work tasks. The Day Calendar is one such example. But the same document is not possible to make available for family members of an individual care recipient. However, it is of great importance, and a responsibility for the nurse, to organise a supporting network of relatives. A husband or wife, a child or a good friend can make a lot to help and encourage the individual. Life is restricted but can be partly rebuilt in one such community of which Mrs Daisy is one in the centre and Mrs Kathleen of another. Each one of the women can be regarded as “host” of the work object in a particular activity system.

Activity theory can be used to highlight common patterns, such as existing document formats, but also to more clearly recognise what is specific in each individual case. Possibly the Contact and Life Story binders as such only exist in this studied bedside spaces but to be noticed is the widely deployed format and size of the paper based artefacts. In the theory terms, the content of those binders are closely coupled to the work object, but the particularities of the format is of importance for such created relation. What is managed in the actual case is nevertheless the requirement that the content shall be shared as a co-operative resource but only “at the bedside” where both nurses and relatives have access.

The theory also stresses the dynamic character of each activity system. What might be possible at the bedside depends on a number of interrelated people and integrated artefacts such as the binders and the contained documents. A nurse needs to be attentive to and aware of much in each different activity. She must be able to switch from an overview position and getting closer into the bedside circumstances. During a day, she may make several such changes of focus and presence, both as planned and as visits
caused by urgent conditions. As this study shows, much of her work with documents, in office areas or on the move and on the go, is preparations for her or her colleagues’ actions to be played out at bedside.

At the office, all supporting artefacts - desks, shelves, computers, faxes etc. - provide the best environment for good document entries. However, close to or at the bedside, the practical matters are different. This study makes clear that reading and writing documents becomes more restricted and difficult the closer a nurse gets work objects such as Mrs Daisy’s and Mrs Kathleen’s health problems. In movements and at the bedside, the document format becomes more critical to actually allow or restrict reading and writing. In this study, paper based documents do pass the test and in combination with digital documents in office environments, it can be concluded that this diversified documentation work plays a central role for nursing activities.

Discussion

In this section I will initially touch upon the AT inspired unit of analysis and then discuss the intriguing use of diverse documents. Emphasis is on the role documents play in supporting the nurses' capacity, and on the nurses as designers of documents in use in their own activities. Here, I find it advantageous to separate the notion of document and text respectively. For simplicity I take documents as the form onto which text is the inscribed content. But first, we will look at the nurses’ actions and the activity systems.

During a work shift, a single nurse performs a great number and a broad variety of actions that might be hard for an observer to interrelate in a sensible way. With the AT notion of activity systems, one option to go for is the signs of orientation towards the central work object, which in this study is the identified and documented health problems of the elderly people. With such an analysis, a single nurse enters into, is temporarily part of and leave, several activity systems in a reciprocal way. In her movements, she interact with other people and her actions are made possible thanks to systematically adopted and integrated artefacts. Those reveal traces, signs and text, oriented towards the individuals’ health problems. Content of notes and more complete text records provide a pattern for systematic categorisation of the work shift actions.

With the notion of activity system taken as the unit of analysis, a study like this might present not only an account restricted to concerns of one single individual, but also what is co-ordinated with others needs and purposeful actions. Text seems as a prominent artefact, which stretches through the different spaces in which a nurse moves in and out. As a thought experiment, the text content stripped away from the document form, will still remain oriented towards or clearly pertaining to the work object. However, the format of the documents affords, or restricts, reading and writing depending on the actual environment. The regular office is very different compared with the residents’ home where the individual lies in bed most of the time. Despite that fact, the unit of analysis span over such differences, while one activity system emerges as distinct to another one through the identification of the work object. This mix of differences and systematic relations help in explaining why, for example a paper binder is a proper format for text and similar in the home environment, and why aspects of the digital documents are best afforded in the office environment.
According to Smith (2006) work practice can be roughly modelled as action – text – action – text and so on. In this study the researchers “shadowing” method reveals an example of the nurse’s effort to obtain privacy data about a relative to the care recipient. Then it is observed short instances of transient moments when a write action is performed. Between other hasty actions that she has to carry out, a little is captured and a first text note is made. The chain of action-text, involving for example a not complete enough note, will in another moment “directs” the nurse to obtain the complementary information and make the second hand-written notation. When the nurse has to leave for another care recipient and another activity system, she also leaves a part of the world supporting her and that is why she sometimes needs a few “support notes” as extensions of her embodied memory. Later, in the office area, she will sit down and transcribe her own memory notes and make the data readable to other people.

In most cases only the author is able to meaningfully read and transform such short notes. Mostly they have a text character, but to create, that is to write text, the particular document format make a significant difference. The document does or does not afford the nurse to make text notes interlaced with her ongoing interaction on the shop floor (see similar considerations in Bertelsen, Eskildsen & Sperschneider, 2003; Harper et al., 1997; Sellen & Harper, 2002). As seen from above her shoulder, her writing of a few letters on a slip of paper, or on the back of her hand, can be considered as scribbled down in a sloppy way. One, who cherishes computers’ discrete and distinct ability to deal with text data, might make an overestimation of the digital format as a fit to a context like this. The hardware and software properties can easily be thought of as a similar good adoption, and a potential better support of nurses’ work, as they presumably are in a design studio or in another typical office environment. However, as is partly shown in this study, paper documents are realised and to some extent integrated into on-the-ground work provided the actual format do allow for it.

To handle discrepancies of transformations between use of paper documents and of computer carried documents is not a simple task, or probably not even one possible to abridge in a “seamless way.” In practice there is a reciprocal move between writing text and other verbal and manual actions of which human actors are necessary components. These moves are far from seamless and difficult to short-cut or even to automate. Even if the most sophisticated current computers were available to the nurses, it is not likely a management instruction to use them would be very successful – at least not in care work characterized by nurses being on the move and on the go. The intermediary and ephemeral realisation of much nursing actions would not be respected or simply just not understood. However, there are more reasons to a computer format resistance than just the nurses’ established practice to write on the back of ones’ hand or on a slip of paper.

What is observed is that even if computer use is integrated in the nursing activities, computer developers and specialists are not the only ones who make document design. In writing text close to the core activities on the shop floor, the nurses formulate their verbal language to be understood within the activity. The nurses so to say design the words they use and the text they inscribe. In a similar way the nurses also design the documents to fit well in their environment, a kind of a general design feature put forward by Gargarian (1996).
Based on the known status and further improved knowledge by reading and getting a “good picture”, a cluster of artefacts (Bertelsen & Bødker, 2002) including various “movable” documents and other tools and instruments are put together by the nurses to be used in the encounter with a care recipient. The clusters as such can be considered as designed and re-designed with an every-day frequency. Further, the nursing community has designed documents such as those found in the “Report book” and “Contact binder” in order to support communication between the nurses and other staff or between staff and a care recipient and her/his relatives. Thus, the nurses are designers of 1) clusters of artefacts and 2) of particular document formats. For an overview of this recognition, see table 3.

To summarise, the overview of documents and the fact that nurses make text and documents for their own community, does mean that nurses have a considerable freedom to make design as an integrated part of their nursing activities. I have been inspired to put together the table 3 by work of Sutter (2002). With an interest in use and design of artefacts, he distinguishes on the one hand learning (and instruction) as a general activity and on the other hand learning (and instruction) as a specialised activity.

Table 3. Design of nursing documents.

<table>
<thead>
<tr>
<th>Designers of nursing documents</th>
<th>Kind of documents</th>
<th>Documents for whom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurses (and other staff in nursing activities)</td>
<td>1) Clusters of artefacts including documents 2) Document formats (paper based)</td>
<td>For the nurses own individual and community use</td>
</tr>
<tr>
<td>Software / computing specialists (in specialist design activities)</td>
<td>Digital document formats (based on mass market computers)</td>
<td>For others’ use (delivered through the market to the nurses)</td>
</tr>
</tbody>
</table>

The distinction between general and specialised holds true also for design. The recognition of nurses as designers helps to reformulate the agenda for computer specialists’ design targeted at nursing and medical care. What matters is to do computer solutions that fit well into and give support to the nursing activities. A computer solution such as the “Day Calendar” has some obvious advantages that would be hard to produce without computer support. Another computer advantage is evident in stable storage of documents within the realms of the office-like environments.

In an ethnographic account from a hospital study, Harper et al. (1997) discuss the impact of replacing a particular paper form with a computer-based system. For that, they stress the need for a detailed study of “the ways in which the paper form serves important functions in the various phases of anaesthetists’ work.” In addition, as pointed out by Sellen & Harper (2002) in notions of “cold, warm and hot documents” at the office, the appropriate design strategy is to develop better transitions between digital storage of documents over to paper printed documents and vice versa. I have got similar results and to me, the most challenging and interesting design problems to address are in the combination of intermediary paper and the more durable computer documents. I imagine that in future design projects, computer specialists and work en-
vironment designers should be aware of the importance of not restricting nurses as designers of the format of their own documents. Probably technical matters concerning the computer interface can be made as a better fit to similar matters in nurses' design. With a broader coverage of actual documents in use, the contribution with my study emphasises not only use, but also design of documents as aspects of on-the-ground work.

The Activity theory perspective discerns the basic documents, the Boxboard and Post-it, as in the first moment an individual nurse's support. But that is not the whole story; they are later transformed into a format that can be shared with the other people related to each other in the activity system. The computer format suits well in later steps of the transformation and as a storage repository for future retrieval, by the text originator or some of her colleagues. On the other hand, the computer format restricts to more conventional office settings since the display devices are not as versatile as would be needed in encounters close at bedside or on the move. Comparatively, the order of shelves, binders, in those index registers and properly ordered forms and other paper documents, is a support system made central by the nurses for mainly their own interests in performing work. The order of paper artefacts suits well for sharing information within the nursing activities on a broad range of places, from the office and in the spaces of bedside nursing.

My conclusion is that the most productive design and development issues to deal with are not in attempts to exchange paper documents but to make computer documents in the office to better match their counter versions on paper, moved in from actions that have taken place in on-the-ground work.

References


Office Work in Shop Floor Work. A Case of Cast Metal Machining

Hans Kyhlbäck, Berthel Sutter

Abstract. The aim of the paper is to conduct a very detailed study on how shop floor workers in a "modern" company do their work. How their new office part of the work is related to the core activity of, in the case reported here, precise machining of cast metal pieces. The method is ethnographic - field notes, still photographs, and video recordings. What we found is that there were four offices built up at the shop floor. The first office was established by the management, and the other three offices were designed by the shop floor workers. The more close the offices were to the place of the core activity of machining, the "simpler" they were. They were designed to support the core activity, taking the concrete circumstances into consideration of how the "office support" could best be constructed. Further, we found that the office actions of the machinists are close connected to their core activity. These findings are finally discussed.

INTRODUCTION

A noticed feature of modern work is that office work is accomplished at the shop floor too. When conducting a long term study on "document at work" - so far within the occupational fields of municipally organised care activity and cast metal machining work - we were surprised by the occurrence of several offices or office-like facilities that were built up on the shop floor. This was the immediate driving force for us to take a closer look at such "offices" at the work floor, and at office work done by shop floor workers. What role did the offices have in the work activity as a whole? Why were they built up? How were the offices used by the shop floor workers?

Traditionally, office workers transform documents and texts, and shop floor workers transform corporeal objects. However, the modern shop floor workers that we have studied transform corporeal objects as well as documents and texts. A lot of descriptions of "the new work order" (Gee et al., 1996), of "integrated production system" (Brulin & Nilsson, 1997), "the information society" (Castells, 2000), "anthropocentric production systems" (Wobbe, 1991) and many more have been published. A multifarious picture of a rapidly changing working life with new qualities and ingredients, and new contradictions emerges.

For us, empirically oriented detailed studies of how work is accomplished in ordinary but yet "modernised" occupations and fields of work is our way to understand what is happening in the modern world of labour and to get a more substantial grip of - paradoxically enough - the still existing "one of the best kept secrets in the modern world, namely how people work" (to paraphrase sociologist David Wellman, quoted by Suchman, 1995).
THE STUDY AND METHOD

This paper is based on an ethnographic study conducted mainly during April 2007 and June 2008 at the shop floor of Kockums Maskin, a subcontracting company specialised in precision machining of cast metal. We have observed machinists for ten periods and totally 21 hours, and recorded by means of still photos, video, and field notes. In addition we have conducted three interviews with technicians and management.

During our observations we have followed close the machinist’s work performance where the small digital video camera turned out to be a very handy recording device. At the shop floor there is sometimes a rather noisy back ground sound from the machines, but to a great deal actions and interactions were possible to record. The machinists have to pay attention to and interact with machines as well as co-workers. That means we observed not only orally utterances but a broad variety of other communicative actions. In the study we have a special focus on the workers’ reading and writing of documents.

THE WORK OF THE CNC MACHINISTS

Our study of machinists is carried out on a middle range size subcontractor company that makes precise machined cast pieces for the vehicle industry. CNC machines are the main tools the skilled labourer operates. To be noted however, “Computer” in “CNC” is to be understood as a very specialised and highly integrated device of the machinery. When it runs the program, the computed output controls the machine tools and in effect the work piece is “worked on”. Only some specific information hold by the machine-computer will be monitored during “run time”. The CNC machine is a high quality and precise machine as such, but it is not able to detect if cutting metal is within tolerance of measurements. No sensors exist to detect deviations during the removal of metal. Instead, it is to be determined after the machine cycle is completed if the machine operations were successful. However, indirectly, a skilled and experienced machinist is able to interpret produced sounds and may stop a cutting that is getting out of bounds. It is always a potential risk, that either the cast material or the tool have weak properties or that the holding device is about to loose the grip of the piece. When such bad conditions are present, a trained human hearing may foresee an hazardous situation and intervene by immediately stopping the machine cycle. Otherwise, not only a measures out of bounds are at risk, a very expensive damage may occur to the tool and the rest of the machine. This is something the machinist regard as an essential part of their skills: to recognise patterns of sounds and sense an audio sign of malfunction.

A production company as this for sure face harsh competition and has a strong incentive to maintain and further develop its strengths. A key factor is the staff competencies, to make them fit to the technology changes and to make them supplement and to complement each other. For that it takes an alert organisation oriented towards improvements and building on its solid experiences from work with cast metal. The company in question explains its success as grounded in a conscious enterprise in staff development. In a presentation folder it is expressed ”To get a good work situation, it takes co-operation between the stake holders in the four-leaf clover”. The four-leaf
c Clover is illustrated and the stakeholders are inscribed as: Owners, Customers, Co-workers and Society. In more concrete projects, the company is involved in "continuous improvement" of its organisation and work practice, inspired by concepts such as "lean production". We also believe, documents and office work at the shop floor are current characteristics of such a company that transforms into modern work order. In the following we give an account of our detailed study at this company where our main informants are machinists at the shop floor. What is a point of central interest for this paper is that those traditional "blue-collar" workers also do a lot of documentary work as the following chosen episodes will tell us about.

**Episode 1: the wrecked machine**

On the previous night shift, there were several wrecks in the "5800" CNC machine. A number of work pieces ended up as crap and three drills and one fixation pin had been broken. This is told to us by the senior CNC machinist Patrik. Now he tries to find the cause to the trouble. He starts to make a try out on only one work piece with a shorter drill which he knows has worked well earlier. During the test cycle he listens carefully to the machining operations to get an immediate sense if his expected solution is a working one. In his course of actions, Patrik investigates why the problem occurred but at the same time, he designs a potential solution. Patrik says: "It leans towards a problem with the drill." After the test cycle, he investigates if the drill holder has got any marks as indication of getting too close to the fixation device. Patrik’s tentative solution seems as an appropriate solution. Now he needs to do some additional changes.

For a regular machining cycle, the cast pieces are loaded on two fixation devices. Each of them holds four pieces, two for one set of tool cutting and the other two for another set. The fixation devices are turned around during a cycle to let both face the working tools. During one intermediate moment of the cycle, the human machinist must manually shift the position of the pieces in order to make the machining complete.

Patrik continues with a closer check out of the fixation devices. He energise the hydraulic guiding pins and find that not only one but two out of the eight positions are wrecked! There are two pins broken and the second one must also be found. He traces the second broken pin to one of the two scrap boxes that are located a bit off from the machine group. To find the pin is very important because nothing except valid pieces
are allowed to be delivered to the customer. The possibility of a problematic piece must be checked and avoided.

![Figure 2. Formal instruction on machine front.](image)

After a thorough examination of the machine, Patrik changes the control software to eliminate the running of the machining positions 2 and 8. In addition he needs to adjust the software control instructions due to his design solution with a shorter drill. Patrik makes a reflective comment: "The wreck might be caused by the drill, that it wasn't sharpened correctly." Further, he says: "This is a difficult fault to understand. One ought to start off the fixture with the build-in guiding pins without pieces to be able see if anyone is missing." It is difficult to be attentive to any sign of a particular fault type since it can take half a year or more between actual occurrences. Experiences about wrecks like this one is communicated orally but some are inscribed in documents. In the log, a notebook located on the desk close to machine “5800”, Patrik writes (see also figure 1):

> 26/4 Well, it wasn't funny ;-) There was some problem at the night shift. There was a number of drills broken and also guiding pins to fix-L2 and 8 so they are gone. I made a new set-up with the older shorter drills and it worked, but maintain attention to the drill, thank you.

During a later regular running of the actual engine bracket job, machinist Tord explains that he is particular attentive to a cutting in the middle of the piece. The machining sounds loud and screeching and Tord says: "Here one must follow closely because it varies a lot between the pieces."

As we understand it, not only from this comment but from several others as well, changes in metal hardness is a general problem for machining, because it might cause a serious wreck. However, in our actual case when Patrik made his investigation and design, it was the drill tool that did break because it wasn't sharpened correctly or it had some deviating steel properties. Interestingly, on a visit that we did two month later, the trace of the wrecking incident was now indirectly visible in a new A4 size document attached to the front of the machine ("5800"). At date June 16th a technician had issued the instruction for how to run the engine bracket job (see also figure 2):
At change of shift the fixation device shall be energised empty/.../ the guiding pin shall then exist and be visible. NB!!!!this applies to both palettes.

**Episode 2: machine set-up**

In this episode CNC machinist Jens shall make a set-up of the fixation device for a job in the “4800” machine. Martina who is an apprentice CNC machinist will try to follow close with Jens and assist him if possible. Jens applies full body strength when he tightens the screws that hold the fixation device connected to the machine’s single palette. For this particular job, the device holds four positions for pieces to be drilled and cut. Since the machine can not sense how accurate an actual machining is, the accuracy of the run operation can only be determined after complete machine cycle.

That is why Jens’ set-up must meet close to the required measures. In the set-up, Jens tries his best to get the device aligned to an absolute position measured in fractions of a millimetre. To achieve this, he chooses and uses a feeler gauge. Each gauge has its specified thickness inscribed in its metal surface. The tolerance for each machining of pieces will often allow for plus or minus one or a few hundreds of a millimetre. Which measures apply in production work are dependent on several different measures on the same piece. As the result of a complete set-up procedure, the machinist tries to get as close as possible to an ideal absolute accuracy. The set-up is supported by a specific set of documents contained in ”the folder” of which there is one for each cast piece job. For this particular job, the folder has a main sequence of instructions printed on one page:

**Description of operation (job piece: Belt tightening)**

1. Blow clean and load the fixation device with 4 pieces 20578689 See attached picture *
2. Connect the hydraulics and clamp steady the pieces with appr. 150 bar.
3. Run the pieces with program 455 under program 4551 and 4552.
4. Edge the spline with an emery cloth to remove all sharp edges.
5. Measure according to the control instruction *
6. The pieces shall be packed according to the packing instructions *

* Authors comment: reference to other documents in the folder.

The folder is consulted repeatedly during Jens’ set-up work. All the documents are supposed to be used as a reminder of what to do during regular production work. In this case, the folder is brought close to the machine front during this “non regular production job” which is a necessary set-up of tools and machinery. At several moments Martina assists by holding the folder. At the moment when Jens makes a first load of pieces he proceeds very cautiously. His gaze goes back and forth between the ”attached picture” in the folder and the metal piece he tries place accordingly. Every set-up procedure involves running a first cycle of machining. This first cycle is the crucial proof of good enough work. The fixation alignment might be a little out of bounds, and when so, it is corrected. Deviations beyond a certain limit may cause a very expensive collision. Most tools rotate at a high revolution speed and the machine is made for very fast transportation between the machining positions. Most movements are fast and there is not much to do during machining even if something obviously goes wrong than to press the stop button. Consequently, the set-up work will determine success or
failure. Anyhow, Jens is very cautious and stay alert prepared to stop the tool movement between the positions of cutting and drilling. "The piece might get lose from the clamping grip or a tool can get in contact with wrong parts," he explains. In this case a first set of four pieces are made with no signs of malfunctioning. Now Jens marks each piece with a number, 1-4, corresponding to the different fixation positions. In the next move, all the pieces will be transported to the Quality Control (QC) department where co-workers will measure with the use of advanced instruments. A QC measurement will mostly result in adjustment instructions marked directly with arrows and numbers on each of the four pieces (see figure 4). In accordance with the QC instruction, Jens will later change and adjust the control software of the machine. Even if deviance within specified tolerance is allowed, good practice is to find an optimal control of the machining.

When the metal is being cut a lot of noise and screech sounds are produced. To a novice is just annoying, but for the experienced machinists, the sounds constitute a distinguishable interface to the machine performance. Among the sounds, some are distinct indications that something is going wrong. On one moment of the first machining cycle Martina poses a question: "It shall sound like that, or?" Jens answers: "It´s a long tool that causes such vibrations.” A few moments later when Jens unload the first machined pieces, Martina remarks: "It looks good from my position”. Jens agrees: "Yes”.

On another observation visit, machinist Tord explains that "very few errors occur during the set-up procedures. The machinist is very alert during such assignments”. He further explains that failures are mainly due to weak attention during the regular production work, since "each piece must be aligned properly to the guiding stop otherwise it will be wrong or might cause a wrecking of the machine.”

**Episode 3: stopped box pallet**

Machinist Tord explains there has been a collision during production work of what is called the "muppet” job in machine “5800”. It is an ”engine bracket” job but at the shop floor the name “muppet” is in practice. In this reconstructed episode, one cast piece has got loose during machining. The collision did cause a deviation in guiding parts that determine precise drilling and cutting. Each piece loaded in such a fixation position will therefore be machined in an uncontrolled way if the machine isn’t reconfigured in respect to the slight deviation. During the production work it wasn't immediately recognised by the machinist that a tool actually had collided. As a consequence, one box pallet "has been stopped” and no one of the approximately 48 pieces will be accepted before an additional control procedure has been made.

Close to the machine “5800” there is a permanently arranged measurement station with specific instruments and a manual document, all devoted to this particular “muppet” job. It is a long run job and regularly samples of pieces shall be measured by the machinists during production work. But even now when there has been a collision, in this case Tord explains ”it is likely all of the pieces can be accepted” by the customer. Each piece is measured by the machinists and the result is marked with numbers on each piece in the box (see figure 3). Since now every fourth piece have measures out of bounds, the procedure has revealed a trend of machining deviation. In addition, the co-workers at the QC department have made even more accurate measurements of a
sample of machined pieces. Based on that, the QC department has given the more urgent adjusting instructions with arrows and numbers written directly on the surface (see figure 4). Those instructions are used by the machinists when reconfiguring the machine.

At the time for Tord’s explanation, the QC department was lacking people and their final measuring of the stopped box pallet was still in a wait state. According to Tord’s story “it might not be that bad”, since the QC department can make a more comprehensive and precise measurement. They are able to make an overall assessment and a compromise on the small deviation. QC also knows that the costumer, a big Swedish car producing company, normally gives little too precise specifications. Based on that and their more precise measurements, they have a ground for negotiating the requirement specifications from the customer. This is the background to Tord’s prediction that ”probably all of those pieces will be accepted.”

ANALYSIS OF THE SHOP FLOOR WORK WITH FOCUS ON DOCUMENTS

We collected the three representative episodes as ground for our analysis work. Because advanced tools and machines are required for machining at very high level of precision, we believe that the practice and organisation of work also need to be advanced. Individuals course of action and its relation to co-workers and other peoples doing and making in the world, we assume as intricate and dependent on changing and versatile circumstances under which the work object is transformed into a new state. With reliance on the rich and detailed empirical material, in this section we first sort out the most significant facts and in next step we will try to distinguish some patterns of interest in modern shop floor work.

First step of analysis

In first step of analysis we use the detailed three episodes and try to answer the questions: What is that we see with help of the recorded observations?; What has been retold and described by the studied participants?; and what are we in addition able to construct in terms of What has or will happened, based on either reading documents or on reasonable conclusions?

In episode 1 (table 1) the night shift machinist orally tells Patrik about how many machined pieces that was categorised as crap because of a faulty machining, and later Patrik tells us about it. Recurring observations during our visits also tells us that a machinist shall enter numbers on all produced and failed pieces in a regular shift report hold by the networked computer record. Further, on the surface of a faulty piece, the night shift machinist did write the code ”BF” (Swedish abbreviation that translates to ”machining fault”) on a number of pieces. Those pieces we did observe in the corresponding one of the two designated scrap boxes. The other second box holds scrap pieces marked ”MF” that means a ”material fault” identified during production work. In the episode Patrik was supported by this order since he understood there was a second broken guiding pin and he tried to find its location. Then he didn’t start to search in the difficult and unlikely places. Instead, as observed and recorded by us, he
walked the 15 meters to the two boxes and after 5 minutes searching in the first choice box, he did find the pin. Alternatively, as Patrik tells us, the pin was likely to be lost under the cooling water level in the bottom of the machine or even worse - stuck in an accepted piece packed for delivery.

Table 1: Episode 1, the wrecked machine (column 5=place for operation/action).

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3 operation/action or fact</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>field notes</td>
<td>night shift machinist orally reports several wrecks, three drills and one guiding pin in fixation device broken</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>field notes</td>
<td>on only one piece, senior machinist Patrik starts a test run with a shorter well known drill</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>- ” -</td>
<td>Patrik is cautiously close to the controls prepared to stop the machine</td>
<td>machine computer controls</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>- ” -</td>
<td>stops machine, looks closer and feels with fingers on replacement drill holder</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>- ” -</td>
<td>says “it leans towards a problem with the drill”</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>- ” -</td>
<td>changes pressure for cooling water and tells co-worker Jens</td>
<td>machine computer controls</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>- ” -</td>
<td>at the machine front, checks out all fixation positions, a second guiding pin is broken!</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>field notes, pictures</td>
<td>In one of two scrap boxes, he finds guiding pin stuck in hole of scrap piece marked “BF”</td>
<td>work object</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>field notes</td>
<td>changes control software to eliminate fixation positions 2 and 8</td>
<td>machine computer controls</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>- ” -</td>
<td>says “..ought to energise the guiding pins”; “difficult fault to understand”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>field notes, pictures</td>
<td>date 26/4, writes in log book: “Well, it wasn't funny :-) /.../ made new set-up /.../ maintain attention to the drill....”</td>
<td>log book</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>pictures, video record</td>
<td>dated 18/6, document issued by a technician, instructs machinists to energise hydraulic powered guiding pins at beginning of each change of shift in order to inspect if they exist or not</td>
<td>instruction A4 sheet</td>
<td>4</td>
</tr>
</tbody>
</table>

Patrik’s try-out with another drill required changes in the machines tool transport but also a review of revolution speed and cooling water pressure. As we observed in real time, the machine did accept Patrik’s review of the software control code and his
"short drill" solution worked out successfully. This result of his approximately two hour effort he reported by a hand written message in the log book located on the desk close to the machine: ”Well, it wasn’t funny” etc. Further, in his reflection about the fault as a potential treat to future smooth operation, he did also tell us that ”...one ought to energise the guiding pins”. Interestingly, this statement did not only remain in our field notes. As can be seen in table 1, the last step of the episode was observed by us on another visit. Nearly two months later the statement was transformed into a special instruction attached on one of the machine’s front doors. But now, it was another person, a technician authorised to issue such kinds of documents who had signed the document (see figure 2).

Table 2: Episode 2, the machine set-up (column 5=place for operation/action).

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3 operation/action or fact</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>field notes, video record</td>
<td>machinist Jens aligns fixation device with use of a feeler gauge</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>- &quot; &quot; -</td>
<td>Jens tightens socket head cap screws on fixation device, applies full body strength</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>- &quot; &quot; -</td>
<td>Jens takes of his gloves, he and apprentice Martina read folder instructions about control software, Martina points with finger into the text</td>
<td>paper sheets in folder</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>- &quot; &quot; -</td>
<td>Jens choses control software</td>
<td>paper sheets in folder, machine computer controls</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>- &quot; &quot; -</td>
<td>Jens gets help from Martina to have instruction folder with picture accessible, checks out pieces loaded in fixation device</td>
<td>paper sheets in folder</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>- &quot; &quot; -</td>
<td>Jens looks back and forth between the picture in the folder and the the metal pieces. He makes meticulously hands on adjustments of loaded pieces</td>
<td>- &quot; &quot; -</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>field notes, video record (reconstructed fact)</td>
<td>in the network computer, Jens looks up exact location of raw material pieces, proceeds driving a fork lift to get the box pallet with the cast iron</td>
<td>network computer</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>field notes, video record</td>
<td>senior machinist Patrik instructs co-workers on how to chose proper control software for this particular job</td>
<td>paper sheets in folder, machine computer controls</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>- &quot; &quot; -</td>
<td>during the “first pieces” machining cycle, Jens is cautiously close to the controls</td>
<td>machine computer</td>
<td>3</td>
</tr>
</tbody>
</table>
In episode 2 (table 2) the machinist Jens and apprentice Martina work together with the regular set-up task. With a small but crucial difference in proximity, Jens occupy the small space in the machine front where he has the work object within reach. Martina has another close but not in reach position. Jens’s hands-on operations and decision making is in the centre of actions while spoken questions and comments are Martina’s approach in trying to get involved and participate. On a number of those interaction occasions when Martina succeeded, she does it with help of mediating text and a picture. To be noted, when she hooks on the main course of action, her move starts with a textual operation such as pointing with her finger into the instruction document (table 2, step 3). In the following step Jens moves to the machine computer and starts to chose the software program for the job. Later, again at the machine front, Jens demonstrates his intent to read a picture of proper piece alignment and at the same time load the four pieces in the fixation device. Martina find her way by holding the folder open for him. At a glance he can get the picture reading and simultaneously his hands can feel the piece aligned in place. Further, when the first machine cycle is completed Jens unloads the pieces while Martina struggles with the folder. She tries to find the main instruction page but now she has gloves on her hands (step 11). The paper sheets are protected by plastic pockets while they also provide stiffness which supports her search effort. After half a minute she finds the instruction and reads loudly (step 12): ”Edge the spline with an emery cloth to remove all sharp edges”. In the next moment they together work on the four pieces resting on the small table at the side of the machine front. Finally they walk away to the QC department with all the pieces for control measurement.

In episode 3 (table 3) we do not observe much of action but are able to reconstruct and predict the handling of a problematic case on the shop floor. Machinist Tord tells us about the stopped pallet in front of us. He say’s that a loose piece caused the collision. As a regular procedure the machinists have made their control measurement on the suspicious batch of pieces. Visible to us, on each piece there is written measurements with a marker pen. According to the machinist it reveals a trend in the faulty production work. Based on that the QC department has made even more accurate measurements on a little sample of pieces from the batch. Also visible are the precise instructions that QC has marked with numbers and arrows directly on the machined surfaces of those few pieces. Tord explains that with use of that, the machinist has reconfigured the machine and the
same job assignment is now in production mode. But, still the batch of the questioned pieces are in a wait state for a final judgement.

Table 3: Episode 3, the stopped box pallet (column 5=place for operation/action).

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3 operation/action or fact</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>video record</td>
<td>machinist Tord explains that there has been a collision because one piece did get loose</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(reconstructed fact)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>- ” -</td>
<td>one pallet box “stopped” with 48 pieces as potentially out of tolerated bounds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>pictures,</td>
<td>all the “stopped” pieces are control measured by machinists following a special instruction document, measurements marked on pieces</td>
<td>paper sheets</td>
<td></td>
</tr>
<tr>
<td></td>
<td>video record</td>
<td></td>
<td>in binder, work object</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>- ” -</td>
<td>every fourth piece is out of bounds, control measurements reveal a trend</td>
<td>work object, (paper protocol in binder)</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>- ” -</td>
<td>Quality Control Department has issued precise reconfiguration measures for the machine written and drawn on a particular piece in the box pallet</td>
<td>work object</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>video record</td>
<td>Tord explains the machine have been reconfigured and production work is now continued</td>
<td>machine computer controls</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>(reconstructed fact)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>video record</td>
<td>Even though some of all the stopped pieces are out of bounds, the QC department can make a measurement compromise and ”probably all pieces will be accepted” is Tord´s guess</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(future constructed fact)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Second step of analysis:

In Patrik’s dealing with the wrecked machine he performs advanced shop floor work in that he makes hands-on operations with tools, with the machine and the pieces that are the work object to be transformed. But, in relation to the other machinists, and with others who are also involved, text appears as mediators to other times and locations where those people are involved in a course of work actions. An example is the rational order we find maintained by use of codes ”BF” and ”MF” written on the surface of faulty pieces. In Patrik’s diagnosis and problem solving work, he was very alert to sounds from the tools and other physical indicators of the present status of the test run of machining. But in his efforts he did include the history of the faulty machining cycles, as orally told, but also written directly at the work objects. Besides of the machine produced sounds and observable visual movements, he also has access to the text based software control. This he could use for some interpretation of current
machine performance and for changing its operation to suit his tested solution. With the help of the computer memory he saves his work to be used, inspected and possibly be changed by himself or a co-worker on a future day. The final routine to write in the log book will also confirm his achievement and communicate a message of special attention to the drill solution. Patrik recognised, and told us during our observation, that the actual problem he investigated is a difficult one seldom occurring and therefore “hard to understand and predict”. That understanding he builds on both attention to the situation at hand and with a vision that stretches out, back in past time and in a future to come. This time dimension includes himself and his co-workers as participants of shop floor work. However, much of the machinists actions in the present and in developing a time aspect of the activity system, we conclude as dependent of what can be seen as office work on the shop floor.

Reading and writing text intertwined in the course of actions can not easily be separated in a problem solving work like the one we observed. Textual codes and short instructions support a good order and a tight interaction among the practitioners. But documents might also obscure some aspects of what really have happened. The knowledge created by Patrik close to the machine, had in some way during time been transcended into the technicians more office like domain. The machinists’ struggle with a number of faulty work objects produced a solution to the problem and a contribution to a more developed set of work instructions for continued work. The new document attached on the machine front is made in a regular office environment more suitable for more formal and official records that omit the original - in this case those who usually are regarded as unlikely authors.

In the set-up work Jens exerts his muscle strengths and fine tuned finger operations. It is truly a “hands-on” character of this practice but for sure both his mental and body capacities are at play. Martina’s struggle to get the role as a participant is restricted by many things. Perhaps Jens is not in the most social mode at the moment. He is a competent machinist but the particular set-up job is new to him while this task is in the centre of what he is supposed to manage. The work to do is demanding and can not be jeopardised by any trial and error approach. The apparent restriction is though a physical one. Most of the set-up work must take place in the small space of the machine front. Two smaller tables on both sides doesn’t allow for the presence of a second machinist’s body. Martina has to play a second role as assistant to Jens. Since he is focused on his task, and is supposed to manage on his own, she must introduce herself in a meaningful way at several moments in the episode. For this she acts in proper time when Jens intends to use documents or the course of actions open up for reading the folder or writing the machine computer. Martina’s physical position in relation to the work object is troublesome when the cast pieces are loaded in the machine. Typically then, she can make a difference in holding the folder visible for Jens (step 6) or she can read loudly a proper instruction in due time (step 12). Another aspect of her close proximity to the work object is that she might have gloves on her hands. Oil and grease is also part of the resistance she is dealing with. The document format is the standard A4 size paper sheets in plastic pockets. On this shop floor it seems as a sustainable format which affords reading, despite problematic precision in flipping the pages of the folder and gleaming lights in the document surface. Her participation becomes easier when the pieces are unloaded and put on the small table. Then she man-
age, as a first role machinist just as Jens, to make hands-on and remove edges from the work object.

![Figure 3. Measured pieces reveals a trend](image1)

In the episode with the stopped box pallet, the cast iron pieces are the material objects visible before our eyes. Those are part of the concrete items of most interest and crucial value for the whole company. The question is if they meet requirements of good enough transformation. Partly, the answer is now produced as intermediate documents, that is, text written on the surface. A trend is visible before our eyes because of the machinists’ measurement and the belonging records. The ”stopped pieces” are not in a mess, they are ordered with help of literacy on the objects of which the QC department did read and transform into precise instructions for reconfiguration of the machine. Advanced machining is supported by office like work intertwined with shop floor transformations of the cast metal pieces.

**DISCUSSION**

What roles do documents and texts play in an activity? An answer is that they are connecting work actions and sub-activities to the overall activity system. In a way documents and texts bring messages from people from other places and other times: Do that, in this way! They mediate top-down control. (Smith, 2005; Latour, 1999). However, when shop floor workers are “integrated” in a larger part of the activity system by doing “office work” too, they not only use texts and documents. They reshape them. And this reshaping or redesign is informed by their object of work, an object (”Gegenstand”) that makes resistance to the transformation made through the work activity.

We believe that the reason why the shop floor workers by their own design build up primitive “offices” at the shop floor is that the plans generated by management are too rough and abstract to be directly realised. The plans have to be re-planned to fit to the concrete circumstances. As Lucy Suchman time and again has reminded us: plans and instructions cannot by necessity be fully specified, and therefore ”your ability to act accordingly to the plan ultimately turns on the embodied skills available to you in situ, which are themselves presupposed, rather than specified, by the plan” (Suchman, 2007, p. 72, note 6). The concrete circumstances are known only by the workers in the course of their activity. The core of the shop floor workers’ work is hands-on actions on the concrete object of work, which they transform into a new state.
With a focus on documents at work and design of information technology, we want to discuss our observed shop floor ethnography and what implications we find for design that might be targeted on such or similar work places. The point of departure is the notion that work, of any kind, is about transforming work objects from one state to another. How this may be realised we have reported in this detailed study (and in a counterpart study on the central role of documents in nursing activity; Kyhlbäck, submitted).

On ground of the above explored episodes, we find reason to ask: Do the shop floor workers only accept texts and documents produced by others, or do they contribute to the design of texts and documents? This question and the answer to it, we argue will have implications, not only for understanding of what role text and literacy play at shop floors but also for design and use of information technologies. In the first episode the machinist Patrik made an innovation. During his effort to find out the cause of the machine problem he also creates a solution to a main problem. He made a novel combination of a particular tool and the rest of the machine. As a result the machine was transformed into a workable new state. In addition, his solution, noted down in a log book, got another effect: the set of general instruction documents for proper operation of the machine was also transformed. A thing to notice here is that his contribution was not preserved in the resulting formal document. The work of the shop floor machinist was made invisible. As pointed out by Winsor (2000), the work of a worker on a "lower level" is concealed by the genre of institutional texts.
In the set-up episode the interaction between the machinist and the apprentice gives us ground to emphases that documents, or information of various kind, do play a central role in a demanding core task. The course of required hands-on actions is intertwined with textual actions. The machinist is able to relate the transformation of the machine to experiences made by others, crystallised in the folder instructions and in the machine computer code. Further, when his work changes by transformation of the raw material, the cast pieces, he adds to the used documents. He actually does write information on the pieces, and in the same format of this information he will receive the final feed-backed instructions from the QC department (see an example in figure 4). This aspect of information on the surface of the work object is also evident in the effort the apprentice makes in trying to transform the actual work circumstances, that is, the access to tools and materials and another division of labour in that course of actions. She did some rather successful intervention in this respect when she cleverly brings a central documents into the ongoing practice. Perhaps we find the most foundational pattern of office work at the shop floor demonstrated by the machinist and the apprentice in their struggle to to align the text and picture instructions with the set-up of pieces in the corporeal world. In concrete terms they did that by opening the folder, flip the pages and read in close proximity to the machine and the work objects.

In an advanced work with high requirements in precision and treatment, the work object resists much of those document affordances that we usually take for granted in a regular office environment. Because the transformation of this kind of work object, the cast steel, requires advanced machines, tools and instruments, we argue that the organisation also need to be advanced. A consequence is that the shop floor workers need to co-ordinate their actions and they must develop advanced skills to be able transform a pieces of steel into precision made products. That is why management has introduced a more regular office space in an ”off the machine area” at the shop floor. We call the first office and in the machinist case, this office looks rather similar to a standard office environments. Another office area is established in a more blurred fashion closer to the machines. Here documents do have an established position but must compete with other shop floor items. In our cases we identify what we call the second and the third offices at the shop floor close in physical distance to where the raw material is transformed (in the nurses case, the patients are treated at the bedside). Finally, when actions are played out in the machine front, documents do not have a fixed repository, as can be said about the other ones. The workers who temporarily have reason to wear gloves do face some problems (the object resist human touch). This temporarily designed work environment we call the fourth office (see also figure 8). It is harsh and will significantly reduce ordinary office documents affordances. In the apprentice struggle to achieve document access, the distance to the work object does determine what role documents might have on the shop floor.

Document handling is a way of collaboration, it is a way of making things go together. To study documents at work, how documents are used in actions, is to study how a document as “[a]n object stands in for an actor and creates an asymmetry between absent makers and occasional users. (...) an action. long past, of an actor, long disappeared, is still active here, today, on me.” (Latour: 1999, p. 189) In our case there are documents that are bringing the orders from the customer to the shop floor workers. In the networked computer at their ”first office”, they daily take instruction from
an actor far away, present and absent at the same time. But most of the texts and documents that have been made visible through the three episodes reported above, are used in a more locally circumscribed communication at the company.

For scholars of activity theory, studies of how document handling actions are accomplished, are interesting, because they may show - as suggested by Smith (2005) - how actions are woven together and are making up an activity. We would claim that such studies will show that every activity that is not only locally oriented (if there is such an activity at all) cannot be established without documentary practices. Leontyev's famous example of early hunting activity (Leontyev, 1981, pp. 212-214) says nothing of documentation, perhaps because in his made up example of early mankind activity there is no need for an out-in-the-world documentation besides oral speech, or perhaps because Leontyev did not focus on the documentary practices of the activity and as a consequence got it out of sight.

When activities grow and are performed through bigger organisations, networks and in a globalised world, documents gain a more central role. A lot of co-ordination actions are performed, and to a substantial part this is done through documents and documentary work. Thus, administrative work - the activity of managing and giving service to the core activity - has expanded, both as a special activity and as a general activity.

In our case of precise machining at a metal manufacturing company, we were able to distinguish several kinds of “offices” in the practices we studied. In both cases we found four offices (see figures 6 - 8). That the number was four is of course circumstantial. Our point is not the exact number of “offices” but that office work (as a general activity) is distributed out on the shop floor. If our point is a real point, then we have to reconsider office work and shop floor work too. The demarcation between blue collar work and white collar work seems to be blurred.

We have found that the series of shop floor offices are all distinguished by design and use of documents, but most notably by a differentiation in proximity (distance) to the object of the core activity. The offices, a kind of common information spaces (CIS) (Bannon and Boedker, 1997), were to a great extent designed and created by the practitioners at the floor. We want to underline that the proximity (distance) between the office and the core shop floor work place, the place of the machining, make significant difference for the design of the offices and for how they may be used. When an office is established closer to the object of the core activity, both document format and the extent of the contents are more restricted. This is most obvious in “the fourth office” where only short inscriptions are made, read and elaborated on. Thus, our findings suggest patterns in both the format and the content of the documents that are dependent on the specific office and its proximity to the object. When document handling through the four offices is in immediate proximity to the object of shop floor work, ordinary office tasks encounter material and corporeal resistance. It may turn out that some of the office task instructions are hard or impossible to carry out. The practitioners are more or less forced to make tricky combinations in attending to the object of the core activity and making meaning out of predominantly text and numbers. The practitioners reading and writing abilities are intertwined with other kind of skills that more directly realise consequences caused by the out-come of performed work. In our cases the combination was a true challenge for the machinists. We claim that it ought
to be a challenge also for those interested in the development of work and design of its supporting artefacts.

The several “offices” we were able to distinguish at the shop floor help us understand the new work practices and their development through their document (and communication) technologies. What, for instance, paper or computers make possible (afford) is highly challenged, for example, in the front of the CNC machine. The Activity-theoretical idea of object-orientedness and the concept of work object highlight a double horizon as the workers need to attend “at the same time” to the texts and the corporeal activity. The recognition of the “four offices” urges us to do further research on the suggested relations between handling documents and the work object of the shop floor.

SUMMING UP

We claim that the several “offices” we were able to distinguish at the shop floor help us understand established and new work practices and their development through their document (& communication) technologies. What for instance paper or computers make possible (afford) is highly challenged at, for example, the front of the CNC machine or close at the bedside of an elderly person. The AT idea of object-orientedness and the concept of work object highlight a double horizon as the workers in advanced practices need to attend to. To approach the object of work in the present, some specific documents are useful, to address the future of the object other document handling support an extended responsibility in time. The recognition of the “four offices” urge us to do further research on the suggested relations between handling documents and any shop floor work object.

REFERENCES


CO-CONFIGURATION OF COMPUTING TOWARDS NEW FORMS OF MANUFACTURING WORK

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Abstract. To meet the challenge of increased complexity that follows with new forms of manufacturing work, a useful and well-integrated computing system is a much needed asset for any company. In this study, close collaboration between software-computing specialists and manufacturing workers is found to be of vital importance for an in-house developed production planning and management system. Ethnographic studies at a Swedish subcontracting company show how the actual system is made and how it fits into manufacturing work. With an Activity Theory perspective, the workers’ capacity not only to make products, but also to expand and enrich their own work environment is seen as a key factor for their successful work performance. Pieces of cast metal to be precision machined are the core objects of this automotive industry. High demands on customization, quality and timely delivery are features of negotiated producer-customer relations that also have consequences for the design and development of the durable computing system. Co-configuration of computing is found to be significant to success in movements towards new forms of manufacturing work organization. Those findings are presumed to be of interest for discussions related to computer supported cooperative work (CSCW) and human computer interaction (HCI).

Key Words: Activity theory, co-configuration, computing, ICT, in-house development, knotworking, manufacturing work, shop floor work

1. Introduction

In research at a medium size subcontracting company (Kockums Maskin AB, a cast metal precision machining company located in Sweden) we investigate a highly integrated, sustained and utilized computing system. It is an in-house developed system performing not only regular office procedures such as invoices and pay rolls but also production planning, inventory control, logistics and similar tasks. As the system was developed several decades ago and for a larger enterprise, it gives us an example of locally conducted and long-term maintained software and computing development. Although it is still in operation and much used both in the office and on the shop floor, at time of writing it seems to be nearing the end of a long life time. Despite this I argue that in several aspects the system can be considered a success and I further believe that its history of informal technology development has something important to tell us.

Through close encounters with some of those who realize and make use of the system, we can look in detail at decades of computer, network, and software development, and we also reach some insights of broader interest. The system can be considered as highly integrated to both office and shop floor contexts at the company. Although it has remained good enough for several years in daily operation, it is now seen...
as becoming obsolete, mainly because of perceived future problems to interoperate with systems belonging to other organizations and businesses. It should be noted that the company does not complain about lack of computing functionality, but is concerned about dependencies of other emerging software and hardware incompatible with the established system. Since it has been, and still is, a key asset for the company, it is reasonable to investigate what are the advantages and drawbacks with a matured and highly integrated system.

In order to enrich the analysis and be better able to discuss findings, I make a comparison with another study conducted at a Danish manufacturer of electric power equipment. From that research Carstensen, Schmidt, and Kock Wiil, (1999, hereinafter referred to as the Danish study) report on “a CSCW approach to production planning”. They summarize characteristics of flexible work organization on the shop floor, which I have made use of in this report from the Swedish company. In addition, the Danish study provides some basic design principles and design goals for computing as support for production planning. These design recommendations I have juxtaposed with design features that are found characteristic of the system at the Swedish company. The Danish study is based on a detailed account of shop floor work and partly on a software prototype development in the Danish manufacturing context. One interest they discuss is related to attempts to realize control on the shop floor. At the time, the “existing computer-based production planning and control systems pose severe obstacles for autonomous working groups” and the Danish study comments on the computing systems that “They were designed for an entirely different world.” The Danish study is concerned with attempts to realize flexible work organization and poor adaptation of available computer support systems to such change. In this article I argue that the Swedish case is an example of control on the shop floor and a supportive computing system.

As a guiding framework for analysis I use Activity Theory (Engeström, 1987) to understand interaction between workers and developers and the driving forces of change towards new forms of manufacturing work. According to the theory human actions are motivated by a work object to be produced or reproduced. Further, the theory suggests an activity system as the unit of analysis. For the researcher it is a micro level unit suitable for examining the interplay between humans and the tools and instruments they use to make something. Thus, the notion of an activity system is strongly related to the work object, which on the shop floor of the case in hand are cast metal pieces to be precision machined. With this understanding, those who produce the pieces are related to each other through the object, the established tools and instruments, rules of work and division of labour, all of which that make up an activity system.

So, due to changes in the work object, people at the workplace have to maintain or expand the activity system's abilities. To achieve this, improved or new tools, support systems, instruments, or other artefacts might be designed, redesigned, realized, contested and possibly integrated by the members of the actual activity system. When doing so, the workers' focus is temporarily moved from the original work object towards a tool producing activity. An alternative way to deal with changes is to introduce tools made elsewhere – in other activity systems. Because of advanced new technologies and specialized division of labour, new computing systems are typically produced by
specialists to be used by other people in other domains of work. However, in this case, workers and developers employed at the same company develop a computing system together.

Since customer-producer relations to great extent have changed radically and become more complex, the construction and development of computing is also under change. In this study I find the workers’ contribution to computing to be in accordance with the more advanced relations in today’s working life and as an instance of knot-working. This term Engeström (2004, 2008) suggest for predominantly informal modes of work in which two or more activity systems temporarily share a work object. He relates knotworking to the historically new era of mass customization and the concept co-configuration work introduced by Victor and Boynton (1998). The concept characterizes forms of production in which new customer-producer relations have emerged with the development of new technologies and new ways of organizing manufacturing work:

The work of co-configuration involves building and sustaining a fully integrated system that can sense, respond, and adapt to the individual experience of the customer. When a firm does co-configuration work, it creates a product that can learn and adapt, but it also builds an ongoing relationship between each customer-product pair and the company. Doing mass customization requires designing a product at least once for each customer. This design process requires the company to sense and respond to the individual customer’s needs (Victor and Boynton, 1998, p. 195).

In our case such changed relations also make it necessary for the workers on the shop floor to be responsive to the company’s customers. But, as will be seen in following sections, it must be emphasized that relations between employees within the company also change. In different roles workers and developers complement each other and make a computing system integrated into new forms of manufacturing work.

2. Method

Data from the field studies is ethnographically obtained at the subcontracting company (for a complementary account, see also Kyhlbäck and Sutter, 2009). With close observations of five CNC (CNC is an abbreviation of computer numerical control that is a specialized computer integrated in the complex machine used for high precision machining) machinists' work practice, and in meetings with one production leader and one software-computing developer, we get into various perspectives of every-day work on the shop floor. In this article the electronic and networked document used at work is in special focus, where computing design and development is found as integrated into the work of both office and shop floor staff. The internally produced computing system and the people who actually maintain and contribute to it have provided ground for analysis and findings. I have specifically chosen to denote the specialists as ‘software-computing developers’, as I find this best describes the work the specialists were observed to perform, which is broader in scope than what is covered in regular descriptions of established occupational work titles.

In one of the following sections, the Danish study, similarly concerned with the problem of how to support intelligent shop floor work, is put into relation with this case. In the Analysis section, I make use of the above explained concept activity sys-
Engeström's (2008) notion of negotiated knotworking, and his developed ideas about learning in co-configuration work (Engeström, 2004). On that I build an activity theory understanding of change and tool development found in the field studies. In the end of the article I draw conclusions with addressed to CSCW and HCI interests in computing in contemporary manufacturing work. The studies that provided ethnographically obtained data were conducted from April 2007 until June 2008. We observed machinists for ten separated periods with a total of 21 hours, and have recorded by means of still photos, video (more than a total of 6 hours), and field notes that make up the most of our empirical material. In addition, stories told to us on visits to shop floor and office areas are dealt with in the following background and result sections. Hereinafter I will refer to the names of the informants: CNC machinists Patrik and Tord, production leader Tommy, and the software-computing developer Christer. One of the three meetings with Christer turned out to be a video recorded special tutorial session, which provides detailed and historical data about the in-house developed production management system.

3. Background to ICT in the manufacturing field

Information, communication and technology (ICT) systems as support for manufacturing work have been used since the 1950s and 60s and today, devices such as desktop computers made for office environments do appear on the shop floor. Digital technologies have long been highly integrated in specialized manufacturing machines, but ICT support for planning and accounting on the shop floor is not seen as a primary tool for “blue collar” workers. To a large extent this can be explained by a history and permeating culture of enterprise management dividing the work force into those who ruled and those who obeyed. Workers in the 1960s and 70s in Sweden considered themselves as being in a “we-and-them” relationship with management (see e.g. Sandberg and Ullmark, 1992). Nowadays, such ruling relations seem not to be as appropriate in a technically advanced manufacturing enterprise. Work roles have changed and much of the workers' broader skills are needed, not at least in coordination and communication with others. This gives a simple explanation for why desktop computers, designed for office use, can now be found in the noisy, greasy but on the ground environment close to specialized industrial machines.

Several decades ago larger companies in metal and in particular in the automotive industry introduced computer support for planning and management. Smaller companies mostly purchased their first computer-based manufacturing and control systems (“computer-based manufacturing and control system” is a used translation from the Swedish “datorbaserad material- och produktionsstyrning”, usually abbreviated to the common mundane utterance “MPS”. In this article the phrase “MPS system” denotes the existing system in the company being studied. It can roughly be assumed as in some aspects an equivalent to systems that in English language contexts are called Manufacturing Resource Planning (MRP), alternatively Material Requirement Planning or later Enterprise Resource Planning (EPR) systems) later in the 1980s. Ovrin et al. (1990) report on this from a study in the Swedish manufacturing context. It is based on interviews covering 12 smaller companies and in addition a case study in one of these. Typically at that time, smaller companies purchased standard business PC sys-
tems. Ovrin et al. (1990) looked at computers through the perspective of a particular conceptual module system. It was created for production, planning and control tasks and considered as applicable in general for manufacturing industry in Sweden (Olhager and Rapp, 1985). It was found that these smaller companies utilized computers at half their estimated potential. The study does not report any in-house software development and since rather few used the systems, it is unlikely smaller companies had such competence at the time. This differs from our case since the company we studied was a larger enterprise until the end of the 1980s. Presumably due to its size, it had a well-established culture of computing and software development competence that transcended through a radical change when it became a smaller, medium size subcontracting company focused on CNC machining.

In high-precision cast metal machining the machinists are those who set-up and run the advanced CNC machines. In line with Butcher and Greenough (2007) this research also confirms that the machinists are skilled in self-management and making use of engineering drawings, CNC programs, and manufacturing and tooling instructions.

I find documents in both electronic and paper form to be highly integrated in the shop floor work. Butcher and Greenough (2007) point out the scope of the CNC machinists’ role and summarize: “In particular, it is noted that increases in independent decision-making and cross-boundary communication are desirable to achieve the wider aims of the skill-based concept. To make this possible, sufficient information systems support is necessary.” A similar statement about shop floor control and information support seems to be appropriate for the Swedish company, not only as desirable, but in fact, also as an established practice.

4. From iron foundry to precise cast metal machining

Ranging from late 1960s until today, our case has a historical background in early computer machinery of which the very first were made for processing punch card data. The Computer and Punch Card Department at the company engaged a work force to carry out different roles to serve, run and take care of the output from the one single computer. Throughout the history of the company, the task of accommodating the machinery and software to changing usage demands and new technologies has been accomplished as very much an internal concern relying on in-house competence. The company itself managed knowledge and skills and was able to carry out two hardware and software renewals in the 1970s and early 1990s. Further, thanks to a practice of step-wise extension and local control of software construction, the ICT system has been integrated to match the company's needs and in later decades to support specific competence in machining cast metal.

Nowadays there is still continuity back to the late 1960s in the ICT system itself and in the fact that a few individual employees have through all, or most of, those years followed in dealing with the ICT system. In the beginning the mainframe machine and work pertaining to it could be described as a highly centralized, specific and distinct; characteristics that during the years have turned into today's much more distributed and decentralized ICT system. The company has made computer usage and development integral to many of its core and supporting activities. In a successive chain of development, it has expanded from being solely an administrative support for
traditional office tasks to also become a tool in shop floor control of work. Thus, later it can be considered to match what is generally understood as a production management system.

In the early days data was punched into paper cards and concerned the task of salary payment and required low status labour carried out by 5-6 women workers. At the time, the whole metallurgical company employed more than a thousand people in a diversity of manufacturing, cast metal and steel mill production. A single mainframe, a Swedish built DATA-SAAB D21 computer, provided all the computing power. Since both the machine and all the supporting work required a lot of physical space, a designated building housed all the hardware and necessary staff. A highly centralized organization built around the new technology carried out mainly administrative work with large quantities of data. Running the D21 was the computer operators’ work of which one distinct task was to change big reels of magnetic tapes. It was only possible to run a single program at a time and there was no network computing. First data was read and then it was sorted and in the end it produced printed lists, e.g. payment slips. The machine could only do one thing at a time. After calculation or sorting, the computing result was printed on hard copies and the updated register was stored on magnetic tape.

In 1977, an IBM 360-138 mainframe replaced the D21. In the procedures carried out to replace the machine, there was no loss of the company data but it did take a lot of work and some hired specialists from the hardware supplier helped to convert the software programs. However, the shift from one mainframe to another was not very problematic because in the seventies timing was not that critical. It was mostly invoices and such printout jobs and not the same as today with plans for delivery and work planning. Running the computer was restricted to administrative applications producing sales and suppliers ledgers. In those years, the company employed educated and experienced people to sustain required skills in computing and programming, but competence was also built up as in-house voluntary learning. At the time the Computer department had about 5-7 programmers employed.

Even though the new IBM 138 did not require changing tape reels and the disks were not switched very frequently, it did not run without human operation. Although fewer people worked with operating the machine a lot of postproduction work had to be done. The computing resulted in large registers on paper print. Special equipment separated carbon copy layers, chopped the running paper into lengths and removed the trailing edges. Everything ended up in a number of boxes that were finally delivered to the client departments.

Less people were needed as computer operators but despite being fewer the company staff managed to carry out another machinery replacement with new prospects of computer use. With the IBM 138 some terminals were made available on other departments, which in effect established networking in the workplace. Read directly from a screen display and with a keyboard used for entering data into registers, a limited amount of information was available. For example, one could not look up any supply storage values and only a few applications produced a little numbers in response to terminal commands. One programming task in the development of the system was to make new fields for entering specific data through the terminal keyboard and display. Gradually much computer operational work changed and began to be distributed
throughout company and consequently some employees at the Computer department were transferred to different work on other departments.

In 1993 the formerly large diversified company had been stripped of many production activities, but construction engineering and precision machining of cast metal remained when the company was reconstructed. Only about 40 people were engaged at the beginning to meet new challenges and sustain key skills in the highly specialized work. Since he was performing many diverse tasks, informant Christer can be considered programmer, system developer and administrator of information and communication technologies. He and a close colleague with computing skills, another “old timer” now retired, followed through the change and with them the IBM mainframe served for a final year. A strategic decision was made to replace the old machine with a PC based network system. Many of the earlier computing tasks were not needed any longer but the most important ones had to be recreated. No standard system was purchased but instead, the company's tradition of making its own computing solutions based on available resources was again revived. According to Christer: “It worked...and we were not in such a terrible hurry. The most important was to take care of the Purchase and Wage systems and make them work”. Everything was rewritten and none of the old code was converted (Old programs and the PL/1 language were now abandoned in favor of dbf files and the Clipper language). Structures for databases and such were made from scratch, and ever since then have just been extended in the still running system. The two software-computing developers managed to make the transition from mainframe to a minor network of PC computers. While they did utilize conceptual structures and naming conventions from the old system, in terms of computer software, they actually created a new production management system specifically for use in the new smaller company. In accordance with the established Swedish term, hereinafter I prefer the denotation “MPS”, which may be understood and translated as the material and production system.

The present status, use and development of the MPS

The current MPS, constructed and developed in-house, is evidently performing well within its clear limitations to rather primitive graphic rendering and poor ability to connect to emerging new printer hardware. All information today is text-based, but before, when the system better fit the older screen drivers, some of the information used was actually photos of the cast metal products. In the nineties all products were documented and digital photos were a part of the databases held by the MPS. Since the picture files are not compatible with the updated computer displays, the photo data is no longer in use at the company.

The information displayed is currently only text and numbers with the advantage of fast access throughout the internal network. Almost all commands are issued with the keyboard and each screen display offers short-key commands for available functions. Most parts of the MPS are available to all employees at a number of standard desktop computers. On the shop floor there are areas set aside for breaks and at these locations there are office-like spaces each with a computer and a printer, providing access to planning information about contracted jobs during upcoming weeks (See further detailed field studies of work at the machine front at the company in Kyhlbäck and Sutter, 2009). It is information about the specific items to manufacture on suggested ma-
chines. All production master plans are available for all employees including the shop floor workers. In the beginning of each shift the workers look up their machine group in the MPS and on one display they have a comprehensive view of all the production tasks they have to take care of (see figure 1 and 2).

Furthermore, the information not only forms a basis for what is to be done, but assumes that the workers will adapt the plan to optimally fit the actual working conditions. After each work shift, the shop floor workers again use the MPS to enter detailed information about work carried out, which is mainly numbers of successfully produced pieces and those with errors of some kind. Further, the MPS provides documents with instructions for machine set-up and configuration for each production batch, for quality measures, and it holds detailed information on exactly where to find raw production material. So, throughout the whole company, the MPS serves well.

Required core information is to a large extent supported, but the practice of using a combination of digital and paper-based information highlights a future problem. Chris ter states that: “Nearly everything relies on there being a printer close to the computer”. On the shop floor and other departments, reading digital text from screen is possible but not on all locations and not in all lightning conditions (see also Dahl, Svanaes and Nytro, 2006; Sellen and Harper, 2002). Paper prints afford a multi modal use of the text (and numbers) and have a significant advantage to computer displays when work is oriented towards and getting closer to the CNC machines that are in the centre of the company's core activities. Without doubt, a future alternative system has to support the combination of digital and paper documents.

In our case, one prominent requirement about a seemingly trivial functionality emphasizes the importance of fast access to features of the MPS in use. More graphical information is requested to visualize trends in planning documents. Digital photos of the cast metal products are also wanted. Most specifications on what and how to machine the metal are given in exact numbers defining very high precision, but images of properly loaded work pieces in the fixation devices should add more value to the information. The old database with digital photos is maintained and for some of the products still in use, it would be possible to display the old files in other applications available on the network computers. However, in practice this option is not employed since it requires additional commands and a little waiting time between leaving the DOS-based (Disk Operative System) MPS and entering a picture display program included in the Windows™ operating system. Strikingly, the delay time is short but still too long for the established high pace practice into which the text based MPS are integrated. Christer explains: “the point is that from the MPS it should be available instantly.”

**Reading of the master plan, and the final decisions**

Throughout the company, the MPS is available for all employees. One particular section with a distinct first screen display is the master plan with a forecast of the forthcoming five weeks, see figure 2. The cast metal items are expensive to make and for some machines there might be as few as 15 or 20 pieces of one kind for a single planned job, but the small amount of work may be repeated during the succeeding weeks. Of course there are several different kinds of items on one machine which is why it would be ideal to have longer series in production without interruption, but the
“just-in-time” customer orders demand another way of organizing work. Since the set-up and re-configuration of a CNC-machine takes about up to one or two hours, it is a delicate and important matter to fine-tune the order of things in the actual sequence of small batch jobs, in which the shop floor workers also take into account all the details of current machine status, available material and human resources.

Each of the two production leaders has a standard desktop machine in their office. The MPS is frequently consulted and printouts are occasionally brought along when moving about in the factory. The machines and work force are divided into three main departments. In each of them the above mentioned shop floor offices are furnished with a standard desktop computer and a laser printer. Together with a classic file cabinet and a drawer for large engineering drawings the CNC machinists have access to the MPS and paper based documents that support the machining work. Machinists Patrik and Tord explain that they access the MPS in the beginning of each shift to get the latest issue of the master plan. They both belong to one of several machine groups into which the department is divided. Within their group, there are three CNC machines operated night and day in three shifts. Work roles and authority is not very formalized but one senior machinist in the group is called the “group leader” (in our case it is Patrik). As the machinists explain, they themselves take responsibility for the final planning of work.

The typical scenario is that they negotiate and decide together, with the group leader's opinion regarded as the most decisive. Although there is a higher ranked department leader, the machinists prefer the regime that allocates much responsibility and planning work to them. The alternative, according to Patrik and Tord, would be inefficient with waiting time for orders of what to do. Further, the machinists explain, an even more serious consequence would be a passive stance on how work should be carried out. Instead, in the current way of organizing work, the machinists' take pride in not only executing the standard work tasks but also overcoming emergent problems and unforeseen events. With a partly self-managing status and given some of the shop floor control, the machinists engage and integrate planning of work tasks as orderly steps in their flow of work. In the beginning of a work shift, the machinists agree on the final ordering of the tasks. Who will be mainly responsible for what, and, more exactly how to achieve efficient work-flow is to a large extent decided mutually. During the day, things might go wrong or other priorities are raised and then again the machine group members negotiate among themselves, with other co-workers, production leaders or other employees.

The MPS master plan, usually confirmed as a paper copy, is a central artifact used for coordinating and reaching a “smooth flow of work”, that can be considered as a desired state of work which Bowers et al. (1995) define as an “even distribution of work across operators, machines and jobs”. So, the office workers issue the MPS master plan that other employees, such as production leaders and machinists, read and in the end, a paper print out serves as the final planning resource (Suchman, 2006), to be negotiated, changed, or simply followed. Production leader Tommy imagines there are better planning instruments but no severe criticism is raised against the graphical layout and the organizational principles the MPS is built on, either by him or the machinists.
The MPS system accounts for most of the ICT used at the company but when it comes to communication with the surrounding world, there is another EDI (Electronic Data Interchange) system and an ISDN connection in use. Particular engineering drawings, and plans for delivery of produced pieces and similar information imply special security concerns and that is why another specific system is needed. Besides the planning and accounting of central shop floor activities, the MPS provides support for most administrative work, that is, all the financial side including customer ledgers, accounting and the wage payment system. Although the driver connection to printers is an emerging problem, paper prints are regularly made both in offices and on the shop floor.

Since picture display no longer works in the MPS, all the information it holds can now be considered as mere text and numbers. Amazingly, this medium size and highly specialized sub contractor company, employing 110 people (in 2008) and serving several different customers, employs a great diversity of digital information, but the size of all those database files probably does not exceed 100 Mega Byte. In terms of performance throughout the company, this highly integrated MPS is very fast because of the limited file sizes. Christer explains: “Well, it is only text: more isn't needed. That is why everything goes very fast”.

**Dialogue and negotiation in development of the MPS**

The MPS has been developed from scratch and in successive extensions and changes it now comprises most of the functions an industrial ICT system needs. It can be characterized as an in-house development through on-going everyday design. Other employees, ranging from office to shop floor workers, have approached the computing developers and asked for something new or different in the MPS. Employees have come to the software-computing developer’s room or he has occasionally been around down on the shop floor and then a desire for change has just cropped up. This is the way it has worked, and on such occasions our informant has responded “Yes, I will take a look at it” and then produced a proposal. To a great extent the MPS has been built like that. Christer says: “Someone has wished for access to ‘this or that information’. And then we have done it”.

The build up of the databases, or registers as they are also called, is a design and co-configuration undertaking. It has been realized by the software-computing developers who implement and deploy the forms as the other employees have suggested and asked for. If the co-workers want to register some additional type of data, then there has reportedly been no problem at all to accommodate them in this in-house development. Although the structures of the several databases are documented, Christer does not need to consult the records, he recalls easily and is strikingly fluent in issuing short-key commands when navigating in the MPS system.

Our informant and his colleagues have constructed the MPS as a skeleton of forms to be filled out. For example, the Quality Control Department (on the shop floor orally referred to as “QC”) writes their Quality Instructions in a form provided by the MPS. Once implemented, the system has worked with very little need for adjustment. Usually the software-computing developers only give little support to co-workers about how to use and deal with the MPS. Each “form” or screen page has a consistent layout and approach. For example, screens for navigating the system structure are much the
same, having a blue or grayish background with numbers and text in a prominently white color in a table layout. To be noted is that the visual screen appearance is consistent across all nodes in the network and thus looks precisely the same to whoever looks at it.

The MPS has been developed as a co-configuration undertaking between the software-computing developers and other employees. It has been built to a great extent on direct and face-to-face communication that requires physical presence. However, there have been discussions about the advantage of moving the software-computing developers to be located even closer to the core production work on the shop floor. Christer continues: “One should have been on the shop floor, we should have been all in one unit. I think we would then have had even closer cooperation”. The developer informant has not been the proactive co-worker in the sense he makes decisions about things to introduce and employ. Other people have had the suggestions and through close contact between employees developments have been made. Christer concludes: “…mostly it is a dialogue, often it has been with the production leaders and those have had a dialogue with the workers on the shop floor. That’s how it works - they have desires and then they come to me”.

5. A more complete picture of manufacturing work

In CSCW research projects, an ethnographic field study is typically made at one or several work places in order to observe and obtain detailed data about peoples' work when they actually get their things done. Findings from such studies are often suggested as good advice or sometimes as the appropriate ground on which to design and build a new ICT system for use in the same or similar work practices. The Danish study appears to be one such model example of research and development (But see also, for example D’Souza, and Greenstein, 2003, and for a participatory design approach specifically aimed at software development: Kensing, Simonsen, and Bødker, 1998; Kensing, Sigurðardóttir, and Stoop, 2007). The approach in this study is to attempt to follow the same ideas, with the difference that in this case a successful ICT system already exists. This is fortunate for the research, to be able not only to understand the context of use but also have the opportunity to study a fully employed and functional ICT system in use on the shop floor and in the office. Another advantage is this manufacturing domain in which the central work objects, the cast metal pieces, are discrete and significant entities and thus provide reliable and observable material production work.

In the Danish study a summary of principles for production control is presented. A great number of different types of manufactured parts are to be assembled at the end of the process as electrical power equipment (the Danish study use the noun 'part' while the corresponding work object in the Swedish study is here translated to 'piece' which is in accordance with the work practice choice of word). All those and the designed interdependencies of the parts, build up the complexity to be dealt with in the planning and performance of work. However, when juxtaposed with the Swedish case of cast metal production, some differences help to make a more up-to-date and complete picture of the realities within manufacturing work. In table 1, such a picture is reflected in the aggregate of properties related to central work objects in the both cases of manu-
facturing work. Properties on rows a – e in table 1 are adopted from the Danish study, properties f - h have been added in this Swedish study. In the third column is the ratings low, medium and high given for the Swedish case, which is an assessment I have made based on obtained empirical data.

Table 1. Properties of manufacturing work, assessment of the Swedish case.

<table>
<thead>
<tr>
<th></th>
<th>In the rightmost column, letters L, M and H stand for low, medium and high rating.</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Multitude of discrete pieces (to be assembled)</td>
</tr>
<tr>
<td>b</td>
<td>Different work processes performed in specific sequences</td>
</tr>
<tr>
<td>c</td>
<td>Different work processes compete for the same resources</td>
</tr>
<tr>
<td>d</td>
<td>The number of existing components/pieces at different stages of completion</td>
</tr>
<tr>
<td>e</td>
<td>Different product modules and variants manufactured simultaneously</td>
</tr>
<tr>
<td>f</td>
<td>Degree of precision in work object transformation</td>
</tr>
<tr>
<td>g</td>
<td>Degree of product accuracy in order delivery</td>
</tr>
<tr>
<td>h</td>
<td>Number of just-in-time deliveries of the same order</td>
</tr>
</tbody>
</table>

Although the cases have similarities, the Danish study covers a large department in a complete manufacturing plant in which a great number of different parts are produced and assembled. In such an enterprise organization, interdependencies between a multitude of production processes and the tasks of getting those into an effective time sequencing make up a specific kind of complexity. For a completed vehicle, the pieces in the Swedish case shall also eventually be assembled. But an important difference is the division of labour where the Swedish company is a subcontractor and responsible for only relatively few of all the pieces to be finally assembled. Consequently, there are much fewer things to control and coordinate. However other aspects of production lead to a considerable amount of complexity to deal with.

In a historical perspective the cast metal pieces must meet increasingly higher demands of specified manufacturing. The most critical moment of production at the Swedish company is when the metal is cut, a process in which the machinists run the expensive and intricate CNC machines. Since machining today has the potential to cut the metal within tolerances of a few hundreds of a millimetre, the customers’ orders often require such high precision. In optimal circumstances, the machines might complete several cycles of machining and produce accepted pieces but the machine itself cannot detect emerging deviations and potential machine damage. To an outsider it might look like simply loading material and pushing a button, but the machining is dependent on the machinists' attention and alert capability to intervene. To accomplish successful work, the machinists need to listen, feel, look, and go to action at the right
time. Additional support measurement is made afterwards by the Quality Control Department using highly sensitive instruments.

So, in contrast to the complexity caused by large numbers, in the Swedish case high complexity is due to very narrow tolerances on length dimensions of the pieces. High demands for delivery on time with no deviating pieces accepted are also matters that add to this kind of complexity (For a detailed account of set-up and production work at the CNC machines, see Kyhlbäck and Sutter, 2009). The properties of work objects in a manufacturing company certainly form the basis of how to organize work and what kind of complexities the shop floor activities need to manage. This obviously makes a significant difference to allow for in comparing the Danish case with the company in this study.

**Machine groups as the organizing units on the shop floor**

For the subcontracting company, other manufacturing enterprises are the customers. In both short- and long-term agreements, a number of products are requested and from a central position it is possible to make a production forecast with a couple of weeks or months as the planning horizon. It is however not possible, or wise to try to take into account all the everyday contingencies when making plans for the shop floor reality. Instead, final decisions about how to go about things are delegated to production leaders, logistics workers and the machinists on the shop floor. The actual cutting of metal takes place in the specialized machines around which the CNC machinists and a few other shop floor workers are organized in “machine groups” that are subgroups of one of the departments. In the MPS system, master plans are organized according to this division where one machine group consists of one or more CNC machines. This way, the digital master plan is printed on paper and brought to the machine front where the last negotiations and decisions are made close to where most critical actions to finally transform the object of work will take place.

While not very formalized, each machine group does have some recognition and a relative self-management. Control is conducted on the shop floor but the master plan sets the frame for what is appropriate to do in a shorter time span of approximately one or a few days. Consequently, the master plan document is not over-specified (Suchman, 2006) but is a suitable artifact that coordinates a division of authority at the company. The MPS does not specify which individual worker shall do what and when but is a minimalist request addressed to the machine group. The master plan document is specific enough to support the effective control and final planning that coordinates the workers. Although the document gives critical guidance, it leaves room for more detailed coordination in finding out, for example: Who shall take care of a specific set-up, estimated to last for one or two hours and who shall run which other jobs with which machines in parallel?

Answers to such questions cannot be found in the MPS but are arrived at through face-to-face oral discussions on the shop floor. Thus it can be stated that an efficient coordination is realized through the combination of a relatively long-term horizon at the office level and a short-term awareness on the shop floor. Further, the self-managing machine group does not live with only a short time responsibility. Since all employees know very well the competitive demands of accurate delivery on just-in-time, everyone knows that her or his performed work can be followed up. The MPS master
plan is not updated to the point in time when final planning is realized, and there is no need at this company to monitor production with minute detail in real time. But everyone who has made a number of pieces to be delivered will individually enter the data into the MPS at the end of the day.

In retrospect, it is possible to construct a more detailed plan. It could be a record of actually performed work to be inspected and used as a resource for future office planning. Since other document systems accompany shipment of each batch of parts, also the workers on the shop floor are involved as individuals in a customer delivery that span over a longer future time horizon. The parts produced, each of which can be traced to the person who machined and handled it, are later assembled to fit into a complex construction such as a car or a truck. Work is divided and systematically interrelated in place and time. Finally all related efforts are materialized into a whole of which the set of documents shows who did what and when.

In the Danish case the relationship between different work processes and subsequent parts can be thought of as framed within the single factory plant. Diversity in terms of specialized production processes is relatively high on that plant floor. To coordinate work in and between what it calls autonomous shop floor groups, the Danish study argues for a communication facility:

It is essential that messages and information on state of affairs (e.g., a defective machine, missing parts and materials, reasons for planning decision) can be communicated from one worker to one more of the others in a persistent and generally visible way. Our findings indicate that such a communication facility should be structured on the basis of the key categories of this particular social world: units of time, machines, parts, processes, jobs, etc. That is, for each object or object class in the system, a facility for notifying colleagues should be available (Carstensen, Schmidt, and Kock Wiil, 1999).

In the Swedish case, the number of pieces (/parts) to be produced is relatively lower, however high demands of precision performance require a high degree of coordination. Interestingly the MPS master plan is structured and based on similar key categories to those mentioned in above quote: units of time, machines and parts (/pieces).

**Design for manufacturing work**

In addition to field observation and analysis, the Danish study also reports on the development of a prototype for ICT support with the goal “to develop a set of general computer tools that assist shop floor productions planners in their work by serving as a basis for decision making” (Carstensen, Schmidt, and Kock Wiil, 1999). The Danish study approach also entails a philosophy of supporting the production planner's “complete control of planning and control tasks.” It has implication in design goals and as a consequence:

the computer tools should be able to function in heterogeneous environments /.../ and should allow for different personal preferences with respect to look (user interface) and feel (functionality) by different (groups of) production planners (Carstensen, Schmidt, and Kock Wiil, 1999).
The prototype is presented as comprising two production management tools: one for human resource administration and the other for production planning and control. In the Danish study those two tools are accounted for in some detail including two figures of full screen displays, providing a comparative design. See also table 2, which is partly adopted from the Danish study but also extended with prominent categories from the Swedish MPS system design. Categories on rows 1-5 are adopted from the Danish study.

Table 2. Shop floor categories in the Swedish ICT design.

<table>
<thead>
<tr>
<th></th>
<th>The Swedish ICT (&quot;MPS&quot; system) design is assessed in the last column.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The individual worker is a planning unit for each job?</td>
</tr>
<tr>
<td>2</td>
<td>The individual workers skills are stored?</td>
</tr>
<tr>
<td>3</td>
<td>(Shop floor) planner writes data in the ICT, i.e. change order of priority etc?</td>
</tr>
<tr>
<td>4</td>
<td>Shop floor change of plan is reflected in changed ICT plan?</td>
</tr>
<tr>
<td>5</td>
<td>User interface can be customized (i.e. color of widgets etc.)?</td>
</tr>
<tr>
<td>6</td>
<td>The individual worker makes daily report of accomplished work?</td>
</tr>
<tr>
<td>7</td>
<td>The individual worker has read access to all manufacturing master plans?</td>
</tr>
<tr>
<td>8</td>
<td>Daily print outs of production plan from the ICT is made?</td>
</tr>
<tr>
<td>9</td>
<td>Paper based notes and messages used in planning tasks?</td>
</tr>
<tr>
<td>10</td>
<td>Instant system response from the ICT?</td>
</tr>
<tr>
<td>11</td>
<td>Shop floor co-configuring in development of the ICT?</td>
</tr>
</tbody>
</table>

Table 2 reveals a strikingly different design between the two ICT systems. The skills and availability of the individual worker form the organizing principle for the human resource tool in the Danish design. In the production plan tool of the same system, the time priority of orders in combination with machines allocated for use is emphasized. As an alternative view of the planning tool, other process-related machines could be chosen for layout of the display. In all, the system provides a high level overview of the department, but due to its flexibility, different organizing aspects (or principles) of work compete with how it will be reflected in the plan display.

The Swedish MPS is made differently with one master plan displayed in relation to one machine group, see figure 1 and 2. In the studied department all machines used for transformation of the work objects are subdivided into nine groups assigned to one, two or three machines. Those distinct machine groups stand out as the organizing units on the shop floor. In the MPS design this work organization is matched with one full screen display for each single machine group, see for example figure 2. A display unit is structured in a matrix with approximately 20 different products on the equal number of rows. In the five columns to the right, the display shows ordered batches of parts for the current and upcoming weeks. Interestingly the display contains no information about which individual workers are supposed to do the job. In a special column in the middle, a cycle number (production of one set of pieces) per hour gives an estimation.
of appropriate machine capacity. According to informant Tommy, this is a crude and questioned kind of goal expressed in a single number. Nevertheless it is given and Tommy says it is calculated when work is monitored for design evaluation of a new or modified machining job to be done.

6. Analysis

In analysis of the case, the existing machine groups are found to be the primary organizing units in the computer and print out visualization of the MPS. This is due to the way computing is realized as a co-configuration undertaking on the shop floor. Related to this systemic feature of the MPS, the master plan document it holds functions as both a central and a local control resource. In connection to this resource, the workers on the shop floor are able to use various other document systems. Besides the relatively persistent engineering drawings and work process instructions, they keep paper based log books and of particular interest, they make annotations on the surface of individual cast metal pieces at some specific points in the process. Although documentation is integrated into the work, face-to-face oral communication is both observed and witnessed as a key aspect of notifying and negotiation at the company.

So, in my analysis, the MPS system is designed to present the office and management view of what production must be done within a given period and which machine group they see as the most appropriate. This view is distributed throughout the company, not as a distinct order, but as a shared planning resource. On the shop floor, the manufacturing work organization not only allows for but encourages the master plan to be criticized and negotiated by the workers who make the final decisions and coordination work. In the Danish study, the authors’ arguments for a communication facility (see above quotation) suggest a similar self-management (with their words: autonomy) on the shop floor, but the prototype design they report on seems to display a too detailed and individualized planning system. Why store and display such detailed
data? Is it not over-specified and would it not be better left open for shop floor intelligence?

**Design of ICT support for shop floor manufacturing work**

A widespread and prototypical ICT design scenario is that information technology/computing professionals are those who create a very specialized artefact to be used by other people. Those others, often abstracted as “users”, are assumed to not understand or master the skills needed in the process of making and developing such an artefact. Further, such a scenario also assumes that the yet-to-be-made future ICT artefact is very powerful and will consequently drastically change the target organization. But in many cases it turns out to be a poor fit and remains unused for various reasons. This contradiction, or “gap”, between design and use can also be seen as being caused by very specialized division of labour in our society. Rapid development of computing technologies explain the prevalence of the prototypical design model during the last decades but since more and more people have become educated and experienced in computing, another competing prototype model can be thought of.

In the Swedish case presented here, the company has its roots in a larger diversified enterprise whose peak in number of employees and diversity of production was during the 1960s and 70s. This legacy dates back to factories founded on the same location in the 1850s. A long history of specialized competence in cast metal manufacturing was certainly a key component in the reconstruction and successful foundation of a different and specialized company, during the early 1990s. From its start, with only 40 employees, it has successively developed and expanded in production volume, financial turnover and increase in the number of employees. The combination of knowledge in cast metal and the organizing of flexible self-managing work groups on the shop floor has been a dynamic way to deal with higher demands and international competition.

A dominant characteristic of the company’s most recent history can thus be sketched. In a move away from a centrally controlled hierarchical organization of mass production, current work requires skilled precision manufacturing to meet the demands of the customers who are also involved in the co-configuration of the products. This change in working procedures, with partly broken hierarchies and the emergence of self-managing machine groups on the shop floor, entails changed attitudes and habits that are reciprocally addressed and discussed at the company being studied. Work-roles are questioned and, at the same time as division of labour becomes more complex, new work-roles seem to be harder to describe and pinpoint.

Although the CNC machinists do wear blue-collar work clothes, they are not machine operators who merely perform predictable operations. On the contrary, the high precision work performance requires a versatile ability. The workers need to perceive the actual status and to take proper actions mainly in response to deviations in material properties of the raw cast pieces and in wear and tear of the numerous machine tools. On each distinct job the machinists make use of a work flow document which in minimalist statements refer to a detailed and specific engineering drawing and sometimes also to very elaborate documents with measurement instructions. Even if use of the documents can be regarded as a type of office work they have become integral to handling the machines and coordinating co-workers work both inside and outside the company. The documents brought to the machine area are reduced to a few short text
and number statements. These give instructive hints on what to do with connections to the work object, the CNC machine cutting and drilling tools, as well as the CNC software program and measurement instruments. How work is carried out is to a great extent left for the machinists to decide.

The importance of interactions with other employees who do support, maintenance, and logistics work should also be emphasized. Documents in both paper and digital form are used and function as bridgeheads that support and direct actions played out on the shop floor. In this manufacturing domain an infinite number of connections and interdependencies make up a highly dynamic flow of task performance of which the physical machines and the cast metal pieces are relatively stable and visible components while a lot of other less tangible things change and fluctuate. To get a good picture and grasp of what is going on, our approach in the research project is to follow both digital and paper based documents that are read, written, reshaped and designed. The ICT system is highly integrated to this web of things and events. One question of interest is how the MPS has been created and by whom?

The MPS design and development has taken place in-house at the company where machines and the cast metal machining manifest a rather stable domain, or to say web, of central activity systems, which, in the activity theoretical approach, are of great importance to an analysis of the other, tool producing activity of the MPS system – in the focus of this article. A brief answer to the above question would be to say that the software-computing developer informant and his colleague made the entire MPS, but that would be to overlook the prevailing problem of design which is the contradiction between those who construct the system and those who are supposed to make meaning and use of it.

The more developed answer refers to observed practice on the shop floor and to the accounts given by the informants. While company information is implemented as a number of data structures and the software-computing developers create the user interfaces, the design is anchored in the everyday practices of the company. However, the in-house developers have not been participants of the central shop floor activities and the machinists have not taken part in writing the MPS program code. Interaction in dialogue has nevertheless been a decisive mode of development and the highly integrated MPS is a representation in itself of contributions from different sources put together as a whole. This MPS tool producing activity has evidently been going on throughout the years as a faithful companion to the company's development and production of precise cast metal pieces.

Much of this mundane and little recognized system development is difficult to make a complete historical account of. However, the strength of the development work is most likely due to the computing legacy of the previous company and the in-house versatile capacity to deal with tool producing activities such as engineering construction of new cast metal products, configuration of machine lay-out on the plant floor, the making of instruction documents, development of measurement methods et cetera. At the same time, this in-house high capacity to develop and change itself does not leave much in the way of ordinary traces such as documented agreements, requirements specifications, design charts, written contracts and similar materials supposed to be produced in a prototypical model of software development or of a participatory design project. Instead, here, a reconstruction of the MPS system developing activity
can be built on ethnographic accounts and, in the analysis continued below, activity theory is used to give a conceptual frame to the empirical findings.

The company’s cast metal production is organized to achieve high precision made pieces to be assembled in other end-customers’ products such as cars and trucks. In combination with construction engineering, maintenance, quality control, logistics, and management - I find an established and highly interrelated web of activity systems where the metal pieces and machines to be relatively stable, tangible and observable entities. However changes that form the company in its movement towards new types of production cannot be realized without additional tool development activities. The integration of the MPS is an outstanding example of such development, and a success in dealing with the contradiction between a tool/system design activity and the central activity that is to make use of the tool/system. The organizing principle of machine groups on the shop floor is the decisive organizing principle of the MPS and I argue it is not a design based on conventional abstract modelling of software, nor is it the result of more radical participatory design efforts. Instead it is grounded in co-configuration work. In reciprocal interactions the computing-skilled employees in the MPS development activity system and employees belonging to other activity systems in the company make it together. Characteristics of intelligent negotiations in the company’s producer-customer relations are thus recursive in the in-house relations between employees belonging to different activity systems.

The web of activity systems gives rise to new needs and wishes that orient the everyday MPS maintenance work to be directed into periods of negotiated system development. Such recurrent instances of development have not been scheduled or highly visible but an evolving, sometimes dormant (to borrow a concept from Engeström, 2008, p. 208) and at other times interactive and visible activity. Reasonable suggestions to add or change the MPS have been implemented, tested and assessed. As a tool production effort this has emerged as a shared work object towards which production leaders, machinists, and other employees have been focused for a while. The development of the MPS can be considered as co-configuration work interwoven with production core activity. An established web of activities has in this case offered a very real testing ground for the MPS. I argue that the organizing principle based on machine groups, stands out as a prominent design pattern (Gamma et al., 1994) in the MPS and can be regarded as an essential crystallization of the work practice at the company. In addition, the minimalist building blocks of short textual and number statements in the MPS also match and complement the way paper documents support flow of work in the core activity systems.

I find that the company's computing development experience, as manifested in the design pattern described above, partly provides an answer to the initial question: How to design ICT in a successful way for shop floor manufacturing work? For work organized to take advantage of the workers skills and practice of coordination and collaboration, it is important that document support is integrated with the practiced mode of interaction. In juxtaposition of the Danish and Swedish cases, I find the materiality of the actual production pieces, the required tools and machines – to be the information content the ICT system should make transparent and available to employees. Precisely how the information format should be designed, and on what organizing prin-
ciple(s), requires a local adaptation, or even integration, to the target plant floor do-
main.
To make a successful ICT system it seems to be crucial that both ICT specialist and
manufacturing practitioners can cooperate to realize computing, that is programming,
designing, testing and evaluating the ICT as a shared task. In such a joint undertaking
the manufacturing knowledge is brought to the system development by the manufac-
turing workers, not only in a single period of initial system/tool production but as a
sustained co-configuration activity. It requires a long-term relationship in contrast to
the mass-market model of making and buying ready-made systems. Notorious prob-
lems of failed ICT deployment are in this case avoided thanks to an adequate in-house
capacity to handle an advanced technological development. The manufacturing case is
illustrative of a prototypical solution when core activity systems are involved in the
development of their own support systems. Many of the things employees do are ex-
pected and clearly visible but others are belong to a fluid and less tangible part of their
work.

Engeström and his research groups have been particularly interested in what he
calls negotiated knotworking, that is:

[An] emerging way of organizing work in settings that strive toward co-
configuration. In knotworking, collaboration between the partners is of vital
importance, yet it takes shape without rigid, predetermined rules or a fixed
central authority (Engeström, 2008, pp. 19, 20).

The experience described here from the MPS development is an example of a negoti-
ated design and co-configuration work. Christer emphasizes that initiatives to change
and extend the MPS have been taken by other employees at the company. He, as the
software-computing developer, does not take the central commanding role but re-
sponds to suggestions by creating proposals and then the MPS emerges as a shared ob-
ject of developmental work. It is then tested in the targeted domain of use and when
the change/extension is completed, employees’ attention moves on to other directions.
The MPS development seems to fit the definition of knotworking in that it can be
“characterized by a movement of tying, untying, and retying together seemingly separ-
ate threads of activity.” (Engeström, 2008, p. 194). The case with its legacy of comput-
ing half a century back in time has requests for change prompted by in-house needs
and it has its manufacturing reality as testing ground for evaluation of MPS customiz-
ation. It is an undertaking of which there is no centralized command centre but a sys-
tem development practice dependent on the existing web of relatively stable activity
systems at the company. The MPS development builds on key material categories in
the social world of high-precision machining and it seems to be a prototypical model,
an instance closely matching the concepts of negotiated knotworking.

6. Conclusions

To conclude findings related to the specific MPS but seen as an ICT development pro-
cess, the following list is suggested as good advice for other manufacturing contexts
and similar activities:
a) ICT system integration to new forms of organizing manufacturing work will be favoured by an in-house capacity to enable shop floor workers and software-computing specialists to work together in co-configuration (also called negotiated knotworking) activities throughout the lifetime of the software system.

b) The combination of a stable computing framework and a co-configuration capacity among an organization’s members makes it more likely that a successful ICT system integration will be achieved.

c) The organizing principles of the ICT should be clear and simple and it should not over-specify the level of detail but match other document systems used on the shop floor.

d) The graphical user interface is sparsely endorsed and the screen display is highly consistent throughout all networked nodes.

e) Data format is only text and numbers while access and update functions have an instant response and consistent display. Both of these factors are significant for integration into smooth flow of work.

Another view might see the MPS as an artefact that brings to mind the free open source software movement, although in this case it is confined to the in-house boundaries of a single company. Such a perspective might suggest that the MPS (still maintained August 2009) could be accessible outside the company. Through networking with other computing volunteers and with skilled manufacturing people, the ICT could become of interest to others for use and further development. In such a futuristic endeavour, the MPS would be even more of what Engeström calls a runaway object. It would probably start in small scale with little notice but could be a potential success in other circumstances. The course of such a future would certainly be hard to predict.

However, the in-house developed ICT system suggests another complementary approach to system development, at least for some parts of the manufacturing industry. Throughout the last two decades, the MPS has been a highly integrated, well used and sustained system. From the start, the developers have had a step-by-step approach to building. Initial data structures and naming conventions were based on in-house experiences and in the beginning only the most essential administrative tasks with large quantities of data were implemented. In parallel with the company's growth, additional functions were added in successive steps. A crucial characteristic has been that other employees have formulated their computing needs and requested the software-computing developers to add the new functionalities. In this way, the MPS has been extended from only typical office administration tasks to production planning and resource management on the shop floor. In the future world of more advanced and complex manufacturing, the employees will not only be literate but most likely also computer literate in the sense that they are capable of computing development and of making their own digital documentation systems. This urges us to provide research and other necessary resources, such as open standards and access to proper technical frameworks as well as recognition of the social skills involved in the design and development of ICT.
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References


This dissertation is about support systems in use for coordination of advanced on-the-ground work activities. Focus is given to work in domains of health care and manufacturing. Both computer and paper-based information and communication technologies (ICT) are found to play an important role for coordination of nurses’ and machinists’ every-day actions. Within the vast field of Computer Science (CS), design and development of computer systems for support of coordination is an important undertaking. The research and development communities of Human Computer Interaction (HCI) provide practical and conceptual tools of interest for this study. In the research projects of which I am a participant and in the research community of Computer Supported Cooperative Work (CSCW), use of ICT in a work context is a central concern.

My interest is then oriented towards coordination, not in ordinary office environments, but in health care and manufacturing where the core accomplishment is realised in treatment or transformation of a material work object. This means a focus on documents as an expression of coordination and as integrated in a flow of work. My studies over a period of eight years, with nurses and partly with CNC machinists, have resulted in a collection of a rich empirical material. Ethnographic studies, CS and the conceptual framework of Cultural-Historical Activity Theory (CHAT) provide data, the theoretical ground and methodological guidelines in this thesis work. From the outset, the design of computer-based prototypes for nurses’ documentation tasks are designed and tested. Further, the thesis highlights studies of employed and integrated technologies in the workplace, and wrap up with contributions to the design of computer support systems.