

# Interwoven Artifacts – Coordinating Distributed Collaboration in Medical Care

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## ABSTRACT

In this article we focus on the affordances of a web of non-electronic artifacts, and the different and partly overlapping roles and functionalities that characterizes this web of artifacts. We argue that an analysis of these affordances and the web of artifacts can be a resource for design, because they are evidence of some of the capabilities that are difficult to capture in software engineering and which are important for cooperative work. The affordances and multiple roles and functionalities of a web of artifacts, are especially informative for design in the light of pervasive computing, which envisions a plethora of interactive artifacts embedded in our daily environment.

## Keywords

Affordances, Coordination, Coordination Mechanisms, CSCW, Healthcare, Pervasive Computing.

## INTRODUCTION

This article focuses on the affordances of a range of interrelated non-electronic artifacts, and analyzes the various and partly overlapping coordination roles that characterizes them.

CSCW has witnessed a range of studies of how professionals augment their computer systems with non-electronic artifact in order to do their job. For example, Luff & Heath [6,7,8] report how medical practitioners continue to use the more traditional paper medical record despite the widespread introduction of a computer system. They show us that this resilience of paper documents is not simply a consequence of an impoverished design, but rather a product of the way that the record is handled and used in practice at the consultation. Similarly, we have shown in a previous study that medical secretaries, despite the use of a computerized scheduling system, still apply a wide range of

supplementary paper-based schedules and wall-size boards to help them coordinate work at a surgical department [2]. Hence, despite the success of personal computers in an office environment it seems like non-electronic artifacts have affordances and a tangibility to them that in some situations enable them to support work processes better than computers. This is also reflected in the plethora of different non-electronic artifacts that are part of almost any work setting and which play different roles and facilitate different functionalities.

Why is this? Is it because software engineers brush away these insights and regards them as neglectable or irrelevant in the light of the computational powers of electronic systems? Well – it is not always easy for the software engineer to model real-world artifacts and ‘put them into’ the computer without loosing some of the benefits and ‘nice feature’ of such real-world objects. The computer is simply a different *medium*. This seems to be true especially when looking at paper but also the use of mundane objects like whiteboards, tables, and walls. Hence, when a paper-based schedule is modeled in the computer it cannot be removed from the many different places that it appears outside the computer without loosing effect. For example, the schedule for an operation theater must be large and visible for everybody to function as a coordination mechanism [2, 14]. These are some of the reasons why computer systems are often augmented by complementary real-world, analogue systems used basically as a way of getting the object ‘back out’ of the computer. Therefore, as often argued in the CSCW community, we can learn a lot from paying attention to the usage of non-electronic artifacts in their work setting and use them as a resource for the design of new systems.

This is becoming even more pertinent since we are now witnessing the emergence of a new area of computing where computational support moves back out of the computer and into the environment again. This notion of ‘Pervasive Computing’ covers that interactive computing power is becoming an embedded part of people’s everyday environment, including cars, buildings, streets, home appliances, hand held devices, construction materials, clothes, paper, etc.[3].

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The promising part of Pervasive Computing is that we (finally) can move away from the client-server computer architecture where computer systems are divided into personal clients located on desktops and servers as a data distribution layer. We can begin to make intelligent devices and embed them in the context where people need them and make the interaction suit this context. For example, an intelligent hospital bed would know the patient and can recognize the physician, and thereby provide him with relevant information about this patient.

The challenges to Pervasive Computing are clearly that it opens up a vast amount of new design dimensions. In the good old days (i.e. now) you would, as a software designer and engineer, 'only' have to consider how a system should be implemented in the classic client-server model. This is of course a quite difficult task, but it is small as compared to how you would go about and designing fundamental new embedded technology in a complex organizational setting.

If – as argued in CSCW – it is important to look at the contextual, everyday use of artifacts in real work in order to design 'classical' computer system, we will argue that it is being considerably more important when addressing the design of Pervasive Computing systems. If we want to create new intelligent devices within a hospital – the intelligent hospital bed for example – it is absolutely critical to know how such 'devices' is used and how it relates to other 'things'. Pervasive computing entails the development of systems that integrate a variety of *different* artifacts that have different functionalities which are to become integrated into work processes rather than put on the table or on the wall.

In continuation with previous studies of medical work [1, 2] this paper looks at coordination of clinical care at a modern Danish hospital. We want to analyze how coordination is achieved by applying not just one artifact, like the schedule, but several heterogeneous artifacts, like schemas, charts, lists, whiteboards, etc. All these artifacts all play a multitude of different roles, but are at the same time highly interwoven. We use this as an example of the challenges of designing Pervasive Computing systems because such a web of intelligent artifacts is exactly what might constitute a Pervasive Computing environment.

The paper starts by looking at related literature on coordination and coordination mechanism within CSCW. We then go on to present the specific case and try to describe how the daily work of caring for patient at a medical ward uses a rather complex set of interrelated artifacts, each playing its part in the web of coordination. If the complexity of the network of artifact and their use makes the reader lose breath, this is in part intentional. We then move on to analyze our observations before we outline the design implications of our case, and finally we conclude the paper.

## BACKGROUND

In a contribution to a conceptual foundation of CSCW systems design Schmidt & Simone have presented the notion of 'coordination mechanisms' [11]. These coordination mechanisms serve to reduce the amount of articulation work, i.e. the work of coordination, in collaborative work processes. A coordination mechanism alleviates articulation work because it "...*stipulates and mediates* the articulation of cooperative work so as to *reduce the complexity of articulation work...*" (ibid. p. 180). Thus timetables, work schedules, tables and the like all serve to facilitate cooperative work. They can do so, because they entail a *protocol*, i.e. an accepted set of procedures and conventions, which are objectified and given permanence by the artifact, i.e. a permanent symbolic construct, which can carry the protocol across time and space. Based on these distinctions, Schmidt & Simone put forward 25 propositions through which they describe and analyze the role of coordination mechanisms in cooperative work. They go on to argue that computational coordination mechanisms may have distinct advantages as to paper-based coordination mechanisms in modern organizations which much operate in a flexible, adaptive and yet very coordination way. They therefore venture to specify the requirements to the design of such computational coordination mechanisms which they organize into two categories: malleability and linkability. Malleability signifies the ability of actors to redefine and modify the computational coordination mechanisms, whereas linkability signifies the ability to align multiple computational coordination mechanisms with one another.

We find their contribution beneficial, but whereas Schmidt & Simone conclude their contribution with an abstract, general notation for coordination artifacts, we would like to bring these artifacts back into the concrete. They remark (proposition 13) that the *material format* of an artifact can provide specific affordances that stipulate and mediate cooperation [ibid. p. 179-80], and we would like to pursue the question of malleability and linkability in this vein. In the concrete, the material format of computational artifacts support and limit cooperative work. Thus computational coordination artifacts can relatively easily present a user with different views of the same data, but there is an inherent conflict in deciding who should watch what when. Thus, Gutwin & Greenberg [4] discuss the conflict and necessary trade-off that have to be made between the individual and the group perspective on shared groupware. In a similar vein, Hertzum [5] argues that a conflict exists between personal information space of actors and the need of organizations for storage and sharing of information. To achieve a common information space, individuals have to do 'extra' work in order to package information into the shared archive of information.

Several studies of the use of mundane artifacts like papers in organizations reveal that coordination artifacts often play several roles. For example, Hertzum [5] describes six roles documents play in professionals' work, namely that documents serve: "...(1) as personal work files, (2) as reminders of things to do, (3) to share information ... (4) to convey meaning, (5) to generate new meaning, and (6) to mediate contacts among people." (ibid. p. 41) (See also [12]). As we shall return to, we have made similar observations when looking at the use of documents in a hospital setting. Hence it is often difficult to look at an artifact as a coordination mechanism only. It is often more the case that documents play many different roles, some of them being of coordinational character. And to the list provided by Hertzum, we would like to add the features of provision of public overview, public status and location-facilitation. Design must aim at a balance between the personal and the organizational needs, which depends on the specific combination of the roles that documents play in a specific work setting. We will analyze such a specific setting, i.e. a hospital ward, and point to the importance of an intermediary level of information space, namely that of the group.

Other studies of coordination and artifacts used for coordination purposes also reveal that public overview is a particularly important part of coordination. The structured use of public whiteboards and bulletin boards is evident for coordination purposes because they can provide an immediate overview of the status of things, and are at the same time public available. For example, Xiao et al. [4] report how a public display board has evolved into a key component for supporting collaborative work in a trauma center in a hospital. Clinicians use the physical and perceptual properties of such a board to support rapid paces and highly dynamic coordination of work, while at the same time its canvas-like appearance affords its users to tailor the board and invent new ways of representing information. Such public available boards facilitate negotiation of scheduling, joint planning, and enhance communication among cooperating clinicians. We have made similar observations in a surgical clinical (c.f. [2]).

The concept of coordination mechanism state that such a mechanism is aligned with other mechanisms devoted to different aspects of the articulation of the same or other activities [11]. Hence, when looking at coordination of work and at the artifacts used for it, it is of particular interest to look at how different artifacts are used for coordination and at the *relationships* between such artifacts. Just as the same document or whiteboard plays several roles in itself, it seems like many different artifacts also plays the *same* role, namely the role of coordination. Reddy et al. argue that providing information in many specialized representations is critical to managing coordination [9]. Hence, it seems like people go through a lot of trouble by re-representing the

same information several places, 'just' in order to coordinate work. Why is it in this way? Is it only reminiscent of analogue systems like paper or whiteboards and old habits?

It is the purpose of this paper to look at how artifacts used for coordination purposes are so-to-speak cooperating or interwoven in the collaborative work of caring for patient in a modern hospital, and how they align, supplement, augment, and contradicts each other.

## THE CASE: WORK PROCESSES AT A HOSPITAL WARD

### The setting

We will base our case on observations of work at a medical ward in a large Danish hospital. The ward is part of a department specialized in hematology (i.e. blood diseases). The most common diseases are different types of blood cancer and chemotherapy is administered regularly. The ward in question is one of two wards with admitted patients, but the department also comprises a reception ward, an outpatient clinic, and two laboratories where samples of blood and bone marrow are analyzed.

Within the last two years, the hematology department has organized staff into teams of physicians, nurses, and social & health assistants (SHA), to which patients are associated. This has been done to further cooperation across professions and in order to limit the number of different staff that a patient meets during her or his treatment. The specific ward normally attends to 24 patients and is divided into two teams, the red and the blue team, which split the ward's workload and patients between them.

### Ethnographic methodology

During the summer of 2001, an ethnographer (one of the authors) made participant-observation at the hospital ward. This consisted in attending the morning meetings of nurses and physicians, following the work of nurses during day-, afternoon- and night-shifts, observing the daily round on the ward by a physician and a nurse, watching administration of medicine and chemotherapy, writing of patient's records etc. All in all, 28 days of 56 hours of fieldwork observation was carried out. During the fieldwork extensive notes were taken by hand and written out in prose the same day or the day after. At the conclusion of the fieldwork, 12 interviews lasting 1 hour each with nurses (8), social & health assistants (2), and physicians (2) were made. The interviews were based on open-ended questions with regards to the planning and coordination of hospital work.

## PLANNING AND COORDINATION OF PATIENT CARE

Curing people with sicknesses and diseases has long been subject of a division of work between those who make diagnosis and prescribe medical treatment, physicians, and those who take care of patients during treatment, nurses

and social & health assistants (SHAs). Whereas the patient record has developed as the physicians' primary documentation tool, this role is (in Denmark at least) paralleled by the care-record for nurses and SHAs.

The patient's record is primarily used by physicians for the documentation and accumulation of information about the patient's disease, present status, treatment, tests-result and medication. The care-record on the other hand is used by nurses and SHAs to document and accumulate information on diagnosis, treatment and evaluation of specific care-problems and the patient's overall well-being. Both these records are thus primarily, but not exclusively, concerned with documentation of treatment and accumulation of knowledge about patients.

However, in the daily work at a hospital ward, there is a vast and complex amount of coordination, planning, scheduling and status-making to be done: patients have to be washed, given medicine, taken for radiology examinations, have blood-samples taken, given extra blood etc. It is not just that these tasks have to be carried out, but also that they have to be handed over across shifts, weekdays and weekends. The patient and the care record are invaluable tools for the long-term coordination of hospital work, but are less important for the daily, short-term coordination of work. Here a number of complementary artifacts as used: two different kinds of whiteboards, the work-schedule, the examinations sheet, and personal notes.

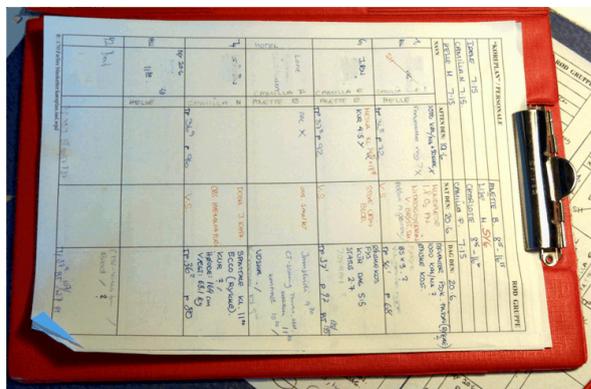
We will describe how these artifacts are part of the daily work processes of the hospital ward in the following section and then discuss why they (at) all are necessary for the coordination and planning of daily work. Taken together the artifacts comprise an interwoven net of common artifacts that alleviate the work of coordination necessary in daily life at the hospital ward. They are 'coordination mechanisms' which alleviate the 'articulation work' of collaboration [11].

### The morning

The working day of nursing is divided into three, roughly equally long shifts (day, evening, and night) in which different numbers of nurses and SHAs are present. Coordination and planning is most intense during the day shift because it is the busiest part of the day. Our description and analysis of coordination will therefore focus on the day-shift.

The day-shift starts in the morning when 2 nurses check in at 7.00 am. They get a short briefing from one of the nurses from the nightshift upon the night's events. They are handed over the 'work-schedule', which has a list of all patients and their present beds. The work-schedule furthermore has a detailed list of tasks, observations, examinations and other things that should be taken care of during each of the three shifts. The schedule is shown in figure 1.

The work-schedule is used by the staff checking in for the day shift to locate patients and get an overview of things that have happened during the night. The staff takes the schedule with them on a tour around the ward and note the morning's measurements of blood pressure, temperature and pulse upon it.



**Figure 1.** The work-schedule of the nurses (In this picture and the following ones all names have been changed or blurred).

Half an hour later the team's leader checks in. She usually goes to the team room and starts looking over the work-schedule to get an overview of patients and tasks due for the day. To her, the heading at the top of the work-schedule is also important since it lists which nurses check in when and whether any has called in sick. She checks whether all relevant patient's records and care-records are in the team-room and checks whether any new results from blood samples, X-rays or CT-scanning have come in at the ward office. She also updates the whiteboard on the wall next to the door just inside the team-room. The whiteboard is in some ways similar to the work-schedule, but does not indicate the working hours for the different nurses and SHAs, just as it does not list work tasks in the same detail. The whiteboard in the team room is shown in figure 2 below.



**Figure 2.** The whiteboard in the team room.

Like the work-schedule, the whiteboard in the team-room gives the patient's room and bed number, the patient's name, which nurse or SHA will take care of her/him today, and the patient's hygiene regime. In addition the patient's disease is indicated by an acronym and an order for the physician's round proposed by the nurse is indicated. Finally there is space for writing notes on major events that are due, for example "X-ray 10am" or "home Friday".

### **The morning conference**

From 08.15am to around 08.45 a conference is held for all nurses and SHAs where the team-leader goes through all patients with the help of the work-schedule. She will read aloud the patient's name, the disease, and give a briefing on the patient's present status including events taken place during the afternoon and night shifts. She will also go through all tests, major chemotherapies, infusion of blood, and things to be observed or remembered in connection with the care of the patient. Nurses and SHAs with previous experience with the patient in question will comment if they think it is appropriate or if discussions arise. Depending on the number of patients, the complexity of their situation and on how many of the nurses and SHAs were there the day before, this detailed briefing will usually last for two to three quarters of an hour. Twice a week the team's physicians also take part in this morning conference and supplement the team-leader's briefing with explanations upon treatment and medication. Nurses and SHAs on their hand give matters of patient care on to the physicians. These common meetings are rather new and serve to exchange issues of treatment and of care between the professions in order to heighten the quality of patient treatment. When the morning conference is over, the nurses will start taking care of their patients or briefly read through their patients' care-record in order to be better informed on the patient's present status. The patient's record is rarely used. All nurses and SHAs make individual notes on a folded sheet of A4-paper during the briefing and when reading the care-record of 'their' patients. At the ward, nurses and SHAs are assigned two to three patients each so that patients will be taken care of by the same nurse or SHA all through the day and afternoon shift. Only one nurse and two SHAs take care of the ward's 24 patients during the night shift and they will handle all 24 patients with no regard to which team they are attached.

### **The ward round**

The physician's ward round starts at 09.00 am, assuming that the physicians' radiology conference is over in due time and that the physician has no other acute tasks to attend to. The round is made by a physician and the team-leader, who is always a nurse, in cooperation. On the round they bring along a trolley containing the patient's records, the care-records, the work-schedule and the medicine-plans. They will usually follow the order suggested by the team-leader, who has tried to coordinate the round with issues

like (i) the severity of the patient's situation, (ii) whether the patient will have to go out for examinations at other departments, (iii) at what time a physiotherapist will attend to a patient, (iv) whether the patient is planned to have a shower, and numerous other things. The physician will change the order if (s)he wishes to. The patient's record is needed by the physician to be able to assess the patient's status and response to the treatment. Since the physician must sign for the total amount of medicine prescribed each day, the medicine schemas are also brought along. The team-leader on the other hand needs the care-records to see details of care and because the examination sheet is inserted here. The examination sheet is a registration of all prescribed examinations and samples and their present status; (i) are they to be ordered, (ii) have they been ordered, (iii) have they been taken, and (iv) have the results come back yet. The team-leader furthermore needs the work-schedule to see the measurements of temperature, blood-pressure, and pulse from the morning. These measurements will also be listed in the medicine schema, which combines prescriptions, fluid-balance, and measurements of blood pressure, temperature, and pulse. Often, however, the team-leader has not had the time to transfer them from the work-schedule to the medicine-plan. Furthermore, the team-leader uses the work-schedule to make notes of new tasks to be performed within the 24 hours that this schedule covers. Requests for blood plasma and examinations are also listed on the 'examination-sheet'.

As the physician and the team-leader make their round, the team-leader will also write new tasks, prescriptions or examinations on post-it notes, which she will either put on the whiteboard in the team-room next to the patient's name or hand over to the nurse or SHAs taking care of the patient, if she meets them.

During the round, which is scheduled to end at 12.30 pm but which might last until 2 or 3 pm, it is very busy around the small trolley: while the physician and the team-leader make the round to the patients, the other nurses and SHAs still have to carry out their tasks and need every now and then to check something on the work-schedule, in the care-records or on the medicine-plan. They do also make use of the whiteboard in the team-room in order to locate patients. It might seem silly that nurses and SHA sometimes find it difficult to locate patients, but these are moved around rather often in order to comply with the need for single-sex rooms and the different hygiene-regimes of patients. Furthermore, since patients might be away from the ward in order to have examinations done in other departments, it is not always immediately apparent why they can not be found: have they been moved or have they gone somewhere else? Here the whiteboard give the relevant information of the actual beds and the major examinations during the day.



**Figure 3.** The whiteboard in the office.

In addition to the whiteboards in the two team rooms, there is a whiteboard in the ward office, where two doctor's secretaries are found. This whiteboard is somewhat similar to the ones in the team-room, but covers all of the ward's 24 patients. This whiteboard is shown in figure 3.

Like the whiteboards in the team-rooms, this whiteboard gives the names of the patients, their actual room and bed number, their hygiene-regime and which nurse takes care of the patient. It is updated by the doctor's secretaries, the team-leaders and the head-nurse. Whereas the nurses and SHAs use it to locate patients and colleagues, the secretaries use it, when they need to give relatives or staff from other department directions on the location and attending nurse of specific patients. Finally, the head nurse uses the whiteboard to get an overview of the ward's patients whenever new patients are admitted. She then has to find out how the criteria of single-sex rooms and hygiene-regime can be accommodated.

### The evening and night shift

Within each team, lunch break is done in two shifts in order to be able to take care of patients all the time. After lunch, each team has a short meeting of 5-15 minutes in order to access the present status: which tasks have been completed, which ones are still in progress (giving of blood, chemotherapy, intravenous antibiotic treatment) and which ones must still be attended to. As in the morning conference, the team-leader goes briefly through the work-schedule.

The nurses and SHAs then strive to complete their tasks within the shift, and update the care-record the next few hours before they go home. The team-leader makes sure the work-schedule and the whiteboard is updated.

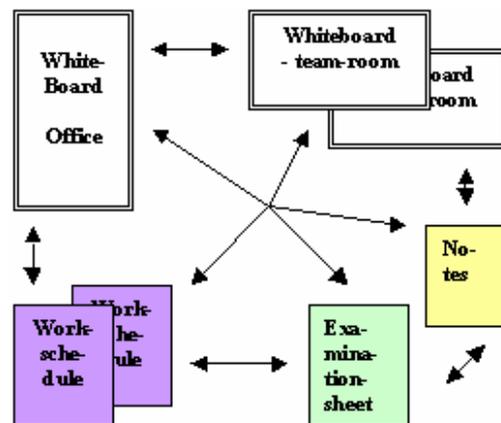
One of the nurses who started late that day is given the task of briefing the afternoon shift, when they come in. It usually

takes her 15-20 minutes to go through the important points using the work-schedule to do this. When the next shift takes over, they briefly check the care-records and commence work. The afternoon shift is usually quieter than the day-shift though the single staff might be busy enough, since they are now only 5 people to take of 24 patients. A physician comes by at 5 pm to make a ward round on those patients that need it; food is given at 6 pm, medicine at 6 pm and at 10 pm.

At 11 pm, the night shift takes over and struggles with their eyelids through the night. Their tasks include updating the medicine-schemas for the next day (since prescriptions are written in advance one day at a time); making statistics on antibiotics, mixing medicine for the next day and general tidying up, since there is generally no time for this during the other shifts.

### DISCUSSION

Hopefully, the previous description gives an impression of the complexity of coordinating tasks involved in patient care. We have described how coordination is achieved by handing over information, creating overviews, and articulating status. We will now focus on four central artifacts that play a central coordination role in this interwoven network of work processes: the work-schedules, the whiteboards in the team-rooms and in the office, the examination-sheets and the individual, personal notes of nurses and SHAs (See figure 4).



**Figure 4:** The net of artifacts

At a first glance there seems to be a redundancy of information within this system of artifacts. For example, information about the room and bed number, associated nurse, and hygiene regime is repeated on the work-schedule, all the whiteboards and the personal notes. Similarly, examinations and giving of blood and chemotherapy are listed on the work-schedule, the whiteboard in the team-room, on the examination-sheet and on the individual notes. There are, however, also some

slight, but important differences in information and in the physicality of the artifacts. Work-schedules can be carried around and have a high degree of detailed information, whereas the whiteboards are large, bolted to the wall and gives in comparison only little information. The examination-card is mobile and carried detailed information on examinations also found on the work-schedule. These differences reflect differences in the combination of purposes they serve. These purposes, we suggest, can be grouped into considerations of: producing overviews, viewing different data differently, revealing status, planning of cooperation, continuous coordination, and passing on messages and notifications, as well as providing individual work-spaces. We will go through these in the following.

### Locating patients and staff

All of the above artifacts serve the purpose of providing care-staff overview, but very different kinds of overview. Starting from the highest level the whiteboard in the office gives an overview of how many patients are admitted at the ward at present, their location, their associated nurse and their hygiene regime. This provides secretaries information they often need when directing people from outside the ward, visitors and staff from other wards who do not have local (i.e. ward-specific) knowledge. The secretaries can tell where to find a patient, which nurse to talk to about the patient's present state, and whether the visitors need to put on masks, white-coats, etc. It furthermore, helps the head nurse in the allocation of beds to newly admitted patients, where she has to solve the puzzle of single-sex, hygiene regime and personal situation.

The whiteboards in the team-rooms give the same information as the whiteboard in the office, and they similarly provide an overview of the location of patients and possibly also colleagues, since these often may be assumed to be near their associated patients. The whiteboards in the team-rooms, however, carry additional information on the order in which patients are taken in the physician's round, their disease and main points on their schedule for the day. This helps locate patients ("she's off for X-ray") and staff, since the latter can be assumed to be engaged with one of the tasks listed for the patient, if not actually close to the patient. The round-order furthermore makes it easier to locate the physician, whose decision and advice is often needed. During the day, a nurse or SHA will often open the door and take a few steps into the team-room (or the office), cast a quick glance at the whiteboard and hurry on. She gets within a second, the information she wants from the whiteboard on the wall. Thus the whiteboards in combination give information on location of patients and personal at different places in the ward.

The information on the work-schedule also enables location-facilitation, but since it is written in small and often

in the hands of the team-leader, it is not as accessible as the whiteboards.

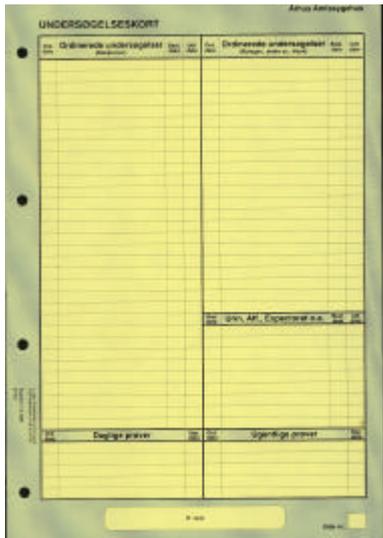
### Cooperative Planning

The main planning artifact in each team is obviously the work-schedule (figure 1 and 5). This is where the team-leader can see which staff will be working when, and assign nurses and SHAs to their respective patients. In this assignment the team-leader relies on the detailed information on the work-scheduled, which enables her to judge whether a patient and associated tasks demand attention from a nurse full time or whether the patient can be one of two to three patients associated to a nurse or SHA. In the assignment, the team-leader of course also takes into consideration the competencies and experience of individual nurses and SHA, which is why the names of staff at the head of the work-schedule is important.

KØREPLAN / PERSONALE		ROD GRUPPE	
Susan	A	P	1 2
Anja	A	P	1 2
Kasper	A	P	1 2
Tina	A	P	1 2
NAVN	AFFEN DEN	NAT DEN	DAAG DEN
Peter	Udvalgt	SIS. LABOR RØNTGEN KONTROL	NO. RD. P. T. H. E. R. I. E. R. / I. N. F. E. C. T. I. O. N. S. / S. E. P. T. I. C. I. A. / S. I. M. P. T. O. M. / S. I. M. P. T. O. M. / S. I. M. P. T. O. M.
Hans	Udvalgt	FASTE	NO. RD. P. T. H. E. R. I. E. R. / I. N. F. E. C. T. I. O. N. S. / S. E. P. T. I. C. I. A. / S. I. M. P. T. O. M. / S. I. M. P. T. O. M.
Mary	Udvalgt	FASTE	NO. RD. P. T. H. E. R. I. E. R. / I. N. F. E. C. T. I. O. N. S. / S. E. P. T. I. C. I. A. / S. I. M. P. T. O. M. / S. I. M. P. T. O. M.
Tina	Udvalgt	FASTE	NO. RD. P. T. H. E. R. I. E. R. / I. N. F. E. C. T. I. O. N. S. / S. E. P. T. I. C. I. A. / S. I. M. P. T. O. M. / S. I. M. P. T. O. M.
Anne	Udvalgt	FASTE	NO. RD. P. T. H. E. R. I. E. R. / I. N. F. E. C. T. I. O. N. S. / S. E. P. T. I. C. I. A. / S. I. M. P. T. O. M. / S. I. M. P. T. O. M.
John	Udvalgt	FASTE	NO. RD. P. T. H. E. R. I. E. R. / I. N. F. E. C. T. I. O. N. S. / S. E. P. T. I. C. I. A. / S. I. M. P. T. O. M. / S. I. M. P. T. O. M.

Figure 5: Work-schedule ("Køreplan" in Danish).

While the work-schedule enables cooperative planning at the level of the team, the examination-sheet (figure 5) enables cooperative planning from the perspective of the individual patient. The examination-sheet gives information on which tests, checks and portions of blood are due, and thus information on when and where the patient should be on respective days. This information is also provided by the work-schedule and the whiteboard in the team-room, but whereas these only cover the next twenty-four hours, maximum, the examination-sheet provides an overview up to several weeks or months.



**Figure 6:** The examination-sheet (“Undersøgelseskort” in Danish).

Finally, cooperative planning is also carried out on the whiteboard in the office by the head nurse when she assigns newly admitted patients to their beds, and on the whiteboard in the team-rooms, when the team-leader numbers the team’s patients in the order in which she thinks the physicians should take his round. This is what happens in the picture of figure 2. The physician and the team-leader, who make the round, thus in a glance know which patients will be due next and may therefore arrange the different documents accordingly. This order, however, also serves as *continuous planning*, to which we will pay attention below.

### Continuous Coordination

Once the morning conference is over, the nurses and SHAs engage in their tasks and do not meet together again before after lunch. During the day, however, there is a need for continuously coordination of tasks, since some resources are scarce (e.g. pumps that administer chemotherapy) and since some tasks need to be carried out in a specific order. Thus, while chemotherapy may already be prescribed for the day, it cannot be commenced before the results of a blood-sample from the patient in question have been returned and acknowledge by a physician. Similarly, patients will not be taken for a shower if the physicians round is imminent. Other tasks, like the giving of blood and chemotherapy requires two nurses, since the procedures prescribes double checking of information to make sure that patients are given the right blood or that the doses of chemo-pharmaceuticals have been calculated correctly.

This kind of continuous coordination relies, of course, to a large extent on verbal communication, but since the staff is spread out and locating specific persons takes an effort, the network of artifacts is also applied. Information on approximately when the physician’s round will get to a certain patient can be gathered from the order written on the

whiteboard in the team-rooms. Especially, since numbers in the order are erased as patients have been seen to. A more detailed, continuous planning is enabled by the list of tasks on the work-schedule, which enables the staff to get an overview of all important tasks that have to be taken care of within the team. This is, in particular, enhanced by the ability of the work-schedule to give a *status overview*.

### Keeping a Status Overview

Most tasks listed on the work-schedule have little signs like “/”, “y” or “x” attached to them. These signs indicate the status of a single task. Thus “/” means that a task still has to be commenced, “y” means it has been commenced, whereas “x” indicates that the task has been completed. Many task move from “/” to “x” right away, typically if there is continuity between commencement and completion. The “y” is usually applied to the giving of blood or chemotherapy, which may take between ½ hour to 6 hours, and where the staff may attend to other tasks while the fluids run into the veins. On top of having the function of a checklist, this system of little signs, enables colleagues to assess in quite some detail the status of other tasks. Especially, since the staff can use their experience and knowledge of the ward’s everyday practice to combine the individual tasks and assigned signs into an overall picture of the situation.

A similar system of signs is applied in connection with the tasks listed on the whiteboard in the team-rooms, and on the individual notes of the staff.

### Messages and Notifications

As mentioned previously, the whiteboard in the team-room is used by the team-leader for putting on messages to nurses about decisions made by the physician during the round: i.e. decisions that imply new tasks or a revision of previous tasks. Through the notes, the team-leader can achieve *continuous coordination* of tasks without having to actually get hold of people. Such new tasks are also written on the work-schedule, but this is only available generally after the round has been completed and the work-schedules return to the team-room together with the patient’s records, the care-records and the medicine-plans.

### Personal Workspaces

Finally, the individual notes provide nurses and physicians with what we term a personal workspaces, where lists of official tasks, i.e. tasks that figure on the work-schedule, and personal items can be listed. The latter may include details of the official tasks, or matters that arise when the nurse, SHA or physician attends to the patient and which must be remembered. Some of the latter may be entered into the care-record, on the whiteboard or in the work-schedule if they have to be handed over, whereas other items just have to be temporarily remembered and will be deleted when

they have been attended to. The advantages of the individual notes are obvious: they are mobile, handleable, and can be fitted into a pocket. They alleviate the need to go to one of the whiteboards or find the work-schedule whenever the person is in doubt about tasks, or whether she has remembered everything.

### **The Network of Artifacts**

As we have tried to unfold in the previous sections, the different artifacts serve multiple purposes. In different degrees and combinations, they serve the purpose of cooperative planning, continuous coordination, keeping a status overview, locating people, providing individual workspaces and serve as media for the passing on of messages. Whereas mobility and handleability of work-schedules, examination-sheets and individual notes is an asset whenever the staff want to bring information with them around the ward, the fact that whiteboards are fastened to the wall make sure that the information they provide can always be found. They do not, in contrast to the staff, move around. Similarly, large boards with relatively little detail of information provide for overviews at a glance and from a distance, while the detailed information of the small-sized work-schedules (A4) and individual notes (A5) provide an overview and status of the shift's tasks.

Thus functionality and physicality are combined in different ways within this network of artifacts, which is why some information found on several artifacts, while other information has more singular representation.

### **SOFTWARE ENGINEERING CONSIDERATIONS FOR COORDINATION SYSTEMS IN MEDICAL CARE**

Our study of the interwoven coordination artifact used in medical care implies a number of interesting considerations for software design and engineering. This is both as regard to the design of computer systems for coordination as well as for the process of developing such systems.

The above analysis reveals how coordination of work activities at the ward is done by applying a wide range of interwoven artifacts, which each represent important but context-specific information about the overall status of work at the ward. This can be analyzed according to the levels of the hospital, department, ward, group, and person.

Unlike paper records, the computer as a platform is especially well suited to create a centralized data server with clients having different views on the same pool of data and thereby decouple information from its representation [9]. Hence, apparently it seems like a computer system would be suitable for augmenting this kind of coordination through interrelated artifacts. We have seen how the same information is represented in various places at the medical ward; much of the same information is re-written on various whiteboards and on various paper-based schemas, schedules, plans, and personal notes. Obviously, it would be

beneficial to design a computer system where such redundant information is held in one place and the user can have different views upon it tailored to their needs. This is exactly the strength of the typical client-server architecture with a centralized database ensuring distribution of a coherent view on data objects to several clients. The main word of advice here is though that the exact look-and-feel of views on a shared pool of data is highly dependent on its concrete usage context. When looking at the way the different interwoven artifacts are used, it is striking how they are constantly adapted to the actual context. For example, the 'whiteboard view' on data is tailored according to its physical placement in the office, and hence to the role it plays in continuous planning, whereas the personal notes of the nurses are tailored to their specific, and more personal needs. Hence, the design of such 'views' must be made in a way to allow users to adopt it to the requirements of its usage context.

The work of designing and engineering software systems are typically described as one of modeling real-world objects into the computer. By using object-oriented methods like use-case modeling, object-oriented analysis and design, and state diagrams the software engineer takes the objects, like the work schedule, and 'puts them into the computer' [10]. However, in this process the work-schedule loses most of its natural affordances, like the possibility to take notes on it, erase things, add post-it notes to it, etc. On the other hand, however, it gains other possibilities, some of them the ability to create different views on common data.

Based on our case, revealing the interrelationships between different artifacts, our main suggestion to the process of creating software is to look at how the objects can be brought 'out of the computer' again, once they are put in there. It is highly relevant for a software designer to consider how a computerized work schedule can be made available in different places like the whiteboards, the personal notes, the structured examination plan, etc. The computerized objects must in a sense enter the real-world again and augment existing ways of coordinating work. We think that this is the real promise of Pervasive Computing, i.e. creating enabling technologies for merging the digital world with the real world, and in this way pave the way for users to benefit from the computer's advantages while keeping the advantages of real-world objects.

### **CONCLUSION**

In this article we have reported from our observations of a web of non-electronic artifacts used at a hospital ward, and we have pointed to the fact that these artifacts have multiple roles and offer different views upon the same information while at the same time adding special features depending on context. We have pointed at mobility, at-a-distance-at-a-glance overview, and markability as some of

the affordances of these artifacts. These artifacts in varying combinations function as coordinating mechanisms by the facilitation of (i) locating staff and patients, (ii) cooperative planning, (iii) continuous coordination, (iv) status overview, (v) notification and (vi) personal workspace. We argue that these affordances and multiple functionalities should inform and make design move beyond systems that only handle large databases, and instead combine different electronic artifacts – for example PDAs for mobility, large screens on the wall for display, on-line scanner-pens for the registration of the giving of medicine etc. Only in combination will they facilitate the need of collaborative work as is going on in a work setting. Finally, we argue that in the emerging era of Pervasive Computing it is a new challenge to start designing the computerized object ‘back out’ into the real-world environment of work. And when doing that, it is of central importance to understand the interwoven nature of such real-world artifacts.

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